Traffic Impacts of an SOV Mode Split Target Policy: Evaluating Seattle's New Transportation Concurrency System

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A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Urban Planning

University of Washington

2019

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Programs Authorized to Offer Degrees:

Urban Design and Planning

University of Washington

Abstract

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Cities in Washington State are required to adopt concurrency policies that stipulate how they will measure the level of service (LOS) of their transportation system. Under the Growth Management Act, cities are also required to deny development permits if they do not meet level of service standards they set. In an effort to refocus their transportation system on moving people, Seattle recently adopted a concurrency system that measure LOS by single occupant vehicle (SOV) mode split but exempts the densest areas of the city. Studies by the city concluded that there will be no impacts to traffic under the new policy. This research scrutinizes that assumption by examining trip generation along selected corridors under both current development and future development scenarios using the output of the city's zoned capacity model. I found that SOV trips are likely to increase in exempted areas even if mode split aligns with targets set in the concurrency policy. This suggests that traffic conditions will worsen under the new concurrency policy and brings into question its efficacy as a policy to reduce impacts to the city's transportation system.

Contents

1 Introduction

As authors like Donald Shoup in 2005 and Anthony Downs in 1992 have pointed out, in the past many sprawl-biased practices have been used by planners to determine what infrastructure should be built. As they showed, the Institute of Transportation Engineers' Parking Generation and Trip Generation manuals were based on a wide range of assumptions that lead planners and other local decision makers to conclude that they could build their way out of traffic issues. However, the solutions they produced have been associated with increasing dependence on automobiles for travel (Shoup 2011; Downs 1992). Many states have acknowledged the lessons of Shoup, Downs and other researchers and started to move away from these kinds of practices (D. Shoup 2011). This work is inspired by Shoup and Downs and seeks to shed light on questionable assumptions in transportation planning practices. It specifically looks at a new transportation concurrency policy adopted in Seattle.

Growth management as a practice arose partly out of the desire to reduce auto-dependent sprawl. Within growth management schemes, transportation concurrency is a policy to contain and control sprawl. Concurrency requirements, also known as adequate public facilities, are meant to ensure land development occurs only where there is public infrastructure to support that development. The intent is to require cities to deny development permits for projects that cause performance of the transportation system to degrade below a certain level or require developers to provide mitigation to improve the system (Pearce 1993). Phrased another way, concurrency could be understood as, "land use regulation which controls the timing of property development and population growth. Its purpose is to ensure that certain types of public facilities and services needed to serve new residents are constructed and made available contemporaneously with the impact of new development," (Boggs and Apgar 1991). Washington State is one of only two states, the other

being Florida, which requires planning jurisdictions, cities and counties in the case of Washington, to implement transportation concurrency systems. As part of the transportation concurrency regulation scheme, Washington State's Growth Management Act (GMA) requires local planning jurisdictions to set minimum level of service (LOS) standards to gauge performance of their transportation systems and to not approve developments that would cause level of service to go below those standards (Pearce 1993, 1025).

In the recent decades, with the movement from car-centric planning to multimodal planning, policy makers have made an effort to change specific infrastructure planning practices in order to produce more compact development, enhance transportation options, and contain suburban sprawl. Authors such as Shoup (2005) and Downs (1992) are two of the most well-known scholars who have shed light on specific practices used in transportation planning that have contributed to the auto-centric communities that became the norm in the post-war era. In reaction to such research, planning authorities have begun to reform their practices to produce outcomes that are more aligned with goals related to reducing sprawl. Cities have rethought how they manage and require construction of parking since Shoup's landmark work on the subject (D. Shoup 2011). Likewise, state highway departments have begun to rethink their models used to forecast the need for new highways in light or research on induced demand and renewed interest in provision of alternative modes of transport (Sonnenberg et al. 2013). In Washington, many jurisdictions have begun to rethink the way they plan for infrastructure and specifically how they measure level of service under the GMA's concurrency requirements.

Washington's Growth Management Act has few specifics on how jurisdictions should measure transportation service or when to trigger mitigation for developments that do not meet level of service standards. It only requires them to adopt ordinances requiring concurrency but does

not specify how to measure level of service or what it should be set at to trigger denial of development permits (Pearce 1993).

In Seattle level of service is now measured by the share of trips that are made using single occupancy vehicle (SOV) modes. However, the densest areas of the city are exempt from concurrency requirements. The new rules assume that these areas, by virtue of being mixed use, having extensive transportation options, and having a higher density of destinations within them, will naturally achieve the SOV mode share targets. This exemption also plays into the city's "Urban Village Strategy" to concentrate growth in those areas. As a result of exempting these areas from the policy, denial of permits or requiring mitigation will not suppress development. That is, more development can take place in the exempt areas without pushing up against limits of transportation concurrency that the city has set. The new system, based on mode split, arose out of one of the goals listed in the city's comprehensive plan regarding reducing the proportion of trips made by single occupancy vehicles. That goal is to, "safely and efficiently connect and move people and goods to their destinations," as the city grows (Seattle OPCD 2018b, 76).

The first two goals listed in Washington's Growth Management legislation are containing urban development to existing urban areas and reducing sprawl *(RCW 36.70A.020: Planning Goals>* n.d.). The purpose of this research is to evaluate the new policy in Seattle and the assumptions it makes about the exempted areas. More specifically, I'll focus on the areas the city has exempted from the concurrency rules so see how traffic conditions might worsen if the city were to reach SOV mode split target set for those areas. The study will look at two corridors in different neighborhoods that are in the exempted areas and examine changing traffic conditions under future growth scenarios. I hope to reveal whether the concurrency system put in place by the City is fulfilling its intended purpose, which is to ensure transportation capacity is sufficient to support future

development in high-growth areas. Thinking of my question about the impacts to traffic from the concurrency policy, I hypothesized that the raw number of SOV trips will continue to increase despite falling SOV mode share and it will further strain vehicle capacity on the city's streets. The study employs exploratory sequential mixed-methods estimate trip generation and vehicle capacity of streets and understand what effect different development scenarios have on traffic. By measuring development capacity in high-growth areas and comparing expected travel demand to the transportation system capacity, this research will reveal how well this concurrency system delivers on the goals of the GMA.

A literature review will examine the research on the sources of sprawl and its effects and why I am adopting the normative position that governments should seek to avoid sprawl. As well, it will review existing concurrency requirements under growth management schemes and how transportation service is measured with a focus on how those concurrency systems impact development. In the methods section I'll detail how I apply trip generation to zoned capacity data to see what the likely number of trips would be under a built out scenario of the current zoning. As well I'll discuss how I'll I calculate SOV trips and I measure traffic conditions to see if they are degrading or not under different growth scenarios.

The study will help inform policy makers and planners in Seattle as they work towards the goals of concentrating urban growth and reducing sprawl that are set out in the Growth Management Act. Specifically it will help them understand how their transportation concurrency systems and zoning codes in place work towards or against these goals.

2 Literature Review

The purpose of this thesis is to evaluate a new measure of level of service used in Seattle, Washington and how it serves the purpose of transportation concurrency. Namely, that purpose is ensuring desired performance of a city's transportation system as new development occurs. The first and second goals of Washington State's Growth Management Act are concentrating urban development and containing sprawl. This review of the literature starts by examining how sprawl has been defined, what the original critiques of it were, what effects the of sprawl are, and what assumptions and practices go into planning infrastructure. I'll then give an overview of transportation concurrency systems under state growth management schemes in the US. This will include the theory behind them and research on how they have been implemented and whether they have been effective at achieving their desired outcomes. Specifically, I'll focus on any research that relates to concurrency requirements and their impact on land development. Lastly, I'll look at multimodal concurrency policies in Washington State and the process the City of Seattle went through to formulate its new concurrency policy.

2.1 Definitions and Critiques of Sprawl

Researchers have acknowledged that the definition of sprawl is ever shifting and can mean different things in different contexts. Williamson (2010) discusses the definition extensively in *Sprawl, Justice, and Citizenship*. He explores how scholars, governments and think tanks have defined sprawl variously as a process, a single phenomenon, or a bundle of development characteristics that have been defined both quantitatively (Galster et al. 2001) and qualitatively (Duany, Plater-Zyberk, and Speck 2000; Williamson 2010). He ultimately lands on the definition for his work, "recently built suburban development characterized by low density and high reliance on automobile transportation," (Williamson 2010, 28). Hamidi et al. (2015) also acknowledge the lack of agreement

on a single definition of sprawl. They draw on research sponsored by the US Environmental Protection Agency and Smart Growth America to define sprawl quantitatively so that its effects on health and environmental outcomes could be studied more closely. They also provide an updated quantitative index to measure compactness as a proxy for sprawl (Hamidi et al. 2015).

Most broadly, sprawl can be thought of as development at low densities that necessitates long trips between origins and destinations. Critics have voiced concerns about sprawl's negative effects going back to the era of Mumford and Jacobs (Mumford 1961; Jacobs 1961). Commenters and researchers have long drawn connections between traditional zoning that favors single uses and single family residences, dispersed development, and long travel times (Talen 2013). As zoning dispersed people across larger and larger distances, use of personal automobiles became more and more widespread and seen by most as the only viable means of travel.

This thesis is inspired by two scholars in particular who questioned the assumptions about specific transportation planning practices that had long been established as industry standards but attracted little scrutiny prior to their work. Anthony Downs (1992), in his seminal work on highway planning, *Stuck in Traffic*, highlighted how transportation engineers exacerbated the trend towards sprawl by standardizing tools that biased policy outcomes toward building more and wider roads thus making other travel modes infeasible. Donald Shoup in his 2005 work *The High Cost of Free Parking* did the same for parking by looking the assumptions and data on which land use codes that require an overabundance of parking were based. He showed how these practices created even more dispersal as more land was taken up for car storage. From both Downs' (1992) and Shoup's (2005) research it's not hard to see how assumptions inherent in many transportation infrastructure planning practices lead to more sprawl.

Arising out of such critiques of sprawl in the planning community, scholars like Duany (1992) and Calthorpe (1993) founded the New Urbanism movement and devised proactive steps planners could take to avoid the negative effects of sprawl that had become familiar (Duany 1992; Calthorpe 1993). Shoup and Downs arose out of a similar line of thinking on sprawl but took a magnifying glass to existing practices in the field in attempt to reform them rather than creating new practices all together as with Duany and Calthorpe.

By the turn of the century, scholars had clearly begun to recognize the impact that urban infrastructure planning has on land use patterns; not just highways and transportation infrastructure, but all kinds of infrastructure that expands into previously undeveloped land further away from the center city. The following paragraphs first look at scholarship that connects sprawl to negative environmental, public health, and civic health outcomes. I'll then discuss research on specific infrastructure planning practices that have contributed to sprawl and its effects. Reid Ewing at the University of Utah is one of the most prominent scholars producing work on the effects of sprawl and this literature review draws heavily on his work. A discussion of ways to improve those planning outcomes and practices that help reduce sprawl follows. Next, I'll look more closely at transportation concurrency in Washington including what the GMA requires and how that has been implemented by cities. Finally, I'll dig deep into the policies in Seattle, specifically how the new SOV mode split based level of service measurement system was established to comply with transportation concurrency requirements.

2.2 Effects of Sprawl

At the turn of the 21st century, around the time Shoup and Downs were shedding light on the sprawl-biased practices in transportation infrastructure planning, extensive research was produced on the negative impacts of sprawl. Peiser decomposed the parts of sprawl and categorized

them into ones that are outcomes of the process of development and ones that are negative end results of the kind of development it produces. He identifies the process outcomes as "low-density development; leapfrog development; scattered development; and land speculation," and the negative end results as, "gluttonous use of land; monotonous development; environmental degradation; poor accessibility; poor infrastructure; and under-provision of functional open space," (Peiser 2001, 285–88). Besides externalities like pollution and public health impacts that may not have factored into cost models for infrastructure, Speir and Stephenson showed that producing sprawl-inducing infrastructure was also not supportive of the financial bottom line (Speir and Stephenson 2002). Likewise, Klug and Hayashi produced a comparative model with Nagoya and Munich to show that more densely developed communities produced significant cost savings in infrastructure projects (Klug and Hayashi 2012).

The social atomization that results from living in sprawling land uses has become somewhat of a defining cultural phenomenon in the popular media. Researchers have also employed their methods to show sprawl can lead to civic disengagement as well as increased social inequality. Williamson (2010) documented these social impacts of sprawl extensively by using results of the Social Capital Community Benchmark Survey to gauge social effects of sprawl. He found the form that sprawl in the U.S. is linked to, "reduced …political participation, especially in more confrontational forms, [and is] part and parcel of a political regime characterized by systemic social inequalities mediated in part by geography." And he further shows, "suburban residence is linked to politically conservative attitudes that resist efforts to rectify those inequalities," (Williamson 2010, 12). However, some research has noted sprawl also supports some forms of social capital. Nguyen, looking at the same survey as Williamson, examined the statistical relationship between the county sprawl index and social capital factors. She found that compact living, as opposed to sprawl, seems

to negatively correlate with, social interaction, faith-based social capital and giving and volunteering which Williamson also noted (Nguyen 2010).

Effects on public health have been much more conclusive. Frumkin details the numerous health impacts from sprawling land use patterns including air pollution, reduced physical activity, vehicle crashes, social stratification and mental health issues connected to more regular driving (Frumkin 2002). Arcaya et al used a natural experiment with Hurricane Katrina survivors to show those whose relocation corresponded with an increase in county sprawl index also saw an increase in body mass index (Arcaya et al. 2014). Likewise, in King County where analysis for this thesis focuses, Hurvitz and Moudon have produced extensive research connecting common aspects of sprawl to higher obesity rates such as prevalence of arterial roads and fast food restaurants (Hurvitz et al. 2009). As well they used data from subjects to show higher public transit use, which is more widspread in less sprawling urban areas, is connected to higher physical activity (Saelens et al. 2014). Ewing et al conducted a similar but more wide reaching study to connect levels of physical activity and health issues like obesity, hypertension and heart disease. The study included over 200,000 adults over three year in 448 counties. They found that there is likely a connection between low density sprawl and reduced physical activity that leads to poorer health outcomes (R. Ewing et al. 2008).

The environmental impacts of sprawl are also well documented in the academic literature, reports from non-profits and think tanks, and governmental agencies. As sprawling development is inherently more spread out and thus resource intensive the connections between worsened environmental impacts are intuitive. Ewing found that residents in sprawling counties are more likely to live in detached single-family homes and have a larger amount of living space which both correlate to higher residential energy use (R. Ewing and Rong 2008). Extensive research has shown

the myriad environmental impacts of sprawl including species loss (R. H. Ewing et al. 2005) and increased greenhouse gas emissions (R. Ewing 2008). Kahn documents aspects of urban sprawl that contribute to these outcomes including increased vehicle use and fossil fuel, land, and water consumption (Kahn 2006, 110–29). In the time of increasing urgency to combat climate change on all fronts, changing how development occurs in our urban areas and reducing suburban sprawl associated with the aforementioned ecological outcomes will be a crucial policy tool.

2.3 Infrastructure Planning and Sprawl

The connection between infrastructure and how it can lead to sprawling land use outcomes has also garnered much attention. Many authors have focused on identifying a connection between how infrastructure is provided, the frameworks around infrastructure provision, and whether or not those mechanisms lead to sprawl. In a report to inform planning practice reform in Florida, Ewing documents the numerous factors that can lead to sprawl including certain ways of providing infrastructure (R. H. Ewing 2008). Maya looks at infrastructure provision and its connection to sprawl through a legal lens to discuss what legal frameworks encourage sprawl inducing infrastructure and how laws can be changed to reduce sprawl (Maya 2008). Pettersson looked at the assumptions that planners in Sweden use when constructing planning models. He takes a philosophical approach and identifies normative assumptions and world views such as the growth paradigm that often undergirds planners' thinking (Pettersson 2013). Tennøy builds on this framework by examining how planners frame questions around transportation. She uses surveys and interviews with practitioners to identify assumptions that inform their work. She concludes that, much like the trip generation manual from ITE that Downs critiqued, transportation planners have operated under the mindset of "predict and provide." She advocates for shifting this perspective to one that is more goal oriented and focuses on desired outcomes such as greenhouse gas reduction

(Tennøy 2010). An area of research within infrastructure planning that has shown why this type of mindset does not serve the public good is induced demand. The phenomenon of induced demand can be traced back to the economic concept known as Say's Law which most often stated as "supply creates its own demand," and was originally articulated by 19th century economist Jean-Baptiste Say (Say 2001). In transportation planning, the concept relates increasing provision of infrastructure with increasing demand for travel via that infrastructure. Noland and Lem reviewed the research on the topic and found strong evidence that increasing transportation capacity leads to increased traffic (Noland and Lem 2002). Ewing and Proffitt examined transportation policies produced by Metropolitan Planning Organizations about how to avoid induced demand but still expand capacity in their transportation systems. They concluded that regions should not abandon highway expansion altogether but rather focus on prioritizing alternative modal systems as well as focus on alternative uses of roadways such as high occupancy lanes for improving capacity (R. Ewing and Proffitt 2016).

Related to Tennøy's work on the worldviews that shape how planners devise infrastructure planning practices, many scholars have also focused on identifying why planners may pursue infrastructure planning in a way that encourages sprawl and how to retool those approaches to produce better outcome. On the topic of operating paradigms used in infrastructure planning, planners often approach infrastructure questions by focusing solely on the supply side and don't consider how user demand might be influenced. Dowall and Whittington (2003) explored how this led to infrastructure crises in California when policy makers in the post-WWII decades attempted to get ahead of the state's infrastructure needs by undertaking massive school, water and highway projects only to see them overburdened and in disrepair in later decades (Dowall 2003). This has started to change in recent years. The field of Transportation Demand Management began to gain prominence with the rise of movements like New Urbanism as local jurisdictions started to change

their supply side thinking on infrastructure. For example, Marvin and Guy pushed for demand responsive infrastructure planning that includes integrated transportation packages and water and power efficiency measures. Overall, they found stronger cases for network management rather than focusing on capacity produced by individual projects (Guy and Marvin 1996). On the consumer side, Noonan et al looked at why green technologies are not more readily taken up by service providers as well as private users. He looked at the beltline in Atlanta as a case study and found the public can be a limiting factor in taking up new forms of infrastructure that seek to produce better environmental, social and health outcomes (Noonan, Zhou, and Kirkman 2017). On that theme of user preferences, Gavrilidis et al examine how infrastructure planners can play on the public desires to improve infrastructure provision. They provide a model to show how vacant urban lands can be adapted to fulfill desires for greenspace that often draw people to suburban areas with the mystique of more sylvan environs (Gavrilidis et al. 2017). De Vos and Witlox looked at Flanders, Belgium as a case study to argue how land use regulations and mobility policies failed to limit sprawl. They conclude that more active promotion of sprawl reducing infrastructure provision should be taken up to change travel habits (De Vos and Witlox 2013). These works together seem to suggest that, in order to reduce sprawl that results from infrastructure, planners need to take a more proactive approach to tie outcomes to infrastructure projects, think in terms of infrastructure networks rather than individual projects, and avoid the supply side focused "predict and provide" mindset.

2.4 Transportation Concurrency in Washington

This study will look at one aspect in infrastructure planning, concurrency requirements, and see how it supports sprawl reduction goals in the GMA. Concurrency was first implemented as part of a growth management scheme in Florida where exponential growth in the mid twentieth century necessitated stricter community planning requirements from the state (Robertson 1996). Florida's

was the first law to require local jurisdictions to set level of service standards for transportation systems, as well as other municipal service systems, in 1985 and require local jurisdictions to deny development permits if those developments would degrade service below those standards (Robertson 1996). The Growth Management Act, passed in Washington State in 1990, established a similar provision but only required local jurisdictions to establish level of service standards for transportation systems and deny permits that degraded service below those standards (Pearce 1993). Some legal reviews noted at the time that it would likely have, "the single greatest regulatory impact on real estate development," among the provisions and requirement of the GMA (Pearce 1993). When the law passed, the most common measure of level of service in transportation was the one outlined in the Highway Capacity Manual that measured vehicle throughput at intersections. This became the default measure that cities used to set standards to comply with concurrency requirements (Hallenbeck et al. 2007).

Though concurrency was meant to control growth at the fringe where urban services might not exist, it often unintentionally ended up restricting development in urban centers because new developments there were judged to generate too much vehicle traffic that would degrade the vehicle capacity level of service at nearby intersections (Comeau 2009; Pfundt 2019). In a comparison of two Florida counties' concurrency management systems, Greg Stuart noted, "concurrency requirements offer an inherent incentive for development to locate in areas of the greatest surplus roadway capacity. In most cases, these areas are associated within the urban fringes," (Stuart 1994, 72). In the same study, Stuart notes that, because there was no funding for infrastructure tied to the state-required implementation of a concurrency system, the counties designed there system so as to avoid issuing any moratoria for development that violated concurrency. Other commentators have also noted the connection between a lack of funding for infrastructure in urban cores and

development moving to the urban fringe where roadway capacity exists in excess (Koenig, Knack, and Quinn 1990).

Florida's experience provides a clear example of how local jurisdictions work around concurrency requirements when they lack a practical means to achieve intended goals of ensuring adequate infrastructure where development occurs. Requiring infrastructure to be built ahead of development seemed like a straight forward way to manage the growth of cities but most recent research has continued to show implementation of concurrency systems in many cases has only lead to more sprawl. Kim, Steiner and Yang showed how this happens by pushing dense development out from urban areas where funding was not available to make the necessary infrastructure upgrades. Development moved to the urban fringe where low density development meant lower volumes on roadways and thus higher levels of service under vehicle capacity LOS systems (Kim, Steiner, and Yang 2014).

In Washington State, reviews of the concurrency systems and requirements have similarly noted that vehicle capacity measures have proven insufficient for use in dense urban areas because they were so restrictive to development (Hallenbeck et al. 2007; Puget Sound Regional Council 2003). As a 2003 report on transportation concurrency notes, cities in Washington, under requirements from the GMA, are trying to concentrate growth in their urban centers but such concentration leads to greater number of trips in those areas and thus pushes developments and the trips they produce over the level of service thresholds set by the city thus restricting development where the GMA seeks to encourage it (Puget Sound Regional Council 2003, 10). A 2007 report to the Washington State Legislature similarly noted how level of service measures that focused on only on vehicle capacity was not serving urban areas well as it did not account for other modes of travel. It notes that the only remedy when measuring level of service this way is to provide more lanes on

streets and roads which is not possible in dense built up areas. Thus, LOS and concurrency systems as they existed acted to prevent development altogether (Hallenbeck et al. 2007, 2)

In the wake of reports documenting these shortcomings of how concurrency was being implemented, many cities in Washington State have implemented multimodal concurrency measurement systems (Comeau 2009; Pfundt 2019). Research in the field has documented the links between vehicle level of service-based transportation concurrency systems, how they can lead to sprawl, and the need for broader measures of concurrency. Guttenplan et. al provided a framework for evaluating multi-modal transit districts developed by Florida's DOT for concurrency systems (Guttenplan et al. 2001). Washington has taken a less top down approach allowing cities to develop their own measurement systems to comply with concurrency. Many cities have developed what they describe as bank account systems that track the trips their transportation system can support on all modes and count trips generated by development against that. For example, in Bellingham policy makers have identified different zones of the city where they measure level of service differently. In central areas that have a more gridded street pattern and more transit and bike lanes, planners account for all the trips available by all modes based on transit services, sidewalks, length of bike lanes, traffic capacity, and other measures. In areas further from the city center where development patterns predispose trips to car travel, less weight is given to alternative modes in measuring level of service (Comeau 2009). However, little has been done to evaluate these new level of service measurement systems in Washington and how they support growth management goals.

2.5 Seattle's New Concurrency Policy

This research will examine the new concurrency system establish in Seattle in the most recent update to its comprehensive plan (Seattle OPCD 2018b). In the following sections I'll use the

terms mode split and mode share interchangeably to discuss splits or shares of trips taken by a certain mode.

Like most other cities in Washington following passage of the GMA, Seattle adopted level of service standards based on vehicle capacity of streets (Seattle OPCD 2016). That system established imaginary screens perpendicular to different arterials around the city, known as "screenlines," measured traffic volume passing through those screenlines and compared it to vehicle capacity as calculated in the Highway Capacity Manual (Transportation Research Board 1985). However, as mentioned above, urban built up areas like Seattle were presented with a conundrum when it came to setting vehicle capacity LOS in their concurrency policy. Setting it to preserve the free flow of traffic would present the city with the impossible choice of either denying all new development because it would degrade traffic conditions or adding lanes to arterials which would require extensive property acquisition and demolition along those arterials. Because of this, the city set levels of at 1.0, that is, the traffic volume equaled the vehicle capacity at screenlines, or even higher so as not have to deal with that impossible choice (Seattle OPCD 2016, 3.1-21; Hallenbeck et al. 2007, A-3).

With the passage of its most recent comprehensive plan update in 2016 Seattle adopted a new level of service standard that would better reflect goals outlined in the plan and previous plans regarding focusing the transportation system on moving people rather than vehicles (Seattle OPCD 2018). Under the new policy, level of service is based on single occupancy vehicle mode share rather than vehicle capacity ratios at screenlines. The policy divides the city in eight zones that have different SOV mode split "targets." Figure 1 shows these different zones as well as their SOV mode splits as of 2015 and their target SOV mode splits that establish the level of service in each zone. The term target is used in the policy documents, municipal code, and comprehensive plan but it is a

bit misleading in that the "target mode splits" act more like thresholds. If a share of a given development's trips generated, as measured in a traffic impact analysis submitted with their development application, exceeds the SOV target for that area of the city then the concurrency policy is triggered and they are required to provide mitigation (City of Seattle 2019, SMC 23.52). However, in line with the goals in the comprehensive plan and goals of the GMA to direct growth to dense, transit-rich areas of the city, the city exempt its densest neighborhoods.

Figure 1 SOV reduction targets for eight sectors in Seattle as the City's adopted LOS. (source: Seattle Comprehensive Plan Final EIS, 2016)

Since the first comprehensive plan adopted in Seattle under the GMA, the city has pursued what it calls its "urban village strategy." The strategy places neighborhoods in different categories. The densest neighborhoods are categorized as "urban centers" under the strategy with the next tier being neighborhoods with midrise mixed use development that are known as "hub urban villages." As part of the strategy to direct growth into urban centers and hub urban villages, the concurrency policy exempts them from the regulations. Parcels within half a mile of light rail stations, of which there are currently 13 along the Sound Transit Link Light Rail line with three more opening in 2021, are also exempted from the policy (City of Seattle 2019, SMC 23.52).

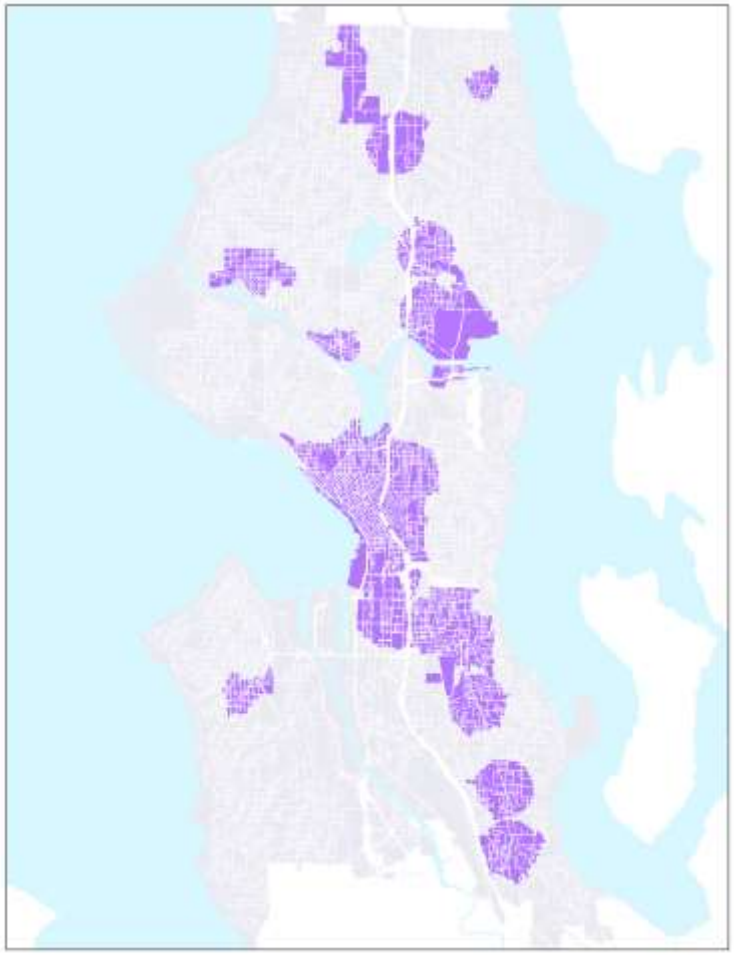

Figure 2 Purple areas show the parcels in the city where development is exempt from concurrency requirements.

shows where these exempt parcels are located in the city. Through the rest of this thesis, I'll refer to these exempted

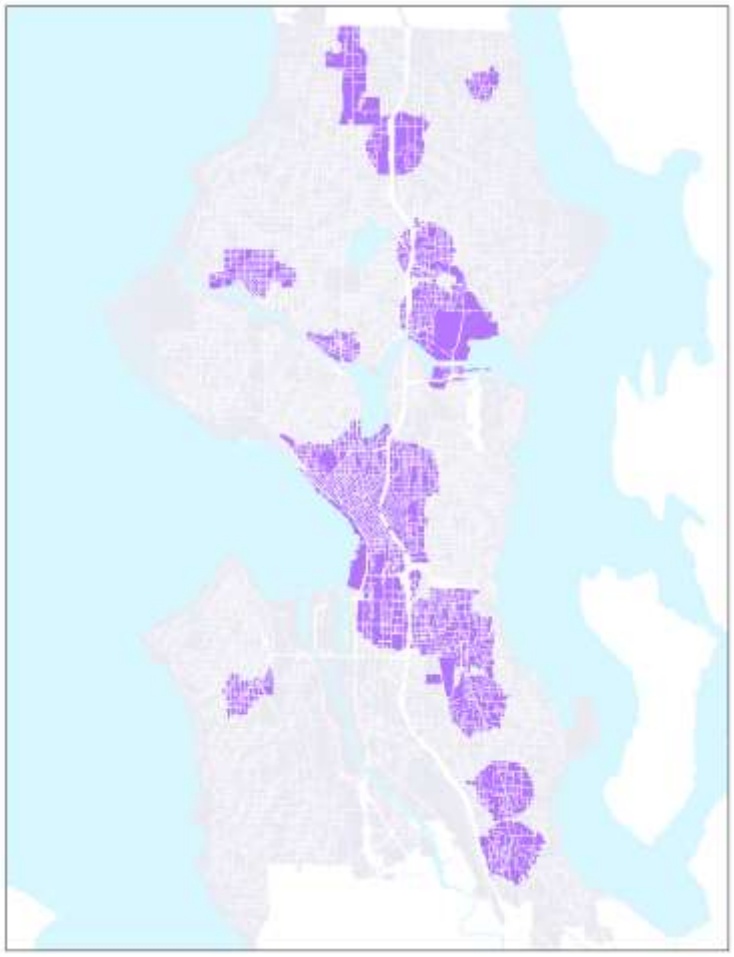

Figure 2 Purple areas show the parcels in the city where development is exempt from concurrency requirements.

areas as "transit centers." Analysis conducted by the city justifies exempting these areas by citing a study done for the comprehensive plan's environmental impact statement and other research that says reliance on SOV travel is less in areas with frequent transit service, employment opportunities, and shops and services. Citing this research, city staff claimed projects in the transit centers meet the standard by virtue of being in areas more conducive to non-SOV travel (Kofoed 2018).

The Environmental Impact Statement (EIS) for the most recent comprehensive plan update analyzed impacts of the new concurrency policy including traffic impacts (Seattle OPCD 2016). The

analysis was conducted for several alternative strategies for planning growth for the next twenty years. This timeframe is based on the projections of population and job growth the city receives from the Puget Sound Regional Council and Countywide Planning Policies that are produced collaboratively by elected official from across the county. Countywide Planning Policies, "provide guidance for the comprehensive plans that the cities in King County must adopt," and, "contain twenty-year housing and job-growth targets for each jurisdiction," (Seattle OPCD 2018b, 9–10). The concurrency policy that existed in Seattle prior to adoption of the 2016 comprehensive plan measured vehicle capacity at screenlines around the city. As mentioned above, screenlines are imaginary lines perpendicular to a street where traffic is counted (Yang, Yang, and Gan 2006). Figure 3**Error! Reference source not found.** shows locations of screenlines where vehicle capacity was evaluated under the old level of service measurement system. Numbers on the map designate individual screenlines and correspond to rows in Table 1. Table 1 shows LOS standard from the previous concurrency policy and the LOS reached under the analysis of the growth projection scenarios that the comprehensive plan assumes, referred to as the "preferred alternative" in the EIS. The level of service targets in Table 1 use vehicle to capacity ratios, the same level of service measurement used in this paper. Based on the results shown in the table, the EIS concludes, "All of the screenlines are projected to meet the LOS standard for the PM peak hour under all alternatives. Therefore, no auto, freight or transit impacts are expected under any of the alternatives, including the Preferred Alternative," (Seattle OPCD 2016, 1–24). That is not to say roadway conditions and traffic are not worsening but simply that vehicle capacity level of service is not degrading beyond the levels the city set. The analysis for this paper will be similar to this screenline analysis in the EIS but at selected intersections along corridors in areas exempted from the new policy rather than screenlines around the city. By comparing current SOV trips generated to SOV trips generated

under future scenarios, this research will question the statement above from the EIS that no impacts are expected under future growth scenarios.

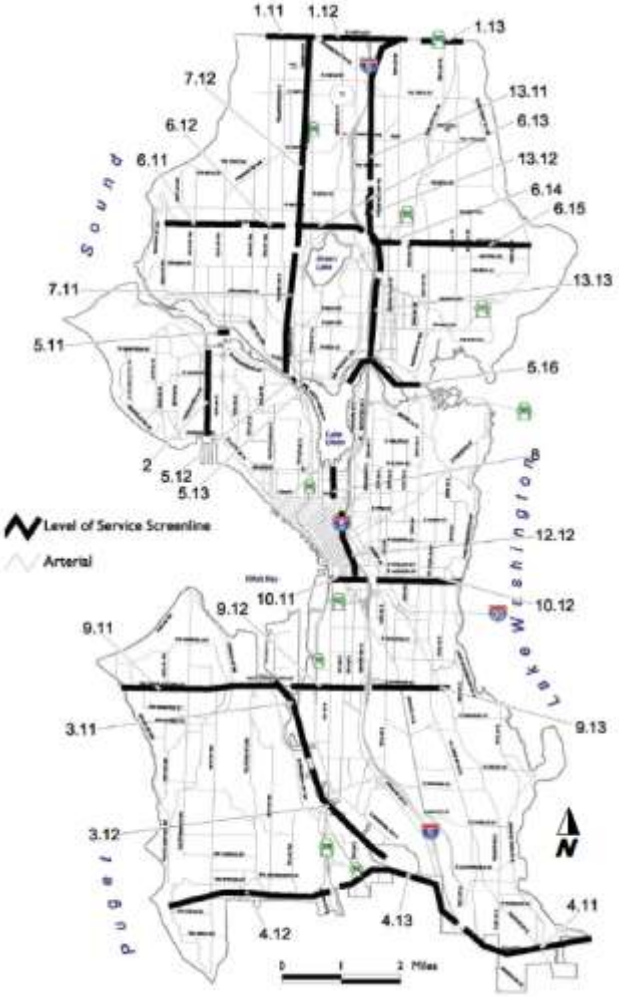

Figure 3 Location of screenlines used under previous concurrency policy where traffic was measured to determine vehicle capacity level of service to comply with concurrency regulations.

Table 1 2035 PM peak volume to capacity ratios (Seattle OPCD 2016, 3.1-22)

			Preferred Alternative V/C	
No.	Location	LOS Standard	NB/EB	SB/WB
1.11	North City Limit—3rd Ave NW to Aurora Ave N	1.20	1.04	0.8
1.12	North City Limit—Meridian Ave N to 15th Ave NE	1.20	0.77	0.64
1.13	North City Limit—30th Ave NE to Lake City Way NE	1.20	0.97	0.84
2	Magnolia	1.00	0.56	0.56
3.11	Duwamish River—West Seattle Bridge & Spokane St	1.20	0.69	1.15
3.12	Duwamish River—1st Ave S & 16th Ave S	1.20	0.38	0.55
4.11	South City Limit—Martin Luther King Jr Way to Rainier Ave. S	1.00	0.56	0.93
4.12	South City Limit—Marine Dr SW to Meyers Way S	1.00	0.56	0.72
4.13	South City Limit—SR 99 to Airport Way S	1.00	0.58	0.74
5.11	Ship Canal—Ballard Bridge	1.20	1.18	0.72
5.12	Ship Canal—Fremont Bridge	1.20	0.79	0.71
5.13	Ship Canal—Aurora Bridge	1.20	0.92	0.82
5.16	Ship Canal—University & Montlake Bridges	1.20	0.95	1.05
6.11	South of NW 80th St—Seaview Ave NW to 15th Ave NW	1.00	0.53	0.5
6.12	South of N(W) 80th St—8th Ave NW to Greenwood Ave N	1.00	0.87	0.78
6.13	South of N(E) 80th St—Linden Ave N to 1st Ave NE	1.00	0.54	0.41
6.14	South of NE 80th St—5th Ave NE to 15th Ave NE	1.00	0.74	0.67
6.15	South of NE 80th St.—20th Ave NE to Sand Point Way NE	1.00	0.63	0.58
7.11	West of Aurora Ave—Fremont Pl N to N 65th St	1.00	0.56	0.65
7.12	West of Aurora Ave—N 80th St to N 145th St	1.00	0.57	0.67
8	South of Lake Union	1.20	0.91	0.82
9.11	South of Spokane St—Beach Dr SW to W Marginal Way SW	1.00	0.59	0.72
9.12	South of Spokane St—E Marginal Way S to Airport Way S	1.00	0.6	0.7
9.13	South of Spokane St—15th Ave to Rainier Ave S	1.00	0.66	0.89
10.11	South of S Jackson St—Alaskan Way S to 4th Ave S	1.00	0.64	0.84
10.12	South of S Jackson St—12th Ave S to Lakeside Ave S	1.00	0.75	0.91
12.12	East of CBD	1.20	0.39	0.52
13.11	East of I-5—NE Northgate Way to NE 145th St	1.00	0.86	0.79
13.12	East of I-5—NE 65th St to NE 80th St	1.00	0.51	0.53
13.13	East of I-5—NE Pacific St to NE Ravenna Blvd	1.00	0.63	0.65

This research seeks to better understand the concurrency system devised for Seattle and how it may or may not be effective for a dense, quickly growing urban area. Specifically, I'll seek to answer the question of how traffic conditions degrade or improve in the exempt areas of the city assuming the areas reach mode splits laid out in the new concurrency policy. To do so, I'll rely on data output from a model Seattle staff use to estimate capacity for land development called the Zoned Capacity Model. In Washington State, in order to support long range planning efforts by cities, counties are required to produce buildable lands reports that estimate how much land and development capacity is available to accommodate growth targets (Washington State Department of Commerce 2012, 84–89) . To support this, Seattle's Zoned Capacity Model draws on parcel information from the King County Assessor to produce parcel-by-parcel data on what development currently exists and what future development of a parcel is likely given current zoning, how recently it was developed, geographic constraints, and other factors (City of Seattle 2019b). These efforts are to show that enough capacity exists under zoning to accommodate the growth that is expected (Seattle OPCD 2018b, 9). In addition to allowing for enough growth, the city uses zoning to direct growth to certain areas of the city, namely urban centers and hub urban villages, by allowing denser development in them. These are also the areas that are exempt from concurrency requirements.

This research is intended to show how the concurrency system in Seattle is serving its purpose: to maintain performance of a transportation system in the face of increasing development. Though I'm evaluating traffic conditions using vehicle capacity measures, the research is not meant to suggest that cities should operate under the goal of ensuring fast travel for private vehicles. It is simply meant to highlight unintended consequences of the policy that may impact travel modes the city wants to encourage.

3 Methods

My research sought to examine whether Seattle's future possible growth based on the zoned capacity model output will push up against the limits of its transportation system. Specifically, I evaluated the policy in terms of the mode split level of service system the City has established to comply with the concurrency requirements of Washington's Growth Management Act. The new rule in Seattle exempts transit centers from complying with the level of service standards. I looked at these areas specifically to test the efficacy of the assumptions underlying this exemption. The question I'm attempting to answer is the following: what unintended impacts in terms of traffic conditions might the exemption of transit centers from concurrency regulations have on the transportation system in those areas? If it worsens traffic conditions, this may suggest the policy is not serving the spirit of the GMA by ensuring adequate transportation facilities are provided concurrently with new development.

3.1 Data Required

To answer the question I needed data on current development as well as future development to be able to estimate the number of trips under current and future scenarios. The data on development used in the analysis was from the city's zoned capacity model. As discussed above, the zoned capacity model is used to support growth assumptions in the comprehensive plan and shows the capacity the city has to develop is sufficient under current zoning. The dataset includes 59 fields and is available through the city's open data portal (City of Seattle 2019b). The relevant fields in the data set for this research were current zoning, the gross square feet of the current development, the current number of residential units, land use description, current commercial square footage, potential residential units, potential commercial floor area, and observed split of commercial and residential. To analyze an alternative scenario based on growth projections in the comprehensive

plan, I used data from the Development Capacity Report that was produced in conjunction with the most recent comprehensive plan update. That report estimated how much of the zoned capacity will be used under the growth projection in the comprehensive plan (Department of Planning and Development 2014, 2) which were used to calculate trips generated under the alternative growth scenario for this research. The Trip Generation Manual is an industry standard among transportation engineers for estimating the number of trips generated by a development based on its use (Institute of Transportation Engineers 2012). Equations and rates from this manual were applied to data from the zoned capacity model for parcels along the selected corridors.

In order to calculate capacity of relevant intersections, I required some data about the intersections to use as inputs to the formulas in the Highway Capacity Manual. This data included street configuration, signal timing, and other inputs used in formula in the Highway Capacity Manual for intersection capacity calculations (Transportation Research Board 1985). These data were obtained by observing layouts of intersections in photographs in Google Street View (Google 2019b), from the intersection dataset produced by the City (Seattle Department of Transportation 2019) and, when data about intersections was unavailable, from the authors own estimates and observations based on past visits to those intersections.

3.2 Overview of Steps

To answer this question, I first examined how the city established the mode split numbers in the concurrency rules. To do so I examined planning documents produced by the city including directors rules and memorandums produced by the Seattle Department of Transportation and the most recent update of the comprehensive plan and its environmental impact statement. I then examined a future scenario under which two selected corridors are built to their zoned capacity based on data output from the city's zoned capacity model. I used ITE's Trip Generation (Institute

of Transportation Engineers 2012) method to estimate trips that such a build out would generate. I then calculated a number of SOV trips using the target mode split established in the concurrency legislation for each neighborhood. I then examined what impacts the increase or decrease in SOV trips would have in terms of change to vehicle capacity level of service for those stretches of street. Finally, I conducted a sensitivity analysis by taking only a share of the trips calculated through the above steps and applying the same methodology to that amount of trips.

3.3 Steps

The first step of my research involved selecting corridors to analyze for trip generation and vehicle capacity. I used data from the output of zoned capacity model for parcels along McClellan St in Beacon Hill and 12th Avenue in Capitol Hill. Both of these areas are designated as urban centers or are within a half mile of a light rail station and thus are exempt from the level of service standards set in the city's concurrency rule. Parcels analyzed for trip generation estimates along McClellan Street are shown in figure 3 and for 12th Avenue in figure 4. I chose stretches that were mostly residential to minimize the number of through trips that would be more prevalent on a commercial arterial.

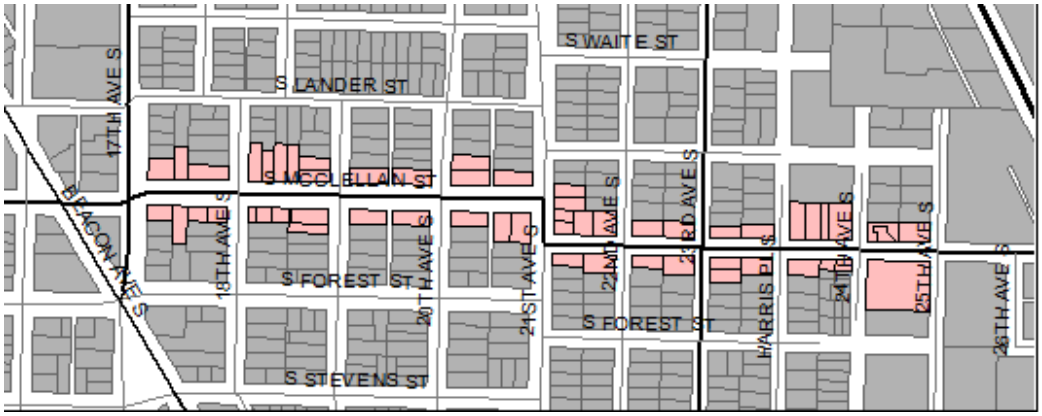

Figure 4 Parcels analyzed for trip generation estimates along 12th Avenue

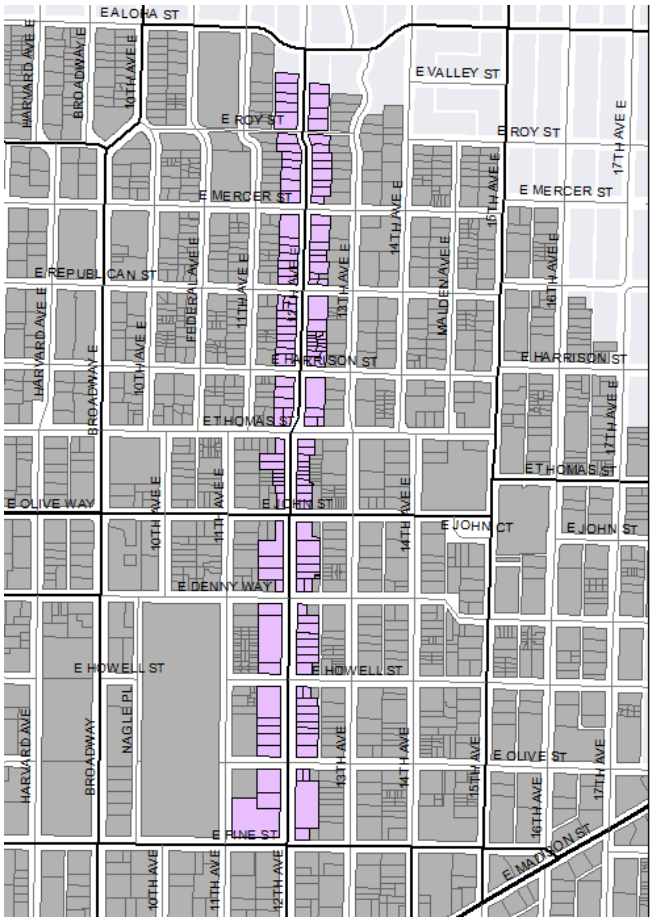

Figure 5 Parcels analyzed for trip generation estimates along 12th Avenue.

In order to set a baseline of roadway traffic for the future scenarios, I calculated trip generation for the existing parcels and vehicle capacity at relevant intersections. Having this baseline allowed me to compare future traffic estimates against current traffic. I then matched land use codes from Trip Generation to land use description for each parcel and applied the Trip Generation formulas to the relevant data point, depending on the use, in the zoned capacity model output. See the appendix for tables of parcels and trip generation output and trip generation land use codes used. I used trip generation for the PM peak period, defined as 4pm-6pm, because that is when capacity is most constrained (Institute of Transportation Engineers 2012).

The next step was to look at the study areas in terms of the expected travel demand that would be produced if they were to develop to their zoned capacity. Using the number of potential residential units or potential commercial floor areas (fields OBS_RDENS_UNITS for residential or OBS_COMM_FL_AREA for commercial in the zoned capacity model output), I again applied Trip Generation method parcel by parcel. Because the exact type of development that would be built is impossible to know, I used the land use designation from the zoned capacity data and matched it with the closest applicable land use code in Trip Generation, the low rise land use code from Trip Generation for parcels in a low rise zone for example. See the appendix for land use trip generation formula inputs and their corresponding Trip Generation land use codes. Only 12th Avenue included non-residential parcels. For mixed use parcels in zones designated neighborhood commercial (NC), I used the residential/commercial split numbers in the zoned capacity data to determine how much of the built square footage would be residential and commercial on a given parcel. I assumed average square footage of an apartment to be 1000 square feet including common space, and calculated a number of units to apply trip generation to. The 1000 square foot per unit is based on the average gross square footage per unit of multifamily buildings in Seattle which I calculated from the zoned capacity dataset by adding all the residential square footage together and dividing by the total number of residential units. For the commercial portion of a parcel's development, I either used the trip generation land use code of what was already existing on the property or, where there was not existing commercial space, I assumed a two thirds office and one third sit down restaurant split. This assumption is based on the mix of commercial space in existing developments on the parcels studied. Of the seventeen buildings that included commercial space, five included restaurants, three included offices and one included both offices and restaurants. No other single use prevailed. This produced an estimated number of vehicle trips under the current conditions and under the built out

scenario. See Equation 1 and Equation 2 below for the calculation of dwelling units and commercial floor area for mixed use parcels. All inputs for these equations were from the zoned capacity model output dataset.

Equation 1 Calculation of dwelling units in mixed use buildings in future scenarios. D=Dwelling Units, S=Developable Square Feet, F=FAR for Residential Buildings, R=Observed Share of Residential Square Footage in Mixed Use Buildings

$$\mathbf{D = (S*F)*R/1000}$$

Equation 2 Calculation of commercial square footage in mixed use buildings in future scenarios. Q = Potential Commercial Square Footage, S = Developable Square Feet, F = FAR for Residential Buildings, C = Observed Share of Commercial Square Footage in Mixed Use Buildings

$$\mathbf{Q = S*F*C}$$

After calculating those two inputs I could then apply trip generation to each and add the total to get a total trip generation for each mixed use parcel. I applied the apartments land use code from Trip Generation to the dwelling units and, as mentioned above, the office and sit down restaurant land use code to the commercial. Trip Generation outputs indicated the number of vehicle trips. The data used in the studies that make up the Trip Generation manual are based on vehicle counts at sampled sites. To convert vehicle trips produced by the Trip Generation calculations to person trips I used estimated vehicle capacity from PSRC's Vision 2040 Environmental Impact Statement of 1.6 people per car ("Vision 2040 : Final Environmental Impact Statement" 2008). Equation 3 shows this calculation.

Equation 3 PT = Person Trips, VT = Vehicle Trips

$$PT = VT * 1.6$$

Next, I calculated future travel demand estimates by using the mode split numbers set in the concurrency ordinance passed in 2019 (City of Seattle 2019a, SMC 23.52). **Error! Reference source not found.**, above, shows the delineations of different zones and their respective current mode split

and target mode split under the new policy. I compared current vehicle capacity estimates of the examined intersections to what they levels would be under the zones' target concurrency level of

Figure 6 Aerial image of intersection at 12th and John showing lane configuration (Google 2019)

service mode split.

To calculate vehicle capacity of the intersections, I used methods from the 1985 Highway Capacity manual (Transportation Research Board 1985). This manual is meant to give an estimate of the number of vehicles per hour that the lanes of the intersection are designed to handle. The basic formula for calculating capacity from the Highway Capacity Manual is shown in Equation 4 (Transportation Research Board 1985, 9–11). Calculating the precise vehicle capacity for a given lane at an intersection involves incorporation of many factors about the intersection's environment. Since this paper analyzed the PM peak, I only calculated capacity for lanes heading to the parcels, rather than away from them, as most trips would be heading home from work and most parcels along each corridor are residential. That is, east, west, and north bound lanes at the 12th and John intersection, and all lanes turning in to or going straight to McClellan at the two McClellan intersections.

Figure 7 Location of selected intersections along 12th Ave corridor

Equation 4 C_i = intersection capacity, s = saturation flow, g = green time for selected lane group, C_t = light cycle length

$$C_i = S * (G/C_t)$$

Figure 9 Location of selected intersections along McClellan corridor

Figure 8 Aerial images of intersections of McClellan and Beacon (left) and McClellan and 23rd (right) (Google 2019a)

The green time is used in the capacity formula to calculated portion of the light cycle dedicated to a given lane. This was calculated by dividing the time a light is green for a given lane by the total time taken to complete a cycle of signals at a given intersection. Table 5 **Error! Reference source not found.**shows the green time for each lane of the McClellan and Beacon. Only two phases were observed at the 12th and John intersection, that is, half the light cycle was solid green for

east/west traffic and half of the light cycle was solid green for north south traffic, so 0.5 was used for G/C_t when using Equation 4 to calculate capacity for each lane group. The same was the case for the intersection of 23rd and McClellan. For the Beacon and McClellan intersection, there were three lanes where traffic moved east on McClellan: southbound left turns from Beacon, northbound right turns from Beacon, and eastbound straight traffic from McClellan. Their observed green times were 0.15, 0.35 and 0.35 respectively. Saturation flow from Equation 4 is a base level of traffic that is modified based on factors present in the intersection. Adjustments are made based on numerous factors including pedestrian volumes, approach grades of the street, existence of a parking lane, existence of a bus stop and bus frequency, and many other factors. Many of these inputs were possible to obtain by looking at photos of the street through Google Street View (Google 2019b) but others such as heavy traffic flow (trucks), pedestrian crossing volume, blocking effect of local buses were not available. However, the adjustments to the base saturation flow would be slight so I made my own assumptions based on my knowledge of the neighborhoods regarding factors that warranted adjusting the saturation flow and factors that did not. Tables in the Highway Capacity Manual chapter 9 give ranges of possible adjustments to saturation flow for each factor. Researchers wishing to reproduce this study should obtain more complete data on intersections analyzed to produce more precise measures of intersection capacity.

I then compared the SOV portion of trip generation estimates to these capacity numbers to see how the SOV portion of traffic is increasing. Since two intersections were analyzed along McClellan, I had to decide on a distribution of trips between the two recognizing that some would pass through both intersection. To do so I assumed one third of the trips would enter the corridor from the Beacon intersection, one third would enter from 23rd Avenue and one third would enter from intersections to the east of the corridor. I assumed trips entering through each of those three

points would be randomly distributed to the parcels along the corridor. Under this assumption, one quarter of trips entering the corridor through the Beacon intersetion would pass through both the Beacon Avenue intersection and the 23rd Avenue intersection. The rest would be traveling to parcels west of 23rd Avenue and thus would only pass through the Beacon Avenue intersection. For trips entering the corridor through the 23rd Avenue intersection, none would pass through the Beacon Avenue intersection and all of them would pass through the 23rd Avenue intersection. For trips entering from the east of the corridor along McClellan, 75% would pass through the 23rd Avenue intersection and none would pass through the Beacon Avenue intersection. Since a quarter of parcels are located east of 23rd, a quarter of trips going westbound approaching form the east on McClellan would pass through neither intersection. These calculation were used to determine the number of trips passing through each of the intersections along McClellan and calculating vehicle capacity ratios for those intersections.

Finally I applied the same methods discussed above to a low development scenario to test what might happen to traffic conditions if development was not as intense as that calculated in the zoned capacity model. Trips for this scenario were calculated by multiplying the trip generation estimates from the zoned capacity build out scenario discussed above by 71% for the McClellan Street parcels and 72% for the 12th Avenue parcels. These percentages are based on supporting materials for the 2035 Comprehensive Plan which stated that, under growth projections, Seattle is

$$L = R * 71\% + C * 84\%$$

Equation 5 Calculation for low development scenario percentage of trips. L = Low Development Scenario Percentage of Zoned Capacity Trips, R = Average Residential Split Across all Analyzed Parcels, C = Average Commercial Split Across all Analyzed Parcels

expected to have 71% of its zoned capacity for housing units built by 2035 and 84% of its zoned capacity for jobs built (Department of Planning and Development 2014). Because 12th Avenue

contains both commercial and residential, the percentage for 12th Avenue was calculated by averaging the split of residential square footage and commercial square footage in all the analyzed parcels then calculating a weighted percentage of zoned capacity built that includes both residential and commercial. Equation 5 shows this calculation.

3.4 Limitations

The research has several limitations that readers should be aware of. It only looks at two corridors in the exempt areas across the city so the results are not necessarily indicative of conditions in all areas of the city. As well, limited data was available for calculating the capacity at intersections. Further research should incorporate more sophisticated traffic modeling in order to get more accurate estimates of vehicle capacity ratios at these intersections. Another limitation is that the mode split used to calculate the number of SOV trips generated was from the concurrency policy that does not apply to the areas examined. Because only one set of targets is established in the policy, this research took them to mean that these mode splits are what would produce adequate conditions in the transportation system in the city to comply with concurrency rules of the GMA. Thus this research applies those targets to the data produced regarding trips in the exempt areas. These targets set in the concurrency policy may only be intended for areas outside the exempt areas and may not reflect the city's expectation of mode share in the exempt areas. City staff likely expect the mode split within the concurrency exempt areas to be lower because of the extensive alternatives to SOV travel which is why they were exempted in the first place. However, no mode split targets for the exempt areas were mentioned in the policy so this analysis is based on the assumption that the target mode split numbers in the concurrency policy reflect mode split both inside and outside the exempt areas within each zone. However, actual SOV mode splits in the areas may be different than mode splits defined in the targets as those areas have different environments that may lead to different mode splits compared to areas that are not exempt and where the targets in the policy apply. The research operated on the assumptions that SOV mode splits in all areas of the city would align with the targets set for the different zones in the policy shown in Figure 1.

For the scope of this paper, I wanted to examine the changes in SOV trip volume along these selected parcels. For this reason, I did not account for all traffic traveling through the intersections in question. Intersection traffic data from the city was unavailable. Attempting to estimate through traffic using the trip generation method above would have involved extensive application to trip generations across numerous parcels, formulation of assumptions about travel patterns and traffic modeling that was out of the scope of this paper.

4 Results

The tables below show the output from the calculations discussed in the methods section. Broadly, the results show that SOV trips continue to increase even when SOV mode split decreases in line with the targets set in the new concurrency policy. The following paragraphs will walk through the results of the calculations eventually arriving at the vehicle capacity ratios that show how traffic conditions would worsen under the scenarios examined.

Table 2 shows the estimated trip generation in the each of the two corridors studied.

Table 2 Estimated Trip Generation in Selected Corridors during PM Peak

	Person trips generation of studied parcels under current development	Person trips generation of studied parcels under zoned capacity buildout scenario
12th Ave	2348	3855
McClellan	137	247

Table 3 shows the resulting SOV trips when existing SOV mode share and target SOV mode share from the concurrency policy (shown in Figure 1) are applied to the person trips in the table above.

Table 3 Estimated SOV Trip Generation in Selected Corridors during PM Peak

	Current Estimated SOV Trips	Zoned Capacity Build Out Estimated SOV Trips	Percent Increase
12th Ave	775	1079	39%
McClellan	55	94	71%

As shown in the rightmost column in Table 3, SOV trips generated by the examined parcels are increasing between 39 and 71%. These calculations are based on the decreased SOV mode split targets and so they show SOV trips continue to increase even while mode split for SOV is decreased.

Table 4 Vehicle Capacity Calculation Results for Selected Intersections

	Capacity Calculated (vehicles per hour)	Capacity For Two Hour Peak Period
12th Avenue and E John Street	897	1,794
S McClellan Street and S Beacon Avenue	1,502	3,004
S McClellan Street and 23rd Avenue South	1,376	2,752

Next, vehicle capacity of the relevant lanes of each intersection was analyzed to get a measure of road capacity. Table 4 shows the results of these capacity calculations.

Trip generation rates discussed above are estimates for a two hour peak period defined as the period between 4pm and 6pm. The leftmost column in the table shows the intersection capacity for a two hour period. Trip distribution between the two intersections along McClellan are shown in Table 5. Applying the SOV trips to the vehicle capacities in Table 3 yields intersection vehicle capacity ratios or vehicle capacity levels of service in the Highway Capacity Manual parlance (Transportation Research Board 1985, 9–1).

Table 5 Intersections that trips pass through based on where they entered the McClellan corridor (zoned capacity scenario)

		Intersection with McClellan where trips enter corridor			
		Beacon Avenue	23rd Avenue	East of corridor	Total
Intersection with McClellan that trips pass through	Beacon Avenue	58	0	0	58
	23rd Avenue	15	58	44	117

Dividing the number of SOV trips passing through each intersection using the selected lanes by the capacity of those lanes reveals the portion of the lanes' capacity that is used by SOV trips to the selected parcels. Table 6 shows the results of the vehicle capacity calculations for the selected intersections including the percent increase in vehicle capacity from current conditions to the zoned capacity build out scenario. The percent increase then shows by how much capacity of the lanes is

being reduced by the change in SOV trips from current conditions to the zoned capacity scenario. This percent change shows the impact of increased or decreased trips as new development comes online and assuming SOV mode split under the zoned capacity scenario is equal to the target set in the concurrency policy for the appropriate zone (Figure 1). It suggests that raw number of SOV trips will continue to increase and that those additional trips alone are significantly increasing and contributing to worsening traffic conditions. This does not account for pass through trips that might make the effect of the additional SOV trips on vehicle capacity even worse.

Table 6 Vehicle Capacity Calculations for Selected Intersections

	Current V/C Ratio*	Zoned Capacity V/C*	Percent Increase
12th Ave and E John St	0.4321	0.6816	57.75%
S McClellan St and Beacon Ave S	0.006	0.010	72.54%
S McClellan St and 23rd Ave S	0.013	0.023	72.54%

* Ratio of SOVs heading to selected parcels along corridors analyzed to capacity of selected lanes under current development conditions and zoned capacity scenario development conditions.

Lastly, I applied the low development scenario percentages to each set of trip generation numbers. Table 7 shows the number of SOV trips in the low development scenario and

shows the results of the vehicle capacity calculation for the selected intersections under the low development scenario.

Table 7 SOV trip estimates for low development scenario

	Current Estimated SOV Trips	Low Development Scenario Estimated SOV Trips	Percent Increase
12th Ave	775	871	12%
McClellan	137	176	27%

Table 8 Vehicle capacity under low development scenario

	Current V/C Ratio	Zoned Capacity V/C	Percent Increase
12th Ave and E John St	0.4321	0.4855	12%
S McClellan St and Beacon Ave S	0.009	0.011	23%
S McClellan St and 23rd Ave S	0.010	0.012	23%

As mentioned in the methods sections, because this analysis only accounted for trips for parcels along the selected corridors and excludes pass through trips, trips to nearby parcels or freight trips, the results from the vehicle capacity calculation should not be interpreted as the actual vehicle to capacity ratio of the selected lanes in the intersection. Rather, the analysis shows how much a zoned capacity buildout, and a buildout based on comprehensive plan projections of the selected parcels may contribute to changes in vehicle capacity ratios at the surrounding intersections. For example, in Table 8 for 12th and John, traffic due to just the parcels analyzed along the corridor is worsening 12%. This is not to mentioned other additional SOV trips of surrounding parcels that would also be increasing.

The analysis suggests that if the transit centers analyzed have SOV mode splits that align with the targets in the concurrency legislation, SOV trips will continue to increase as development proceeds towards the zoned capacity built out scenario. Likewise, in a comprehensive plan growth projection scenario, the areas will continue to see an increasing number of SOV trips although not to the extent of the zoned capacity built out scenario. Both of these findings translate to worsening traffic conditions measured by vehicle capacity of nearby intersections. A smaller share of trips may be SOV trips in neighborhoods where the city is seeking to direct growth, the urban centers, hub urban villages and areas around light rail stations, but the raw number of SOV trips is likely to grow. The vehicle capacity level of service analysis shows that roadway performance in the three corridors

is likely to degrade as the neighborhoods they're located in take on more growth. As noted, the raw vehicle capacity numbers should not be taken as the actual capacity ratio that is likely to result from a zoned capacity build out but rather, it is indicative of the increase in traffic that is likely to result from such a development scenario. That is to say, the calculations conducted for this analysis do not suggest utilization of intersection capacity but by how much added SOV trips are contributing to increasing usage, through vehicle capacity ratio, during the PM peak at the intersections studied. The results suggest a significant increase in traffic due to SOV trips at the intersections analyzed.

Contrary to the finding in the EIS (2016) that no impacts to traffic will occur under future growth scenarios, this research suggests there will be significant impacts that contribute to worsening traffic conditions on the city's streets within the areas exempt from the new concurrency policy.

5 Discussion

These results bring into question the efficacy of the exemption of transit centers in the city's new concurrency policy. The results suggest that despite the goal of decreasing the mode share of SOV traffic, traffic conditions are likely to get worse as the raw number of SOV trips increases. This finding conflicts with the assertion in the EIS (2016) for the 2016 comprehensive plan update that no impacts are expected to the city's transportation system

Furthermore, the analysis in the EIS states, "Reduction in levels of SOV travel over time will help preserve effective capacity by reducing road-space use per-capita, meaning that passengers using transit and other mode choices will consume less road space than vehicles driven by one person," (Seattle OPCD 2016, 2–5). While non-SOV modes clearly use up less road space than SOVs as the EIS demonstrates in its transportation appendix (Seattle OPCD 2016, B.3-3), it's not necessarily the case that achieving a mode split target will lead to improved traffic flow, that is to say, reduced vehicle to capacity ratios (V/C), on streets. As this research reveals, mode split targets for SOVs may be less than current mode splits, but if the city continues to grow at a rapid pace and approaches a build out of its zoned capacity, streets will still be strained in terms of traffic flow because of the raw number of increased SOV trips along them. Put another way, if areas that are exempt from the concurrency policy are built out according to the city's zoned capacity and if mode split in those areas reaches the targets for their respective zones outlined in the concurrency policy, they are likely to see significant increases in congestion. Even if SOV mode share decreases in those areas, the raw number of increased trips that will be made by SOV based on the targets for modal split set in the city's concurrency policy will still result in a net increase in SOV trips. Traffic will continue to worsen during peak hours and all modes that use general purpose lanes on the city's streets will experience longer delays.

In discussing the results of its study on impacts to vehicle capacity ratios at screenlines, the EIS (2016) concludes, "all the screenline volume-to-capacity (v/c) ratios are expected to meet the existing LOS standards," (Seattle OPCD 2016, 3.1-21). In practical terms, this means that the level of service standard for all screenlines, including ones located in transit centers examined in this study, are not expected to exceed vehicle capacity LOS set in the old concurrency policy within the timeframe of the comprehensive plan. This is shown in Table 1 in the literature review. However, the study in the EIS only bases the assertion of no impacts on the finding that V/C does exceed a certain level. It does not say anything about how the V/C changes from current conditions to future scenarios.

By looking at certain corridors and the trips they produce under current conditions and trips they would produce under a zoned capacity build out, this research found vehicle capacity level of service will continue to degrade in the zones that are exempt from the policy. Indeed, traffic would continue to worsen, even if mode share of SOV trips were to decline to the target levels set in the policy. Both the screenline analysis and analysis conducted for this paper suggest traffic conditions in the PM peak will continue to degrade as the number of jobs and residents located in the city's densest neighborhoods continue to increase. Though the EIS presents the analysis to show that the growth plan will not put any of the screenlines above their designated vehicle capacity levels of service, it does not show how much vehicle trips are expected to increase from current conditions in any part of the analysis. Likewise, the comprehensive plan itself presents no comparison of current trips to expected trips on roadways or how vehicle to capacity levels of service are changing. This is the area which this paper seeks to better understand. By looking at how SOV trips increase along the corridors despite declining SOV mode split, I've shown that the assertion of no impact is not true

and that traffic conditions are likely to degrade even if they don't reach the V/C LOS standards from the old concurrency policy.

5.1 Generalizability

My question is concerned with how the city's concurrency system impacts the traffic conditions in a dense built out urban setting. By comparing the trips generated from a zoned capacity buildout, specifically the expected SOV trips, with conditions under which the concurrency system was devised I showed how the concurrency rules and LOS measurement system in Seattle are affecting the traffic capacity of the streets in the selected corridors.

This research method is broadly applicable. The two main tools used, Trip Generation for estimating trips produced by each development and the Highway Capacity Manual for estimating intersection capacity, are standards in the transportation engineering field that are used across the country. However, all cities may not produce data such as the zoned capacity data used in this study. That data is produced as a result of requirements in the Washington State GMA. As such, cities in other states may not have models that produce the same type of parcel by parcel data that is required in Washington State to fulfill the regulatory requirements. In states where similar datasets are not produced, researchers would need to reproduce the zoned capacity model for the city in question in order to reproduce this research. The final point regarding generalizability is that this research was focused on a policy unique to Seattle, its new concurrency system and accompanying level of service standards that set SOV mode split targets Calculations of SOV trips were based on the targets set in the policy. Researchers attempting to duplicate this study in different city's would either need to assume certain mode split target for future scenarios or analyze a similar policy that sets SOV modes split targets.

6 Conclusion

This paper sought to evaluate Seattle's new level of service measurement system under its transportation concurrency policy that requires developers to not exceed a certain percentage of SOV trips generated from their development. Transportation concurrency was an integral part of the Growth Management Act that was passed in Washington State in 1990. All cities in Washington defaulted to using vehicle capacity level of service to measure the performance of their transportation system at the time it was passed, but many have switched to measuring transportation more holistically to avoid encouraging private vehicle use. Seattle made such a change with the adoption of its most recent comprehensive plan update but, in order to encourage development in areas with greater access non-SOV modes, it exempted the densest, fastest growing parts of the city from concurrency requirements. This study evaluated the efficacy of that choice by demonstrating that increased densities encouraged through zoning in these areas will result in increased numbers of vehicle trips and increases in SOV use even if the City manages to meet its stated targets of SOV mode split. To do so, I analyzed a sample of corridors in areas exempt from the city's new mode share level of service concurrency policy. The new policy requires new developments to meet a certain level of SOV mode share for the trips they generate or provide mitigation to encourage non-SOV trips. Certain areas, by virtue of having many transportation options other than driving alone, are exempt from the policy. The city's logic in formulating the policy this way was that those areas would naturally reach SOV targets because they offer so many non-SOV travel options (Seattle OPCD 2018a). The analysis in this thesis of the sample corridors suggested that SOV trips in those areas will continue to increase in the case that SOV mode split targets in the policy are met and put strain on the street network around them. By calculating current trip generation of existing developments, trip generation of developments under a zoned-capacity build out scenario, and trips

generated under a low development scenario based on projected production of housing units and jobs, I produced estimates of the number of trips that were generated along the sample corridors. To calculate an estimate for SOV share of total trips, I applied the mode share numbers from the city's concurrency policy that give both current SOV mode share across the city as well as SOV mode share targets for the future. This produced an estimate of the increase in the SOV trips that would result from a build out of zoned capacity in the selected corridors and an estimate of the increase in vehicle capacity levels of service for surrounding intersections. The results showed significant increases in vehicle to capacity ratios and thus degrading traffic conditions under the zoned capacity build out scenario. Vehicle to capacity ratios still increased under the low development scenario but to a smaller degree. This suggests the new level of service measurement system that exempts the densest areas of the city could still be contributing to worsening traffic and increased delays along streets in those areas.

However, the analysis presented in this paper is not to say that the city should concentrate more on ensuring decreasing vehicle to capacity levels of service to ensure SOV travelers can enjoy short travel times. Doing so would only encourage further SOV travel among residents and visitors to Seattle and be contrary to the goals that informed the formation of the policy. That is the type of policy cities in Washington are trying to move away from as they devise new level of service measurement systems to abide by concurrency rules. It *is* to say that the city should not ignore the impacts of growth on the densest areas of the city as they relate to traffic conditions on the streets. Doing so would have adverse impacts on transit, freight, bicycle, and carpool trips that operate in mixed traffic. The city's strategy to concentrate growth in dense transit rich areas so that more people have access to a diverse array of transportation options is laudable. However, it is unlikely that such growth will not contribute additional SOV trips even while SOV mode share continues to

decrease. This research highlights the stakes involved as the city attempts to meet targets for decreasing the percentage of trips taken in SOVs. Meeting these targets will still result in increased SOV travel. Put simply, many people will continue to choose to drive alone despite other options available.

Despite this possibility of worsening traffic conditions, as measured by vehicle capacity level of service, the city is moving in the right direction, towards transportation planning that focuses on moving people, not vehicles. By enhancing the performance of other modes through providing separate right of way and other improvements, the city can encourage more people to choose non-SOV options in the concurrency exempt areas as well as preserve performance of those modes. Not attempting to funnel growth in the transit centers with more extensive transportation options would likely push more SOV trips to areas outside the exempt areas as more costs would be put on developments in the densest areas of the city.

7 Appendix

Parcels along 12th Avenue in analysis

Parcel ID	Land Use Description	Zoning	Current Vel Trip Genera	Current Person Trip Generation	Potential Vehicle Trip Generation	Potential Person Trip Generation
1336300150	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1336300155	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1336300160	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1336300165	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1336300170	Apartment	SF 5000	2.48	3.97	3.11	4.97
1336300180	Apartment	LR3	13.02	20.83	7.31	11.70
1336300185	Apartment	LR3	4.96	7.94	7.31	11.70
1336300335	Single Family(C/I Zone)	LR3	1.67	2.66	5.68	9.09
1336300345	Triplex	LR3	3.09	4.94	7.31	11.70
1336300350	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1336300360	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1336300365	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1336300380	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
1494000000	Condominium(Mixed Use)	NC3-40	9.33	14.92	60.80	97.28
3133000000	Condominium(Residential)	LR3	8.35	13.35	8.90	14.24
6003000635	Apartment	NC3P-65	16.74	26.78	54.55	87.28
6003000680	Triplex	NC3P-65	3.09	4.94	15.05	24.08
6003000690	Single Family(C/I Zone)	NC3P-65	1.67	2.66	14.16	22.65
6003000990	Parking(Assoc)	NC3-40		-	56.96	91.14
6003000995	Service Building	NC3-40	28.13	45.01	56.96	91.13
6003001000	Apartment(Mixed Use)	NC3-40	3.16	5.06	28.79	46.07

6003001005	Service Building 10710	NC3-40	10.85	17.36	28.79	46.07
6003001010	Retail Store	NC3-40	26.65	42.63	78.10	124.96
6003001015	Retail Store	NC3-40	12.25	19.59	37.67	60.28
6003001025	Grocery Store	NC3-40	40.31	64.49	77.27	123.63
6003001040	Office Building	NC3-40	2.21	3.53	9.56	15.30
6003001041	Single Family(C/I Zone)	NC3-40	1.67	2.66	20.15	32.24
6003001390	Apartment(Mixed Use)	NC3-40	8.06	12.90	39.46	63.13
6003001395	Apartment	NC3-40	36.99	59.18	37.94	60.70
6003001400	Duplex	NC3-40	2.16	3.46	37.74	60.39
6003001410	Apartment	NC3-40	5.58	8.93	37.55	60.08
6003001415	Single Family(Res Use/Zone)	NC3-40	1.67	2.66	31.93	51.09
6003001420	Vet/Animal Control Srvc	NC3-40	9.27	14.84	44.17	70.68
6003001430	Apartment	NC3-40	6.20	9.92	37.74	60.39
6003001434	Apartment(Mixed Use)	NC3-40	10.20	16.33	25.48	40.76
6003001880	Single Family(Res Use/Zone)	LR3 RC	1.67	2.66	5.80	9.28
6003001900	Triplex	LR3	3.09	4.94	5.68	9.09
6003001915	4-Plex	LR3	3.97	6.36	7.31	11.70
6003001925	Apartment	LR3	-	-	7.31	11.70
6003001930	Apartment	LR3	6.20	9.92	12.72	20.35
6003500510	Industrial(Heavy)	NC3P-65	237.32	379.71	285.59	456.95
6003500575	Retail Store	NC3P-65	49.21	78.73	63.20	101.13
6003500665	Apartment	NC3-40	27.90	44.64	161.30	258.07
6003500680	Apartment	NC3-40	14.88	23.81	40.59	64.94
6003500690	Apartment (mixed use)	NC3-40	31.08	49.73	40.62	64.99
6003500699	Apartment	NC3-40	22.94	36.70	60.91	97.45

6003500705	Apartment	NC3-40	14.88	23.81	60.91	97.45
6003500780	Mini Warehouse	NC3-40	70.97	113.55	242.06	387.29
6003500806	Apartment(Mixed Use)	NC3-40	11.69	18.70	60.75	97.20
6003500920	Duplex	LR3	2.16	3.46	7.31	11.70
6003500925	Apartment	LR3	5.58	8.93	10.45	16.72
6003500930	Vacant(Commercial)	LR3		-	10.45	16.72
6003500935	Single Family(C/I Use)	LR3 RC	1.67	2.66	5.80	9.28
6003501540	Single Family(Res Use/Zone)	LR3	1.67	2.66	5.68	9.09
6003501560	Duplex	LR3	2.16	3.46	7.31	11.70
6003501565	Triplex	LR3	3.09	4.94	7.31	11.70
6003501570	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501571	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501572	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501573	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501577	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501578	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501579	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501580	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6003501584	Single Family(Res Use/Zone)	LR3	1.67	2.66	3.09	4.94
6003501586	Duplex	LR3	3.09	4.94	4.84	7.74
6003501620	Single Family(Res Use/Zone)	LR3	1.67	2.66	4.84	7.74
6003501630	Apartment	LR3	3.10	4.96	4.84	7.74
6003501640	Single Family(Res Use/Zone)	LR3	1.67	2.66	4.84	7.74
6003501680	Single Family(C/I Zone)	LR3	1.67	2.66	5.68	9.09
6003501690	Single Family(Res Use/Zone)	LR3	3.11	4.97	5.68	9.09

6003501970	Triplex	LR3	3.09	4.94	7.31	11.70
6003501975	Single Family(Res Use/Zone)	LR3	1.67	2.66	4.84	7.74
6003502020	Single Family(Res Use/Zone)	LR3	3.11	4.97	5.68	9.09
6395500000	Condominium(Mixed Use)	NC3P-65	91.35	146.17	95.12	152.19
6669160000	Condominium(Residential)	LR3	16.72	26.75	8.90	14.24
6851700220	Apartment	LR3	14.88	23.81	19.94	31.90
6851700265	Apartment	LR3	9.30	14.88	8.11	12.98
6851700266	Single Family(Res Use/Zone)	LR3	1.67	2.66	3.97	6.36
6851700270	4-Plex	LR3	3.97	6.36	7.31	11.70
6851700275	4-Plex	LR3	3.97	6.36	7.31	11.70
6851700280	Apartment	LR3	4.96	7.94	8.90	14.24
6851700285	Apartment	LR3	16.12	25.79	15.66	25.06
6851700325	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6851700326	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6851700327	Townhouse Plat	LR3	1.38	2.20	3.09	4.94
6851700328	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
6851700330	Apartment	LR3	3.72	5.95	8.90	14.24
6851700335	Single Family(Res Use/Zone)	LR3	1.67	2.66	3.97	6.36
6851700336	Single Family(Res Use/Zone)	LR3	1.67	2.66	3.97	6.36
6851700340	Triplex	LR3	3.09	4.94	5.68	9.09
6851700345	Apartment	LR3	2.48	3.97	7.31	11.70
6851700380	Triplex	LR3	3.09	4.94	3.97	6.36
6851700381	Duplex	LR3	2.16	3.46	6.50	10.41
6851700385	Single Family(Res Use/Zone)	LR3	1.67	2.66	5.68	9.09
6851700390	Triplex	LR3	3.09	4.94	8.90	14.24

6851700395	Duplex	LR3	2.16	3.46	6.50	10.41
6851700400	Triplex	LR3	3.97	6.36	6.50	10.41
6852700005	Single Family(Res Use/Zone)	LR3	1.67	2.66	6.50	10.41
6852700010	Apartment(Subsidized)	LR3	-	-	6.50	10.41
6852700015	Apartment	LR3	4.96	7.94	8.90	14.24
6852700020	Apartment	LR3	4.96	7.94	8.90	14.24
6852700055	Apartment(Subsidized)	LR3	14.88	23.81	15.66	25.06
6852700065	Apartment	LR3	3.72	5.95	5.68	9.09
6852700066	Triplex	LR3	3.09	4.94	5.68	9.09
6852700070	Duplex	LR3	2.16	3.46	5.68	9.09
6852700075	Triplex	LR3	3.09	4.94	5.68	9.09
6852700076	Single Family(Res Use/Zone)	LR3	1.67	2.66	5.68	9.09
6852700080	Single Family(Res Use/Zone)	LR3	1.67	2.66	5.68	9.09
6852700115	Single Family(Res Use/Zone)	LR3	1.67	2.66	3.97	6.36
6852700116	Duplex	LR3	2.16	3.46	3.97	6.36
6852700120	Triplex	LR3	3.09	4.94	5.68	9.09
6852700125	Triplex	LR3	3.09	4.94	5.68	9.09
6852700126	Triplex	LR3	3.09	4.94	5.68	9.09
6852700130	Single Family(Res Use/Zone)	LR3	1.67	2.66	4.84	7.74
6852700131	Duplex	LR3	2.16	3.46	5.68	9.09
6852700135	Single Family(Res Use/Zone)	LR3	1.67	2.66	4.84	7.74
6852700175	4-Plex	LR3	3.97	6.36	7.31	11.70
6852700176	Apartment	LR3	3.72	5.95	8.90	14.24
6852700185	4-Plex	LR3	3.97	6.36	7.31	11.70
7507000000	Condominium(Residential)	LR3	7.58	12.12	11.97	19.15

8584800010	Duplex	LR3	2.16	3.46	3.97	6.36
8584800020	Townhouse Plat	LR3	1.38	2.20	3.09	4.94
8584800030	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8584800040	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8584800050	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8584800060	Single Family(Res Use/Zone)	LR3	1.67	2.66	3.97	6.36
8584800070	Townhouse Plat	LR3	1.38	2.20	3.09	4.94
8584800080	Townhouse Plat	LR3	1.38	2.20	3.09	4.94
8584800090	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8584800100	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8584800110	Townhouse Plat	LR3	1.38	2.20	1.17	1.88
8584800120	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8584800130	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8584800140	Townhouse Plat	LR3	1.38	2.20	2.16	3.46
8725000000	Condominium(Residential)	LR3	6.79	10.87	11.97	19.15
8725700000	Apartments mixed use	NC3P-65	322.43	515.90	191.56	306.50
6851700269	Townhouse Plat	LR3	1.38	2.20	2.28	3.64
6851700271	Townhouse Plat	LR3	1.38	2.20	2.28	3.64
6851700272	Townhouse Plat	LR3	1.38	2.20	2.28	3.64
6851700273	Townhouse Plat	LR3	1.38	2.20	2.28	3.64
6851700276	Townhouse Plat	LR3	1.38	2.20	2.28	3.64
6851700277	Townhouse Plat	LR3	1.38	2.20	2.28	3.64
6851700278	Townhouse Plat	LR3	1.38	2.20	2.28	3.64
6851700279	Townhouse Plat	LR3	1.38	2.20	2.28	3.64

Parcels and Trip Generation Outputs for S McClellan Street

			Existing		Potential	
PIN	Land Use Description	Zoning	Vehicle Trip Generation	Person Trip Generation	Vehicle Trip Generation	Person Trip Generation
2597660010	Townhouse Plat	LR2	1.38	2.20	2.16	3.46
2597660130	Townhouse Plat	LR2	1.38	2.20	1.17	1.88
2597660140	Townhouse Plat	LR2	1.38	2.20	2.16	3.46
3083000205	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000215	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000250	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000255	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000270	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000275	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000315	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000620	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000670	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000695	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000705	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083000710	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083001140	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083001145	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083001150	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083001181	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3083001231	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3084001501	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66

3084001502	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3084001535	Park, Public(Zoo/Arbor)	SF 5000	0.00	0.00	1.67	2.66
3085001565	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
3085001995	Park, Public(Zoo/Arbor)	LR2	0.00	0.00	28.15	45.04
5260300135	Single Family(Res Use/Zone)	SMR		0.00	34.15	54.64
5260300205	Utility, Private(Radio/T.V.)	SF 5000	0.00	0.00	1.67	2.66
5260300206	Parking(Commercial Lot)	SF 5000	0.00	0.00	1.67	2.66
5260300220	Park, Public(Zoo/Arbor)	SF 5000	0.00	0.00	1.67	2.66
7319900066	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900070	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900075	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900081	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900082	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900085	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900105	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900106	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900150	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900155	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900156	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900157	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900158	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900200	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900225	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66

7319900226	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900227	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900230	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7319900235	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900025	Triplex	SF 5000	3.09	4.94	1.67	2.66
7320900030	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900055	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900100	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900105	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900150	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900175	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900180	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66
7320900181	Single Family(Res Use/Zone)	SF 5000	1.67	2.66	1.67	2.66

The table below shows equation inputs that were used from the Trip Generation Manual to estimate trip generation of each parcel. Use for a parcel was based on the land use description in the zoned capacity output table. Uses below that have the note "nlog" are ones for which the regression equation was used rather than the average rate per unit. For those equations the multiple was multiplied by the natural log of the dwelling units (for residential) or thousands of square feet (for commercial) then the y intercept was added. An exponential function in Excel (=EXP) was then applied to get the final trip generation. For those not noted nog, the number of units or thousand square feet was multiplied by the appropriate multiple in the table.

Existing Trip Generation Calculation Table

	unit	multiple	y intercept	notes	Trip Generation 9th edition land use code and page number
Single Family(Res Use/Zone)	dwelling units	0.9	0.51	nlog	210, p. 298
Apartment	dwelling units	0.62	0		230, p.396
Single Family(C/I Zone)	dwelling units	0.9	0.51	nlog	210, p. 298
Triplex	dwelling units	0.88	0.16	nlog	221, p. 364
Condominium(Mixed Use)	N/A	N/A	N/A	N/A	N/A
Condominium(Residential)	dwelling units	0.82	0.32	nlog	230, p.396
Parking(Assoc)					
Service Building	sqft	2.41	11.79		942, p. 1976
Apartment(Mixed Use)	N/A	N/A	N/A	N/A	N/A
Retail Store	N/A	N/A	N/A	N/A	N/A
Grocery Store	1000 sf	0.74	3.25	nlog	850, p. 1647
Office Building	1000 sf	1.49	0		710, p. 1261
Duplex	dwelling units	0.88	0.16	nlog	221, p. 364
Vet/Animal Control Srvc	1000 sf	4.72	0		640, p. 1249
4-Plex	dwelling units	0.88	0.16	nlog	221, p. 364
Industrial(Heavy)	1000 sf	1.43	-157.36		110, p. 104
Mini Warehouse	1000 sf	0.64	1.14	nlog	150, p. 204
Single Family(C/I Use)	dwelling units	0.9	0.51	nlog	210, p. 298
Townhouse Plat	dwelling units	0.82	0.32	nlog	230, p.396
Apartment(Subsidized)	dwelling units	0.55	17.65		230, p.396
fast food	1000sf	26.15			933, p. 1907
sit down restaurant	1000sf	9.85			932, p. 1887

dance studio	1000sf	0.95	1.43	nlog	492, p. 942
café	1000sf	40			own estimate, insufficient data in TG
wine shop	1000sf	15			own estimate, use not in TG
funeral home	1000sf	0.5			own estimate, use not in TG
dentist	1000sf	0.9	1.53	nlog	720, p. 1296
hair salon	1000sf	1.45			918, p. 1858

Potential Trip Generation Calculation Table

	unit	**multiple**	**y intercept**	**notes**	**TG 9th edition land use code and page number**
LR3	dwelling units	0.88	0.16	nlog	221, p. 364
LR3 RC	dwelling units	0.9	0.51	nlog	210, p. 298
SF 5000	dwelling units	0.9	0.51	nlog	210, p. 298
SM/R-65	dwelling units	0.55	17.65		220, p. 335

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