3-2012

Development and Sensitivity Testing of Alternative Mobility Metrics

John Gliebe
Portland State University

James G. Strathman
Portland State University

Citation Details

Gliebe, John P., and James G. Strathman. Development and Sensitivity Testing of Alternative Mobility Metrics. SPR 716. ortland, OR: Transportation Research and Education Center (TREC), 2012.

DEVELOPMENT AND SENSITIVITY TESTING OF ALTERNATIVE MOBILITY METRICS

Final Report

SPR 716

Oregon Department of Transportation

DEVELOPMENT AND SENSITIVITY TESTING OF ALTERNATIVE MOBILITY METRICS

Final Report

SPR 716

by

John P. Gliebe
Resource Systems Group, Inc.

and

James G. Strathman

Center for Urban Studies
Portland State University

for

Oregon Department of Transportation
Research Section
200 Hawthorne Ave. SE, Suite B-240
Salem OR 97301-5192

and

Federal Highway Administration
400 Seventh Street, SW
Washington, DC 20590-0003

‘

March 2012

Technical Report Documentation Page

1. Report No. FHWA-OR-RD-12-15	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Development and Sensitivity Testing of Alternative Mobility Metrics		5. Report Date March 2012 6. Performing Organization Code
7. Author(s) John P. Gliebe and James G. Strathman		8. Performing Organization Report No.
9. Performing Organization Name and Address Portland State University Center for Urban Studies 506 SW Mill Street Suite 320 Portland, Oregon 97201		10. Work Unit No. (TRAIS) 11. Contract or Grant No. SPR 716
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Section and Federal Highway Administration 200 Hawthorne Ave. SE, Suite B-240 Salem, OR 97301-5192 400 Seventh Street, SW Washington, DC 20590-0003		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The Oregon Highway Plan's (OHP) mobility policies guide various planning and programming activities of the Oregon Department of Transportation (ODOT). Among these activities are ODOT's land use change review responsibilities under the Transportation Planning Rule, as adopted by the state's Land Conservation and Development Commission. This report examines supplemental transportation performance metrics beyond the volume-to-capacity metric that currently supports OHP mobility policies. Selected supplemental metrics are empirically analyzed using a travel demand model calibrated for a Medford, Oregon study area.

17. Key Words MOBILITY STANDARDS, HIGHWAY, TARGETS, ALTERNATIVE STANDARDS, PERFORMANCE METRICS, VOLUME/CAPACITY		18. Distribution Statement Copies available from NTIS, and online at http://www.oregon.gov/ODOT/TD/TP_RES/	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 140	22. Price

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized ♲ Printed on recycled paper

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

The authors gratefully acknowledge comments and suggestions provided by this project's Technical Advisory Committee members, including David Boyd, Jazmin Casas, Brian Gregor, Douglas Norval, Lidwien Rahman, Michael Rock, and Mark Vandehey. In addition, Terry Cole provided helpful insights on the administration of the Transportation Planning Rule, as well as the Rule's recent evolution. Kathryn McGovern and David Ruelas served as graduate research assistants, providing support for the literature review on transportation performance measures. Sam Ayash of ODOT provided the model files and programs that were used in the Medford region case study, while Steve Tuttle of Resource Systems Group, Inc., conducted numerous model runs and produced output for the analysis. Lastly, the project benefited from the efforts of two research coordinators: Amanda Pietz (initially) and Myra Sperley (subsequently through completion). Given that the program environment related to this research was changing during the course of the project, their efforts were vitally important in maintaining the relevance of the research and ensuring prospects of successful implementation.

DISCLAIMER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

The Oregon Department of Transportation (ODOT) manages the state highway system under the guidance of the 1999 Oregon Highway Plan (OHP) (*ODOT 1999*). Among other things, OHP policies and actions emphasize efficient use of limited resources. This emphasis, in turn, underlies ODOT's general commitment to sound maintenance of the existing highway system and preservation of its function and safety. OHP Policy 1F establishes mobility standards for state highway facilities to further orient ODOT's planning and programming activities. The mobility standards are expressed as the ratio of the 30th highest hour traffic volume to the facility design hourly capacity (i.e., v/c), and are presented in OHP Tables 6 and 7 (*ODOT 1999: 83-84*).[1]

The OHP mobility standards provide a policy foundation that ODOT relies on for coordinating transportation and land use among other activities. Although land use decisions are the responsibility of local governments in Oregon, ODOT becomes involved when new or planned development has functional or safety consequences for state highway facilities. Thus, in collaboration with local governments, ODOT employs the OHP mobility standards for a variety of purposes. For example, the mobility standards influence the preparation of transportation system plans (TSPs), corridor plans, and area access management plans (*OAR 734-051*). In the development review process, OHP mobility standards have served as a potential basis for negotiating traffic mitigation agreements (*ODOT 2008*). Achieving the design life of interchange improvements on the state system is ensured by interchange area management plans' conformance to mobility standards (*ODOT 2006*). Lastly, under the Transportation Planning Rule (TPR) (*OAR 660-012-0060*), the mobility standards provide a basis for evaluating and mitigating the effects of land use changes on state highway performance.

Under the TPR, when it is determined that projected traffic increases associated with a comprehensive plan amendment will have a significant effect on state highway facilities, the effect must be mitigated through several options, which may include planned improvements with identified funding. OHP Policy 1F addresses circumstances where such mitigation may not be achievable for financial, environmental, or land use reasons, resulting in instances where mobility standards will be exceeded.

The OHP provides an option of proposing alternative mobility standards in cases where meeting the mobility standards is not feasible. OHP Action 1F.3 elaborates on possible alternative standards, identifying transportation and land use actions that local governments can take to reduce traffic impacts on state facilities.

---

[1] The OHP's mobility policy was refined by the Oregon Transportation Commission during the latter part of this study. Changes included the adoption of terminology for "mobility targets" in place of "mobility standards." This change is discussed in Section 2.1. It should be noted that the use of mobility standards terminology is generally maintained throughout this report.

The purpose of this report is to analyze mobility metrics that can potentially supplement v/c in representing the performance of state transportation facilities. Although ODOT intends to retain the OHP's v/c-based mobility standards in representing facility performance, it also anticipates an increasingly number of instances where comprehensive plan amendments with significant traffic effects will be unable to satisfy the funding conditions of the TPR (*ODOT 2009*). In addition, there has been increasing interest in facilitating the use of alternative mobility standards for reasons other than funding constraints (*LCDC/OTC Joint Subcommittee 2011; ODOT 2011a*). Under these conditions it will be important to gain a better understanding of the relationship between v/c and other potential metrics, as well as a better understanding of the effects of land use change on such metrics. Such understanding will ultimately assist the Oregon Transportation Commission (OTC) - which administers the OHP and is responsible for approving mobility standards - in determining whether locally planned actions represent productive (or viable) outcomes for the state highway system in balance with local government objectives.

1.1 ORGANIZATION OF THE REPORT

The remainder of the report is organized as follows. Chapter 2 describes ODOT's evolving use of the OHP mobility standards, focusing mainly on TPR-related applications. Several case studies are presented to illustrate the role that the standards play in ODOT's review of local comprehensive plan amendments and TSP updates. Chapter 3 presents a review of the literature on transportation performance metrics, and identifies a representative inventory of candidate metrics for further analysis. In Chapter 4 the performance and relationships among selected mobility metrics are analyzed with a travel demand model, focusing on hypothetical land use changes in an actual setting (Medford). Chapter 5 presents the conclusions of the report.

2.0 BACKGROUND AND CASE STUDIES

This chapter addresses ODOT's use of OHP mobility standards in evaluating land use changes under the TPR. ODOT's review responsibilities have evolved in response to statutory changes, and were most recently refined during the latter part of this study. Several case studies are also presented to illustrate how the OHP mobility standards have been employed in practice, and what may be learned from this experience.

2.1 OHP MOBILITY STANDARDS AND THE TPR

ODOT's responsibilities under the TPR were refined by amendments adopted by LCDC in 2005.These amendments refined the process for ensuring that land use changes contained in comprehensive plan amendments can be adequately supported by existing and planned transportation facilities. Under the amended TPR, when it is determined that traffic increases associated with a land use change have a significant effect on the performance (as represented by exceeding OHP mobility standards or worsening a facility that has or will exceed the standards) of state facilities, the effect must be mitigated by managing land uses or by committing to capacity, operational and/or safety improvements. Relevant local improvements must be identified in TSPs along with identified funding. Relevant improvements to state facilities must either be identified in the State Transportation Improvement Program (STIP) or be determined by ODOT to be "reasonably likely" to occur within the planning period. Before the 2005 amendments, the review of land use changes under the TPR was guided by what McCourt (*2006, 58*) characterized as "the polite fiction of planned but unfunded projects."

Cortright (*2008*) reported that in the two-year period following the 2005 TPR amendments there were 120 instances involving findings of significant traffic impacts from local comprehensive plan amendments in Oregon, with a majority of these instances relating to zoning changes involving land located along state highways. Cortright (*2008*) also noted that a shortage of conventional funding for both state and local transportation improvements was resulting in growing interest in alternative mobility standards as well as in new infrastructure financing mechanisms.

A subsequent ODOT (*2009*) publication provided guidance for the use of alternative mobility standards. Among other things, the report identified a number of performance metrics that could serve to supplement or substitute for the OHP's v/c metric. These metrics were identified as being particularly suited to congested conditions where performance beyond a specific location or time point is relevant. Examples of possible substitute metrics presented in the report included corridor and network average v/c, as well as average daily traffic (ADC)/C. Potential supplements included metrics representing safety, delay, reliability, and multimodal capacity. The report also presented case studies illustrating how mobility standards have been set to preserve capacity to serve future development (Fort Hill and Chenoweth IAMPs), as well as how improvements in local multimodal facilities, along with urban design and demand management initiatives, have served to mitigate traffic impacts on congested state facilities (South Medford IAMP).

In its 2009 session, the Oregon Legislature responded to state and local funding limitations by enacting House Bill 3379 (ORS.367.850), which addresses land use changes associated with economic development projects. A prominent provision of the administrative rule implementing the statute (OAR 731-017) is a qualified allowance, subject to OTC approval, of a limited number of land use changes that would otherwise not meet TPR requirements. In such instances, documentation of primary job creation from forthcoming (rather than "aspirational") development projects is required, and is subject to review by Business Oregon (the state economic and community development agency). The administrative rule limits the number of OTC approvals of such cases as follows:

- Four per ODOT region per year;
- One per local government jurisdiction per year;
- One per "traffic impact area" every three years.

The administrative rule specifies other provisions wherein local governments may apply for time extensions to meet the TPR requirements, prepare a plan identifying alternative financing mechanisms for funding transportation improvements, or propose adjustments or alternatives to the OHP mobility standards. Lastly, the rule calls for an evaluation of the cumulative consequences of the applications approved by the OTC over a two-year period following OTC rule adoption, which occurred in December 2010. As of September 2011, ODOT had not received a local government application under the rule.

Subsequent to the adoption of OAR 731-017, a joint subcommittee of LCDC and OTC met with representatives of local government, economic development, and other stakeholders to assess issues related to the TPR -0060 requirements for plan amendments and the OHP mobility standards. Information gathered by the joint subcommittee indicated that administration of the TPR and OHP mobility standards was leading to unanticipated and unintended outcomes (LCDC/OTC Joint Subcommittee 2011). Generally, the joint subcommittee concluded that a better balance between transportation performance and economic development is needed, and that the TPR requirements and OHP mobility standards are sometimes conflicting with goals to increase the intensity of development in urban centers and to achieve compact development. The subcommittee recommended that LCDC and OTC revise the TPR and OHP to reconcile issues raised in their report.

Following the LCDC/OTC joint subcommittee report, the respective commissions have been engaged in a coordinated process of drafting revisions to the TPR and the OHP. These processes have also become subject to the directives of Senate Bill 795, enacted by the Oregon Legislature in the 2011 session. Although quite brief, the bill directs the commissions to address specific issues raised in the joint subcommittee report, including:

- Zone changes that are consistent with adopted comprehensive plans;
- Development of practical methods for mitigating transportation impacts related to economic development;
- Requirements related to zone changes in urban centers;
- Analysis of transportation impacts of growth boundary amendments;
- Requirements related to transportation system plan updates;
- Thresholds triggering the analysis of transportation impacts;
- The method of trip generation used in transportation impact analysis;
- The development of mobility standards;
- Analysis requirements in instances addressing avoidance of further degradation of transportation facility performance.

Lastly, Senate Bill 795 sets a deadline of January 1, 2012 for adoption of revisions to the TPR and OHP, and directs OTC and LCDC to report to the Legislature shortly thereafter on actions taken and preparation of associated guidance documents.

In anticipation of forthcoming OHP mobility policy revisions, the Director of ODOT issued a statement in May 2011 clarifying policy intent and agency practice with respect to ODOT's responsibilities under the TPR (*Garrett 2011*). The Director's statement addressed three subjects. First, the statement affirmed ODOT's commitment to work collaboratively with local governments in administering OHP policies, particularly with respect to the establishment of alternate mobility standards in the TSP update process and in the development of ODOT facility plans. Through such collaborative efforts, ODOT would seek to achieve a balance reflecting likely funding, transportation system constraints, growth expectations, community values, and use of various measures to reduce travel demand on state highways.

Second, the statement recognized circumstances in which a state facility is performing at or beyond the OHP mobility standard and, as a result, land use changes with very modest traffic increases are interpreted as having significant impacts that sometimes would require substantial mitigation under a strict interpretation of TPR to "avoid further degradation." Thus the statement establishes minimum thresholds to clarify the amount of traffic increase for which the interpretation of "significant" would apply.

Third, the statement addresses the level of precision allowable in evaluating proposed mitigation for projected traffic impacts. While past practice required projected v/c after mitigation to be within .01 of the projected performance without the proposed plan amendment, the statement establishes a precision limit of .03 v/c for the projected performance with the plan amendment and mitigation in place. For a three-lane highway functioning near the OHP mobility standard level, such a precision margin would amount to about 750 daily trips.

The statement concludes by directing staff to begin carrying out the changes described above immediately, while ODOT simultaneously undertakes a review of its TPR and OHP related policies, procedures and guidance.

Recently, a draft of the revised OHP mobility policy was approved for public comment by the OTC (*ODOT 2011b*).Generally, the draft policy revisions incorporate changes previously stipulated or recommended by the legislation, rules, directives, and reports summarized above. There is also a notable substantive change in the orientation of the draft mobility policy. The draft refers to “mobility targets” rather than “mobility standards.” Mobility targets are interpreted in the draft as an “… initial tool to identify deficiencies and consider solutions for vehicular mobility on the state system” (*ODOT 2011b: 6*). Local governments are required to employ these targets in their analysis of state facility deficiencies. Beyond such initial applications, local governments may consider or propose alternative mobility metrics in system or facility plans (both v/c and non-v/c based) in situations where such metrics would be consistent with local conditions, policies, plans, and community values. Collaboration with ODOT is required in such situations, and final OTC approval of alternative mobility target values or metrics would be still required. For purposes of implementing the TPR, the targets continue to serve as standards to ensure consistency and certainty for rule compliance and implementation.

As before, the draft mobility policy addresses instances where mobility targets are exceeded and transportation improvements that would return facility performance to target levels within a 20-year period are not planned. In such cases the policy objective of avoiding further degradation still applies. Actions taken toward this objective could include capacity increases, system connectivity improvements, transportation demand management, multi-modal improvements that would reduce vehicle travel demand, efficiency-enhancing operational improvements, and actions that would manage or contain trip generation. The draft incorporates the traffic increase thresholds contained in the Director’s policy intent statement as the basis for determining when actions to mitigate traffic impacts or avoid further degradation will be required.

The draft revised mobility policy acknowledges that traffic congestion in some areas will be greater, consistent with local transportation, land use, and economic objectives, and in recognition of funding limitations and other constraints. When OTC-adopted outcomes of the collaborative planning process involve conditions where OHP mobility targets are exceeded, the draft states that local policies should acknowledge that state improvements to further reduce congestion and improve traffic mobility are not expected.

Facility specific mobility target values for the Portland metropolitan area and the remainder of the state are continued in the draft mobility policy. Values for Portland area facilities are unchanged from existing mobility standards, while values for urban areas in the remainder of the state are greater than existing levels. Here, increases in target v/c values are generally smaller for Interstate and expressway facilities, as well as for designated freight routes, with the intent being to ensure statewide mobility along with reliable goods movement.

The final development in the recent evolution of ODOT's land use change review responsibilities relates to forthcoming revisions of the TPR, which have recently been published in draft form (*LCDC 2011*). Collectively, the TPR revisions address issues related to OAR 731-017, the LCDC/OTC Joint Subcommittee report, and Senate Bill 795.

The draft TPR revisions identify several circumstances in which a land use change would be exempted from mitigating significant effects on transportation facilities. The first concerns zoning changes that are consistent with an acknowledged comprehensive plan and TSP. The second concerns changes (typically up-zoning) that occur in a newly-designated category: multimodal mixed-use areas (MMAs). The MMA designation has been added to the TPR to recognize local planning policies that promote higher intensity development in urban centers.

The draft TPR revisions include provisions that account for reductions in trip generation from implementing demand management measures, noting that such measures can reduce or sometimes completely eliminate an otherwise significant effect on given facility. The draft revisions also include a new ("balancing") option for mitigating significant traffic effects. In this case, a local government now has an opportunity to mitigate traffic impacts by making improvements to facilities other than an affected facility when it can demonstrate that the system-wide benefits of the improvements are sufficient to balance the affected facility consequences. Such cases would require the affected facility provider's written confirmation.

In the case of land use changes associated with economic development projects, the draft TPR revisions include language for two alternative processes that will need to be reconciled in final adoption. The first definition is similar to OAR 731-017 and Senate Bill 766 (2011 Legislative Session), while the second broadens the applicability for cities with fewer than 10,000 residents, located outside a Metropolitan Planning Organization (MPO), in a county whose unemployment rate exceeds the state average.[2]

With respect to interchanges, the draft TPR revisions emphasize that ongoing conformance to IAMPs, where they exist, is required. Land use changes near interstate highway system interchanges not located within MMAs remain subject to review under the present terms of the TPR, except that the buffer area within which such reviews apply is now defined as ¼ mile from the interchange ramp terminal intersection (in contrast to the existing ½ mile from the interchange center point). The draft revisions also interpret the actual designation of an MMA as a land use amendment, and states that the effects of such a designation on the safety and operational performance of an affected interchange are to be evaluated. Such an evaluation would take into account whether the facility has an elevated crash rate history and whether current or projected ramp queues pose a significant safety risk. In the event that operational or safety risks are determined to exist, the draft revisions indicate that the mitigation of their effects may be addressed in a

---

[2] The TPR revisions subsequently adopted by LCDC include provisions for non-MPO cities outside the Willamette Valley with fewer than 10,000 residents. The draft language addressing unemployment was dropped from the adopted revisions.

traffic management plan (whose intent would be to divert traffic away from the interchange) prepared under an agreement between ODOT and local government.

2.1.1 Discussion

It is evident that substantial policy changes loom as ODOT moves forward in administering the OHP mobility policy under the most recent TPR revisions. While the specifics are still in development, evidence from the joint subcommittee report, Senate Bill 795, the Director's policy intent statement, the draft TPR and OHP amendments, and internal review (*ODOT 2011b*) suggest two general types of refinements that are likely to occur. The first type can be characterized as technical or procedural. Examples of such refinements include the treatment of zone changes that are consistent with adopted comprehensive plans, the methodological treatment traffic volume projections of proposed mitigation measures, and the establishment of threshold volumes in determining what constitutes a significant traffic impact.

The second type of refinement will be more substantive. An important consideration in this regard has been the limited amount of available capital funding at the state and local levels, despite the increasing utilization (primarily at the local level) of alternative funding mechanisms. Funding limitations, in turn, have resulted in growing levels of congestion on the state highway system and have constrained the ability of local governments to undertake transportation system improvements. Thus, as highway performance approaches or exceeds the OHP mobility standards, the orientation of the TPR review process has increasingly focused on avoiding further degradation of performance. If it is sustained, this shift in orientation will have several likely implications. First, although existing policy emphasizes ODOT's commitment to work collaboratively with local governments, the breadth and depth of collaboration that will be needed to balance multiple state and local goals will likely expand. Second, effective collaboration in this context will likely become increasingly dependent on a more robust representation of transportation performance than what is presently provided by the OHP's v/c-based mobility standards. Although the OHP and related guidance documents currently address options involving the use of alternate metrics, greater procedural flexibility would facilitate more extensive utilization.

The substantive refinements will also likely address the consideration of policies and values at the community level, providing guidance for reconciling differences in circumstances where local policies and values and other state policies and values (such as economic development and compact urban growth) and the OHP mobility policy diverge.

2.2 CASE STUDIES

Two case studies are presented below, with the first addressing an IAMP and the second addressing a local TSP. State facilities are involved in each case, and the mobility standards in each plan have been adopted by the OTC as an amendment to the OHP. The case studies were selected with two general purposes in mind. First, each illustrates the successful resolution of a "problem" that the OHP mobility standards and the TPR were designed to address. Second, each offers potential insights in light of changes in the TPR and OHP mobility policy addressed earlier in this chapter.

2.2.1 Chenoweth IAMP

Interchange projects are costly, particularly when they are constructed in or near urban areas. Also, locations near interchanges provide a high level of regional accessibility, and thus tend to attract commercial development activity (*Strathman et al. 2005*). Oregon's state highway system includes over 300 interchanges, with a majority being located in urban areas.

As the gap between Oregon's highway trust fund balance and capital improvement needs grew in the 1990s, the OTC became increasingly concerned with preserving the function and ensuring the safety of interchanges on the state highway system. Many interchanges were prematurely carrying traffic volumes that approached their design capacities, and land use changes in interchange areas were identified as one contributor to this outcome. For example, in determining facility design capacity in an interchange capital project, ODOT planners would commonly forecast facility traffic volumes based, among other things, on area zoning contained in local comprehensive plans. However, following project completion, local plans were often amended to accommodate commercial development seeking to capitalize on the interchange area's regional accessibility. Commercial development from such plan amendments commonly led to traffic volume growth on the interchange exceeding what would otherwise have occurred.

In seeking to preserve interchange function and safety, OAR 734-051-7010 has made the preparation of an interchange area management plan (IAMP) a condition for OTC approval of a new interchange or significant modification of an existing interchange.[3] IAMPs establish interchange area land use and development expectations, set access management conditions, identify necessary local transportation system improvements, define funding responsibilities, and, in some instances, set limits on future trip generation (through "trip budgets"). The OTC adopts IAMPs as an amendment to the OHP.

Although IAMPs are most often prepared in connection with a planned interchange project, they can also be undertaken for other reasons, including instances where the OTC is concerned with protecting an existing interchange, or where an ODOT regional office determines that an IAMP is needed for planning or project development support (*ODOT 2006*). Nevertheless, of the 29 IAMPs adopted by the OTC between November 2002 and September 2011, it appears that just one – the Chenoweth IAMP (*Kittelson & Associates 2009*)–was undertaken for reasons other than a planned interchange project.

---

[3] The IAMP requirement may be waived by the OTC based on evidence from the ODOT region manager of a)the existence of conditions that preclude practical improvement of access conditions; b) assurance of safe operation over the design life of the facility; c) the facility's location in a fully developed Urban Interchange Management Area in which there is no opportunity to benefit interchange area safety or operations through local plan changes; or d) the subject state facility is a lower level service interchange.

The I-84 Chenoweth Interchange (Exit 82) was built in 1997 to provide visitor access to the Columbia Gorge Discovery Center, freight access to the Port of The Dalles, and traffic access to the western edge of the urban area. The primary motivation for the IAMP was an industrial-to-commercial zoning change approved with conditions by The City of The Dalles in 2006 for a 67 acre parcel located adjacent to the interchange. Concerned that such unanticipated development would compromise the function of the interchange, ODOT appealed the zoning change to the Land Use Board of Appeals (LUBA). ODOT and the City then agreed to suspend the LUBA case and subsequently reached a settlement that allowed commercial development to proceed on 25 acres, with the remainder of the parcel placed under covenants prohibiting non-industrial development until an IAMP was prepared and adopted. The OTC also adopted a lower mobility standard to protect the interchange while the IAMP was being prepared. The IAMP was completed in December 2009 and was adopted by the OTC in July 2010.

Traffic projections in the interchange management area to the year 2030 under alternative development scenarios provided an initial frame of reference in the preparation of the Chenoweth IAMP. The projections demonstrated that the interchange would exceed OHP mobility standards before 2030 and that mitigating actions would thus need to be taken. Subsequent analysis was undertaken in which development within the interchange management area was related to corresponding transportation improvements that would need to be implemented to meet OHP mobility standards. A key finding in this analysis was that major reconstruction of the interchange could be avoided if development in the area was limited to 75% of maximum density build-out. Development beyond this level would require a substantial widening of the interchange deck. This finding provided a foundation for the IAMP's effective two-tier transportation improvement program and funding plan.

A parcel-based trip budget was established for the first ("threshold") tier of the program, covering future development in the interchange management area corresponding to the 75% build-out scenario. The improvements associated with this scenario – totaling about $27 million – were focused on the local transportation system and consisted of intersection control and reconstruction, and construction of new streets, street extensions, and turning lanes.

To fund the first tier improvements, the City of The Dalles agreed to adopt a system development charge (SDC) in the interchange management area. The nominal charge itself – about $5,500 per weekday peak hour trip generated – was obtained by dividing the cost of the first tier improvements by the first tier trip budget for the area (about 4,900 trips). The IAMP identifies opportunities to reduce the SDC by as much as 20% in exchange for committing to a progressive set of transportation demand management measures.

While the first tier improvements and SDCs define the principal orientation of the IAMP, the plan also anticipates a possible future where development-related traffic growth exceeds the first tier's trip budget levels. Such a future would trigger a transition to a second tier requiring a widening of the interchange deck to six lanes (at a cost of about

$12.8 million), which would accommodate approximately 1,300 additional peak hour trips. A resetting of the SDC to about $9,700 per trip, roughly 75% above the first tier rate, would also be necessary to fund the second tier improvement. The considerable SDC increase with the second tier thus provides a strong economic incentive to manage development activity consistent with the first tier trip budget.

The Chenoweth interchange was among the last projects completed before ODOT's IAMP process was implemented. In this respect, the Chenoweth IAMP illustrates an important motive of the program: ensuring that the designed life of a costly transportation facility is realized. With the Chenoweth IAMP arising from a legal challenge of a land use change rather than preceding a planned interchange project, the state-local collaborative approach that is characteristic of the IAMP process was tested. The successful resolution of this case yielded innovations that are likely to benefit future IAMPs, and offer potentially useful lessons related to ODOT's future responsibilities under the TPR.

Possibly the most valuable lesson from the Chenoweth case, and the IAMP program more generally, relates to the gains that are achievable from a focused collaborative approach to coordinating state and local planning activity. With a growing number of important urban facilities approaching or exceeding OHP mobility targets, an IAMP-like collaborative framework could be employed to identify solutions that preserve acceptable functional and safety performance levels. In this context, the objective might be to find the best achievable solution under a "no build" scenario, either due to the high cost or undesirability of interchange reconstruction. With respect to key interchanges, for example, the solution may involve modest improvements that protect through traffic and prevent ramp queues from extending into the main travel lanes. In such cases, the planning process would benefit from the use of supplemental safety and queue-based performance metrics.

The Chenoweth IAMP employs an alternative financing mechanism (i.e., SDCs) to fund local transportation improvements. A number of other IAMPs have also turned to alternative financing mechanisms and, in some instances, a part of the interchange improvement cost is covered by local contributions. While this may reflect a lack of resources from conventional transportation funding sources, the local financing arrangements employed in selected IAMPs nevertheless fare well when evaluated against public finance criteria (*Strathman and Simmons 2010*). Such arrangements are now also promoted under OAR 731-017. What distinguishes the Chenoweth case from other IAMPs is the two-tier structure of its SDCs. This structure reflects an underlying objective of identifying and encouraging the most cost effective solution to extending the life of an interchange. Such an approach would also likely transfer well to a setting where a variety of potential solutions for maintaining the performance of key state facilities at elevated mobility target values exist.

2.2.2 Seaside TSP

Traffic congestion along the US 101 corridor in the coastal community of Seaside has been worsening for a number of years. Prior ODOT efforts to address these conditions have met local opposition, polarized local interests and strained the relationship between the community and the state. For example, in the early 2000s ODOT programmed a widening of US 101 through Seaside from two to five lanes. Seaside residents voted against the project in a 2005 referendum, with the opposition split between those who felt that the project's disruption of local businesses would be too great and those who preferred a bypass alternative. Given expressed local opposition, the US 101 widening project (known as "Pac-Dooley") was subsequently cancelled.

Local governments in Oregon are required to prepare a transportation system plan (TSP). TSPs are reviewed by ODOT to ensure consistency with OHP mobility standards, as well as other OHP policies and standards. In the wake of Pac-Dooley, ODOT and the City of Seaside agreed to collaborate in updating the city's TSP with the objective of finding a mutually acceptable solution to congestion along US 101. This collaborative effort (which also involved the Department of Land Conservation and Development, Clatsop County, and Sunset Empire Transportation District) produced the *Seaside Transportation System Plan (2010),* which employs alternative mobility standards. The OTC adopted the Seaside TSP's alternative mobility standards as an amendment to the OHP in September 2011.

Initial analysis supporting the preparation of the Seaside TSP found that seven major intersections along US 101 would fail to meet OHP mobility standards in 2030 under no-build assumptions, with projected v/c values in several locations increasing to more that twice the applicable standard. Initial evaluation also determined that the bypass option favored by some Seaside residents had low feasibility due to environmental impacts, funding limitations, and land use regulation constraints. With options that would substantially expand the US 101 footprint and the bypass option essentially moved "off the table" fairly early in the process, the Seaside TSP team proceeded with the objective of finding the best realistically achievable solution to congestion problems on US 101, relying extensively on input from residents and city officials.

High seasonal variation in traffic volumes along US 101 in Seaside implied that improvements designed to comply with the 30th highest hour volumes underlying the OHP mobility standards would be strongly influenced by traffic conditions that generally prevailed on summer weekend afternoons. Beyond the incidence of such "super peaks," more modestly scaled improvements still held the potential to provide fairly substantial congestion relief. Thus the Seaside TSP team turned its attention to an alternative performance metric – annual average daily traffic (AADT) – which is less sensitive to seasonal peaking effects. More specifically in this case, the metric measures annual average weekday peak volume. Analysis employing this metric focused on facility performance associated with scenarios comprised of hypothetically achievable improvements, with predicted outcomes that addressed both AADT/C and duration of delay consequences. The resulting Seaside TSP and its recommended improvements include a proposed joint AADT/C – Delay mobility standard for four intersections on US 101 (see Table 2.1). These are the alternative mobility standards subsequently adopted by the OTC.

Table 2.1: Seaside TSP Alternative Mobility Standards

Intersection	OHP Mobility Standard	Proposed Mobility Standard	Projected (2030) Annual Average Conditions	Expected Delay Duration
US 101 / Lewis & Clark Rd.	0.80	1.0	1.10	2 hours (3-5 pm)
US 101 / 12th Ave.	0.85	1.0	1.05	1 hour (4-5 pm)
US 101 / Broadway	0.85	1.0	1.10	3 hours (3-6 pm)
US 101 / Ave. U	0.85	1.0	0.95	<1 hour

Collectively, the 20-year schedule of improvements identified in the Seaside TSP are also quite consistent with actions recommended in the TPR for the purpose of mitigating impacts on state facilities or avoiding further degradation. This includes local street improvements that would divert traffic to routes running parallel to US 101 and improve local circulation through better connectivity; consolidating approaches and (where feasible) relocating approaches on US 101 to side streets; reducing setbacks by encouraging rear side parking; promoting greater transit use by improving service frequency, adding satellite parking facilities with shuttle service, constructing a transit center, and re-establishing a central area trolley bus circulator service; promoting more walking and biking by improving sidewalk connectivity, improving crosswalks, expanding the network of bike lanes, extending shared use pathways, and constructing bicycle/pedestrian facilities. US 101 improvements are primarily focused on four major intersections, with a fifth improvement addressing the extension of a local parallel street to a tie-in with US 101 at one of the four upgraded intersections. Although the TSP does not call for the creation of a trip budget, it does establish an overlay zone along the US 101 corridor within which new uses that are substantial trip generators would be given closer scrutiny in the development review process.

The 20-year capital cost estimates for implementing the Seaside TSP total nearly $55 million, and are divided between ODOT and the City. The TSP identifies a variety of alternative funding mechanisms that may be employed by the City, including tax increment financing (through urban renewal), creation of local improvement districts, SDCs, developer contributions and exactions, and voter-approved tax levies or bonds.

The Seaside TSP illustrates an application of alternative mobility standards as envisioned by the OHP mobility policy. That it was crafted in a setting with a history of conflict makes it a remarkable achievement. This feat was recognized by the Portland Chapter of the Women's Transportation Seminar (WTS), which selected the Seaside TSP as its *Project of the Year* in 2010 (*WTS 2010*). Given that there are a number of other communities along the Oregon coast and elsewhere that are experiencing seasonal traffic conditions that are similar to those resolved in the Seaside TSP, this project is likely to serve as a useful template for future plans. More generally, the lessons offered by the Seaside TSP experience can be characterized as follows: be realistic in setting performance expectations; adapt to circumstances in recognizing community values and identifying improvement opportunities; work together toward the best achievable outcome.

3.0 LITERATURE REVIEW

The purpose of this chapter is to review the literature on transportation performance metrics that have the potential to supplement v/c in its applications under the OHP. Of most interest are the metrics for which empirical evidence of effects on performance at the facility, segment, or network level has been reported. However, the objective of the review is to be as comprehensive as possible in identifying potential metrics. Thus, for some metrics the empirical evidence may be limited. It should also be noted that even where empirical evidence from the literature is fairly substantial, this still may not be sufficient to support transferability to Oregon's transportation and land use planning environment. Consequently, subsequent effort in this study is devoted to simulations of selected metrics using a locally calibrated travel demand model.

The remainder of this chapter is organized as follows. First, a brief general appraisal of the transportation performance measurement initiative in the United States is presented in Section 3.1. Section 3.2 then identifies and discusses supplemental performance metrics that hold potential for responding to the needs of this study. Section 3.3 discusses issues related to the application of supplemental performance metrics from a travel demand modeling perspective. The chapter concludes in Section 3.4 with a summary discussion.

3.1 TRANSPORTATION PERFORMANCE METRICS IN THE BROADER CONTEXT

Formal experience in the United States with transportation performance measures dates from the U.S. Army Corp of Engineers' elementary cost-benefit studies of harbor and river navigation projects in the 1930s (*Quade 1971*). At the state level, Oregon's 1937 highway cost allocation study, the nation's first, is considered a milestone in the use of pavement performance information to support transportation policy and decision-making (*Balducci and Stowers 2008*).

Today, state departments of transportation (DOTs) rely on performance measures to serve diverse objectives and responsibilities. According to Cambridge Systematics et al. (*2009*), the current generation of DOT performance measurement systems evolved from the early 1990s in response to a variety of influences, including

- the "re-inventing government" movement, which called for greater accountability, transparency, and adoption of the performance-driven management practices of the private sector;
- increasingly complex planning objectives reflecting both formal and informal recognition of transportation's relationship to the natural environment, system user rights and social interests, state economic development policy, the built environment, and community welfare;

- a growing disparity between resource availability and resource needs, which has forced more careful consideration of trade-offs involved in resource allocation decisions;
- increasing flexibility in the allowable uses of federal-aid funds, beginning with the passage of the Intermodal Surface Transportation Efficiency Act of 1991;
- advances in information and intelligent transportation system (ITS) technologies, which has opened up new operations management opportunities, yielded enormous amounts of data, and improved data analysis tools;
- a growing number of state legislative mandates.

One way of fundamentally distinguishing the features of state DOT performance measurement systems is through a hierarchical division of the purposes that the systems are designed to serve. At the first level, performance measures facilitate communication with DOT stakeholders about state highway system conditions. It is likely that all state DOTs utilize performance measures for this purpose.

At the second level of the hierarchy, performance measures are used to support management's programming decisions in allocating resources across operations, maintenance, and improvements. Further, within each of these areas, performance measures can support project prioritization processes. A majority of state DOTs rely (to widely varying degrees) on performance measurement systems for these purposes.

At the third level of the hierarchy, performance measures can serve as a basis for legal or regulatory decisions. For example, access to a transportation facility can be withheld when it can be demonstrated that public safety (as evidenced by safety-related performance measures) would otherwise be compromised (*see Paradyne Corp. v. Florida Department of Transportation 528 So.2d 921 1988*). With respect to land use, Florida's transportation concurrency program conditions local development approval on mitigation that ensures conformance with facility level of service (LOS) standards (*FDCA 2007*). Generally, however, the use of transportation performance measures in a legal or regulatory context is not a very widespread practice among state DOTs.

The need to ensure the integrity and fidelity of performance measures becomes progressively more important from the first to the third level of the hierarchy. Integrity relates to the ability of performance measures to consistently and accurately portray defined phenomena across relevant temporal and geographic scales. Performance measures possess integrity when underlying data quality is high and when space/time inferences made from available data are subject to acceptably low levels of estimation/forecasting error. For example, LOS and v/c are widely considered to be measures with high integrity. Among state DOTs, concerns about integrity (i.e., "data quality") are reported to be a challenge to the adoption and use of transportation performance measures for regulatory purposes (*Cambridge Systematics et al. 2009*).

Fidelity relates to the extent to which given performance measures adequately represent stated concepts or conditions. For example, while v/c and LOS are intended to represent mobility, there are concerns that they do not reflect certain operational attributes (e.g., reliability) that are also important to highway users (*NCHRP 2007; NTOC 2005*). More fundamentally, it has been argued that accessibility to destinations, rather than mobility, is the more appropriate concept to be represented in metropolitan areas (*Cervero 2005*). However, given that travel time metrics can be related to both mobility and accessibility, these concepts may not be as distinct from each other as they seem to appear.

There is fairly widespread agreement in the literature that LOS and v/c are too narrowly representative of mobility and thus should be supplemented by other metrics (*Cambridge Systematics 2000; Cambridge Systematics et al. 2009; NCHRP 2007; NTOC 2005*). Collectively, supplemental metrics should be capable of representing important contributors to congestion, its spatial and temporal extent, and its consequences (*NCHRP 2007*). It is also recognized that some metrics must either be derived or modeled because they cannot be directly measured (*Cambridge Systematics et al. 2009; NCHRP 2007*).

While a system of multiple metrics will likely represent mobility with greater fidelity, there may also be negative consequences if the metrics supplementing v/c lack its high integrity. This trade-off should be carefully considered where the system is intended to support resource allocation and (especially) regulatory decisions. More generally, Brown (1996) stresses the importance of parsimony, arguing that performance measurement systems should be organized around a "vital few" rather than a "trivial many" set of metrics.

A more general concern relates to the question of whether transportation performance measurement systems contribute to improved outcomes with respect to such benchmarks as accountability, quality of service, economic efficiency, safety, and environmental quality. Given that there has been essentially no research under controlled conditions, the evidence related to this question is mixed. For example, both federal and state transportation agencies have been praised as early adopters and innovative users of performance measurement systems in the public sector (*Cambridge Systematics et al. 2009*). However, another appraisal focusing on transportation and four other public sector functions concluded that "(e)xamples in which performance measures are used to enforce greater accountability are the exception rather than the rule" (*Stecher et al. 2010*). In another case, the Washington Department of Transportation has been characterized as a performance measurement leader among state DOTs (*Cambridge Systematics et al. 2009*). However, a Washington State Auditor's Office evaluation of the Department's transportation improvement program in the Puget Sound region found that congestion measures were not directly factored into the project prioritization process, despite evidence from regional surveys showing congestion to be residents' top transportation concern. Moreover, the Department was unable to document the effect of its Puget Sound region transportation improvements on congestion itself (*WSAO 2007*).

Lastly, a scan sponsored by the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (ASHTO) focused on transportation performance measurement systems employed in four industrialized Pacific Rim countries. The scan report (*MacDonald et al. 2004*) concluded that the subject countries' systems were generally more advanced and strategically engaged in decision-making processes than those commonly found in the United States. Key distinguishing features of the systems reviewed by the scan team include:

- beyond congestion, the systems typically included travel metrics relating to mobility, accessibility, safety, travel time, and travel time reliability;
- customer satisfaction metrics were common;
- performance targets distinguished between urban and rural areas in order to address equity considerations;
- transportation program outcomes were commonly evaluated in relation to defined benchmarks;
- efforts were made (with varying success) to connect resource allocation with performance outcomes;
- a variety of freight performance measures covering travel time, reliability, bottlenecks, terminal access, modal productivity, and regulatory compliance.

3.2 INVENTORY OF CANDIDATE METRICS

The population of performance metrics reported in the literature is quite large, even after accounting for many near-redundancies. However, the identification of candidate metrics becomes more manageable when this study's principal objectives are taken into consideration. These objectives encompass the need to provide a more robust portrayal of mobility, the need to better integrate mobility metrics with metrics representing complementary OHP policies, and the need to empirically relate selected supplemental metrics to v/c with reasonable ease and precision. The resulting roster reflecting these objectives numbers 41 candidate metrics, many more than will subsequently be considered for further analysis in this study. The candidate metrics are organized into the following six categories:

• Mobility	14 Metrics
• Reliability	8 Metrics
• Land Use/Urban Design	11 Metrics
• Safety	2 Metrics
• Infrastructure	4 Metrics
• Energy/Environment	2 Metrics

The table of selected metrics presented below is the product of a screening process applied by the research team. While the study's objectives served as a basis for screening, evidence from the literature was sometimes lacking and judgments were necessarily involved. Another consideration was the need to anticipate potential scenarios involving multiple metrics. For example, assessing the traffic impacts of transit-oriented or compact development would potentially draw on metrics representing density, transit access, transit service frequency, land use mixing, and parking. Scenarios involving incident management would likely draw on recurring/non-recurring congestion, delay, and ITS-related metrics. As these two examples illustrate, the metrics selected should be applicable across a broad range of policy, operations, and design options.

The candidate metrics are presented by category in Table 3.1. The table also presents the following summary information for each metric:

- definition;
- value basis (i.e., the means or method employed to obtain a metric's value), which includes direct measurement, derivation (e.g., using a data tool such as a geographic information system), and modeling;
- modal applicability, including auto, truck, transit bus and rail, bicycle, and pedestrian;
- spatial resolution, including point, segment, zone, district, and area-wide;
- temporal resolution including hourly, seasonal, annual, or self-defined scales;
- references, listing citations from the literature related to the metric's use or empirical relationship to v/c;
- data requirements;
- relationship to v/c, based on empirical evidence associated with such phenomena as trip generation, mode choice, trip length, and other factors;
- examples of the purpose(s) served by given metrics.

Regarding reference applications, a number of the citations listed in Table 3.1 (e.g. *Cambridge Systematics 2000; Cambridge Systematics et al. 2009; Klop and Gunderian 2008; NCHRP 2007; NTOC 2005*) provide general insight on the logic for including given metrics in a highway performance measuring system. Collectively, these citations also document a large array of performance metrics serving a variety of purposes. However, they rarely address the relationship between a given metric and a defined outcome, such as v/c. Thus, other citations addressing the empirical relationship between v/c (or its constituent attributes) and each metric are included where such evidence could be found. In some instances, such references may have focused on a close variant of the metric defined in the table. An effort was also made to identify studies that synthesize published empirical findings. For example, Ewing and Cervero's (*2010*) meta-analysis proved very helpful in documenting the relationship between VMT and selected land use and urban design metrics from the substantial literature on that subject. The following discussion proceeds according to the organization of Table 3.1.

3.2.1 Mobility Metrics

Both v/c and LOS are included in Table 3.1 as reference metrics. Collectively, the remaining 12 metrics represent temporal, spatial, and operational dimensions of mobility. Conceptually and, to varying degrees empirically, all are relatable to v/c.

While v/c is a very useful metric for transportation planning, engineering and design, it has been argued that it is less reflective of travelers' mobility perspectives (*NCHRP 2007*). Both personal travelers and freight carriers are concerned about delay (generally), the geographic and temporal extent to which their travel is subject to delay, and the real and implicit monetary costs they bear as a result of delay. Thus, the widely-recognized *Urban Mobility Report,* published annually by the Texas Transportation Institute, includes four of the mobility metrics listed in Table 3.1: Recurring Delay (along with total and non-recurring delay), Congestion Duration, Congestion Extent, and Percent of Congested Travel. Together, these metrics provide a fairly robust representation of congestion and its consequences for travelers.

With its primary focus on delay, the *Urban Mobility Report* is also able to consistently assess the effects of alternative congestion-relieving treatments related to operational improvements and transit provision. In 2007, operational and transit-related "avoided delays" were estimated to amount to nearly 23% of total delay across the 439 urban areas covered in the report (*Schank and Lomax 2009*). Separately, analysis by Chin et al. (*2002*) indicates that potential further reductions in delay from operational improvements are large.

The travel time and trip length distribution metrics jointly reflect motorists' exposure to congested travel. They also provide a means of assessing selected congestion mitigation strategies. For example, holding trip lengths constant, the effects of capacity or operational improvements can be examined through changes in travel times. Alternatively, holding travel times constant, the effects of scenarios focused on improving accessibility can be examined through changes in the distribution of trip lengths.

Table 3.1: Characteristics of Supplemental Performance Metrics

Performance Metric	Definition	Value Basis	Mode(s)	Spatial Resolution	Temporal Resolution	References	Data & Tools Required	Relation to V/C	Purpose
Mobility									
V/C Ratio (Reference Metric)	Ratio of traffic volume to facility capacity	Measured Modeled	Auto Truck	Point; Segment	Hourly	Cambridge Systematics et al (2009); Klop&Guderian (2008); ODOT (1999; 2004; 2009); Wray (1998)	Hourly traffic volumes; Facility design capacity; HCM	Same	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
LOS	Progressive letter grades A-F used to stratify performance measure chosen to determine LOS (v/c, delay, density)	Measured Modeled	Auto Truck Bus Rail Bike Pedestrian	Point; Segment Facility	Hourly	Cambridge Systematics et al (2009); FDCA (2007); FDOT (2009); GDOT (No date); TRB (2000); VDOT (No date)	Generally hourly traffic volumes, capacity, inventory data; HCM	May be used to categorize v/c (and other measures)	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Travel Time	Travel time required to traverse a segment, facility (all modes), or a region (most relevant to freight)	Measured Modeled	Auto Truck Bus Rail Bike Pedestrian	Segment; Facility	Self-defined (Minutes)	Cambridge Systematics (2009); Gregor (2004; 2009) NTOC (2005)	Measured travel times (pavement detectors, vehicle onboard devices); Modeled networks;	Non-linear positive relation to v/c up to point of jam density	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Waiting Time	Out-of-vehicle time spent waiting by transit passengers, including transfer time	Measured Modeled	Bus Rail	Segment; Facility	Self-defined (Minutes)	Strathman et al. (1999)	On-board surveys; transit schedules; modeled transit networks	Directly related to v/c through mode diversion	Facility operations/sizing; Evaluating system plan objectives
VMT	Vehicle miles traveled within a specified area and time period	Derived; Modeled	Auto Truck Bus Rail	Facility; District to Area-wide	Hourly Daily Annual	Cambridge Systematics et al (2009); Klop&Guderian (2008) NCHRP (2007)	Modeled trip tables; Network based distance skims	Auto, Truck - directly related; Bus/Rail – inversely related	Land use impact assessment; Evaluating system plan objectives
VHT	Vehicle hours traveled within a specified area and time period. May be volume-weighted (autos), or weighted by commodity tonnage or value (trucks)	Derived Modeled	Auto Truck Bus Rail	Facility; District to Area-wide	Hourly Daily Annual	NTOC (2005)	Measured travel times (pavement detectors, vehicle onboard devices); Modeled networks; Shipment data needed for freight	Auto, Truck - directly related; Bus/Rail – inversely related	Land use impact assessment; Evaluating system plan objectives
Recurring Delay	Vehicle delays that are repeatable for the current time of day, day of week, and day type below a threshold (e.g. 70th percentile)	Measured Derived Modeled	Auto Truck Bus	Point; Segment; Facility	Hourly	Cambridge Systematics et al (2009); Klop&Guderian (2008); NTOC (2005)	Travel times by time segment (e.g., 1-hour, averaged over 30 days); ITS sources; DTA	Recurring delay generally increases with increases in v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives

Person Throughput	Number of persons (vehicle occupants, pedestrians, and cyclists) traversing a segment or facility in one direction per unit time (or crossing a screen/cordon line)	Measured Derived Modeled	Auto Bus Rail Bike Pedestrian	Point; Segment; Facility; Multi-modal corridor	Hourly Daily Annual	Klop&Guderian (2008); NCHRP (2007); NTOC (2005); RITA (2004)	Auto counts with surveyed occupancy data; Transit passenger counts; Bike and Pedestrian counts	Holding occupancy constant, directly related; holding vehicles constant, inversely related	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
PHT	Person hours of travel within a specified area and time period, sometimes expressed in terms of excess delay.	Modeled	Auto Bus Rail Bike Pedestrian	Segment; Facility; Multi-modalcorridor; District to Area-wide	Hourly Daily Annual	Cambridge Systematics (1998); Capital District Transportation Committee (2007)	Modeled trip tables; Vehicle occupancy assumptions; Network based distance skims	Generally, directly related to v/c, but will vary depending on non-auto mode utilization	Land use impact assessment; Evaluating system plan objectives
Mobility Index	PMT/VMT*Average Speed	Modeled	Auto Bus Rail	Segment; Facility; Multi-modal corridor; District to Area-wide	Hourly Daily Annual	Bertini (2005a); Cambridge Systematics (2000); Cambridge Systematics et al (2009)	Modeled trip tables, network based distance skims, surveyed occupancy rates, modeled travel time skims	Generally inversely related to v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Trip Length Distributions	Frequency distribution of trips by 1-mile bins for different purposes and by different modes.	Modeled	Auto Truck Bus Rail Bike Pedestrian	Zonal; District to Area-wide	Daily Annual	Trip length distributions are a common product of travel demand models	Household surveys; OD surveys; Establishment surveys; modeled trip tables and networks	Local effects on v/c will vary	Land use impact assessment; Evaluating system plan objectives
Congestion Duration	Time expressed in hours that a directional highway segment remains congested, subject to speed threshold definition of "congested condition"	Measured Modeled	Auto Truck Bus	Segment Facility	Hourly	Cambridge Systematics et al (2009); Bertini (2005a); NTOC (2005)	Travel speeds by time interval	Congestion is usually defined by speed or travel time thresholds, which positively correlate with v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Congestion Extent	The length of a freeway segment, by direction, that experiences speeds below 'X' mph for 'Y' minutes or more; miles of roadway within an area and time for which average travel times are X% longer than unconstrained travel times	Measured Modeled	Auto Truck Bus	Segment Facility; District to Area-wide	Hourly Daily	Bertini (2005a); NCHRP (2007); NTOC (2005)	Travel speeds by time interval, segment lengths	Congestion is usually defined by speed or travel time thresholds, which positively correlate with v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives

Percent of Congested Traffic	Ratio of congested VMT to total VMT; Total VMT = total traffic volume * the length of the road section (for the time period of interest) Congested VMT = Traffic volume * the length of the road section that occurs below a present threshold (for the time period of interest)	Derived	Auto Truck Bus	District to Area-wide	Hourly Daily Annual	Cambridge Systematics et al (2009); MDOT (2005); NTOC (2005)	Measured or modeled volumes and speeds by time interval, segment lengths	Congestion is usually defined by speed or travel time thresholds, which positively correlate with v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Queues	Point (Frequency of Spillback) - Proportion of time when queue spills back beyond threshold; Area - Percentage of intersections where point spillback is a problem - occurs 'X' times during specified time	Derived Modeled	Auto Truck Bus	Point Segment; District to Area-wide	Hourly Daily Annual	Bertini (2005b); Cambridge Systematics et al (2009); NTOC (2005)	Segment lane geometry, access/egress points, traffic control operations (timing plans, metering), directional volumes	Directly related to v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Reliability									
Non-recurring Delay (General)	Vehicle hours of delay in excess of recurring delay for a given time of day, day of week, and day type	Measured Derived Modeled	Auto Truck Bus Rail	Segment Facility; District to Area-wide	Hourly Daily Annual	Cambridge Systematics et al (2009); Hallenbeck et al. (2003); NJTPA (No date); NTOC (2005)	Travel times by time segment (e.g., 1-hour, averaged over 30 days); ITS sources; DTA; Transit schedules	Auto, Bus, Truck: directly related to v/c; Rail: no relation to v/c	Facility operations/sizing; Evaluating system plan objectives
Non-recurring Delay (Incident Occurrence and Management)	Average time required to clear an incident	Measured Derived Modeled	Auto Truck Bus	Segment Facility; Area-wide	Annual	Cambridge Systematics et al (2009); Carson et al. (1999); Dailey (2006) NCHRP (2007) NTOC (2005)	Time of incident, response arrival time, clearance time, return to normal flow	Relation to v/c unclear	Facility operations/sizing; Evaluating system plan objectives
95th Percentile Travel Time	Travel time corresponding to the 95th highest out of 100 (or 19th highest out of 20)	Measured Derived Modeled	Auto Truck Bus Rail Bike	Facility; District to Area-wide	Hourly Daily	Cambridge Systematics et al (2006; 2009); FHWA (2007); NCHRP (2007); Noland and Small (1995); Small (1982)	Travel times by time segment (e.g., 1-hour, averaged over 30 days); ITS sources; DTA	Generally, directly related to v/c, but will vary dramatically when traffic densities reach critical thresholds	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives

Buffer Index	Percent of extra travel time travelers add to expected travel time to ensure on-time arrival “X”% of time, e.g., (95th percentile travel time – mean travel time)/ mean travel time	Measured Derived Modeled	Auto Truck Bus Rail Bike	Facility; District to Area-wide	Hourly Daily	Cambridge Systematics et al (2006; 2009); FHWA (2007);McMullen and Monsere (2010) NCHRP (2007); Noland and Small (1995); Small (1982)	Travel times by time segment (e.g., 1-hour, averaged over 30 days); ITS sources; Modeled congested travel time skims, DTA; Transit schedules	Generally, directly related to v/c, but will vary dramatically when traffic densities reach critical thresholds	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Planning Time Index	Total travel time travelers should expect to take to ensure on-time arrival relative to free-flow conditions “X”% of time, e.g., (95th percentile travel time – free-flow travel time)/ free-flow travel time	Measured Derived Modeled	Auto Truck Bus Rail Bike	Facility; District to Area-wide	Hourly Daily	Cambridge Systematics et al (2006; 2009); FHWA (2007); NCHRP (2007); Noland and Small (1995); Small (1982)	Travel times by time segment (e.g., 1-hour, averaged over 30 days); ITS sources; Modeled free-flow travel time skims, DTA; Transit schedules	Generally, directly related to v/c, but will vary dramatically when traffic densities reach critical thresholds	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
On-time Performance	% On-time performance (within industry thresholds)	Measured Derived	Truck Bus Rail	Facility (transit line); District to Area-wide	Annual	Cambridge Systematics et al. (2009); Strathman and Hopper (1993)	Transit or truck arrival time data; from ITS or internal records	Inversely related to v/c	Facility operations/sizing; Evaluating system plan objectives
Fluctuations in Travel Times	Travel time variation across 'X' minute intervals; coefficient of variation = standard deviation / mean	Measured Derived	Auto Truck Bus Rail	Point; Segment	Hourly Daily	Cambridge Systematics (2000); NTOC (2005)	Travel times by time segment (e.g., 1-hour, averaged over 30 days); ITS sources	Expect fluctuation to be lower for high values of v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Fluctuations in Traffic Volumes	Traffic volume variation across 'X' minute intervals; coefficient of variation = standard deviation / mean	Measured Derived	Auto Truck Bus Rail	Point; Segment	Hourly Daily	Cambridge Systematics (2000); NTOC (2005)	Volumes by time segment(e.g., 1-hour, averaged over 30 days); ITS sources	Expect fluctuation to be lower for high values of v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Land Use/Urban Design									
Accessibility to Destinations	Percent of population living within “X” miles or “Y” minutes of defined destinations, by trip purpose and mode	Derived Modeled	Auto Bus Rail Bike Pedestrian	Zonal; District; Area-wide	Hourly Daily	Bhat et al. (2002); Cambridge Systematics (2000); Cambridge Systematics et al (2009); Cervero (2005); Ewing &Cervero (2010)	Population data; Employment data by sector; Transit network data; Detailed street network data; Travel time skims	V/C may increase or decrease locally depending on net effects of accessibility on trip generation and mode choice	Land use impact assessment; Evaluating system plan objectives

Accessibility to Employment and Population	Composite formulas for defining access to job or retail markets by single modes or composite modes. Gravity-model-like formula with travel cost/distance-decay relationship, or within "Y" minute buffer	Derived Modeled	Auto Bus Rail Bike Pedestrian	Zonal District Area-wide	Hourly Daily	Reiff and Gregor (2005)	Employment data; Transit network data; Detailed street network data; Travel time skims	V/C may increase or decrease locally depending on net effects of accessibility on trip generation and mode choice	Land use impact assessment; Evaluating system plan objectives
Accessibility to Transit	Percent of population that can access fixed-route transit within "X" miles or "Y" minutes	Derived	Bus Rail	Zonal; District; Area-wide	Hourly Daily	Bhat et al. (2002); Cambridge Systematics (2000); Cambridge Systematics et al (2009); Ewing &Cervero (2010)	Geo-coded population data; Transit stop and station data	Inversely related: Holding density constant, auto trip generation decreases with increasing access to transit	Land use impact assessment; Evaluating system plan objectives
Accessibility to Freight Terminals	Number of industry-specific jobs (as proxy) within "X" miles or "Y" truck travel time minutes of port or intermodal facilities	Derived Modeled	Truck	District; Area-wide; Statewide	Hourly Daily	McMullen and Monsere (2010); MacDonald et al. (2004)	Geo-coded locations of ports and intermodal terminals; industry-specific employment data by zone; network travel times	Accessibility would generally increase with v/c, but local effects may differ	Land use impact assessment; Evaluating system plan objectives
Bike/Pedestrian Network Circuitousness	Ratio of shortest network path distance to shortest Euclidean distance	Measured	Bike Pedestrian	Zonal; District; Area-wide	Annual	Dill (2004)	GIS street network, Transit routes; Bicycle facility shapefiles; Sidewalk shapefiles	Generally inverse: Reduces v/c through a reduction in VMT and lower auto trip generation	Land use impact assessment; Evaluating system plan objectives
Street Connectivity	Index measured as the ratio of intersections to lane-miles for a given area, or neighborhood link-to-node ratio	Measured	Bike Pedestrian	Zonal; District; Area-wide	Annual	Chapman & Frank (2004) City of Portland (1998); Ewing & Cervero (2010); FHWA (1999); Hedel & Vance (2007) Reiff & Gregor (2005)	GIS street network, Transit routes; Bicycle facility shapefiles; Sidewalk shapefiles	Generally inverse: Reduces v/c through a reduction in VMT and lower auto trip generation	Land use impact assessment; Evaluating system plan objectives
Land Use Mix	Multi-family, Retail and Services, Office, Entertainment, Institutional, and Industrial land use relative to Single Family use within a defined area	Derived	Auto Truck Bike Pedestrian	Zonal; Multi-modal corridor; District; Area-wide	Annual	Ewing &Cervero (2010); Frank and Pivo (1995); Hess et al. (2001)	Geo-coded parcel level land use data; Floor area data	V/C may increase or decrease depending on net trip generation, length and mode choice changes	Land use impact assessment; Evaluating system plan objectives

Population and/or Employment Density	Structures: Square footage of improvements divided by district area; Households and workers: Persons divided by district area.	Derived	Auto Truck Bike Pedestrian	Zonal; Multi-modal corridor; District; Area-wide	Annual	Cervero & Murakami (2010); Ewing&Cervero (2010); Frank & Pivo (1995); Handy et al. (2002);	GIS parcel data; Zonal& area wide population & employment estimates	V/C may increase or decrease locally with increasing density depending on its net effects on trip generation, length and mode choice	Land use impact assessment; Evaluating system plan objectives
Off/On-Street Parking V/C	V/C of parking facilities within a specified area (e.g., CBD)	Measured	Auto Bus Rail Bike Pedestrian	Segment; Facility; Multi-modal corridor; District; Area-wide	Hourly Daily	Kuzmyak et al. (2003) Young et al. (1991);	Parking space inventory; Peak/Off-Peak utilization counts	V/C of parking supply will have positive correlation with adjacent segment or facility v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Transit Station Parking V/C	V/C of parking facilities for bus & rail park-and-ride	Measured	Auto Bus Rail Bike Pedestrian	Multi-modal corridor; District; Area-wide	Hourly Daily	Klop & Gunderian (2008); Turnbull et al. (2004)	Parking space inventory; Peak/Off-Peak utilization counts	V/C of parking supply will have positive correlation with adjacent segment or facility v/c, but negative correlation with v/c on area-wide level due to mode diversion	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives
Bike Storage Facility Utilization	V/C of bike lockers or other facilities	Measured	Bike	Multi-modal corridor; District; Area-wide	Hourly Daily	Kuzmyak et al. (2010)	Parking space inventory; Peak/Off-Peak utilization counts	V/C of bike storage facilities should have loose inverse correlation with highway V/C due to mode diversion	Land use impact assessment; Evaluating system plan objectives
Safety									
Crash Rates	Total, fatality, injury, and non-injury crashes per VMT or PMT	Measured	Auto Truck Bus Rail Bike Pedestrian	Point; Segment; District; Area-wide	Annual	Cambridge Systematics et al (2009); Dickerson et al. (1998); Golob et al. (2004) NCHRP (2007); USDOT (2002); Wang et al. (2009)	Crash counts by severity by mode; VMT/PMT by mode; HSM	Generally, crash rates increase with v/c	Facility operations/sizing; Land use impact assessment; Evaluating system plan objectives

Crime	Crimes per 1,000 transit passengers	Measured	Bus Rail	Point; Segment; District; Area-wide	Annual	Cambridge Systematics (2000); Needle & Cobb (1997); Sacramento Regional Transit (2008)	Geo-coded crime data; Transit passenger counts	None	Evaluating system plan objectives
Infrastructure									
Freeway Lane-Miles With ITS	System extent of deployment of ITS technologies	Measured	Auto Truck Bus	Facility; Segment; Area-wide	Annual	Cambridge Systematics (2000); Mannering (1989); NCHRP (2007)	Inventory data	Inversely related to v/c (ITS facilitates operational improvements affecting volumes or effective capacity)	Evaluating system plan objectives
Total Freeway Lane-Miles	Total freeway lane-miles	Measured	Auto Truck Bus	Area-wide	Annual	Cambridge Systematics (2000); Cervero (2002)	Inventory data	Inversely related to v/c (e.g., freeway capacity additions)	Evaluating system plan objectives
Transit Supply	Revenue hours/miles of service provided; Service frequency/average headway	Measured	Bus Rail	Facility Segment Zonal District Area-wide	Hourly	Evans et al. (2004)	Archived transit operations data	Inversely related to v/c	Evaluating system plan objectives
Bicycle Lane-Miles	Miles of striped bicycle lanes	Measured	Bike	Facility Segment Zonal District Area-wide	Annual	Pucher et al. (2010)	Inventory data	Uncertain	Evaluating system plan objectives
Energy/Environment									
Fuel Consumption per VMT or PMT	Fuel consumption per VMT or PMT	Derived Modeled	Auto Bus Rail	Area-wide	Annual	Cambridge Systematics et al (2009); FHWA (2008); Greene (1998); NCHRP (2007); Stecher et al. (2010)	VMT & fuel consumption rates by vehicle class	Loosely directly related to v/c	Land use impact assessment; Evaluating system plan objectives
Tons of Pollutants Generated	Tons of carbon monoxide, nitrogen oxides, sulfur dioxide and particulate matter generated	Derived Modeled	Auto Bus Rail	Area-wide	Annual	Cambridge Systematics (2000); Cambridge Systematics et al (2009); Flanigan & Howard (2008); NCHRP (2007); Stecher et al. (2010)	VMT & emission rates by vehicle class	Loosely directly related to VMT and v/c	Land use impact assessment; Evaluating system plan objectives

ODOT selected v/c to represent the OHP mobility standard following an evaluation of 11 alternative metrics against 8 criteria (*ODOT 1998*). Three of the mobility metrics listed in Table 3.1 were among those evaluated: Vehicle Miles Traveled (VMT), Delay, and Person Throughput. The evaluation concluded that the greatest distinctions between v/c, VMT, Delay, and Person Throughput were concentrated in the following four areas:

- V/C can be much more consistently applied across diverse circumstances and jurisdictions than VMT, Delay, or Person Throughput.
- V/C serves as a somewhat better indicator of intercity mobility than VMT or Person Throughput, although it fares somewhat worse than Delay.
- V/C offers a much better basis of support for operations decisions (e.g., in the areas of signal control and access management) than VMT or Person Throughput, and a somewhat better basis than Delay.
- V/C can be forecasted with much greater confidence than Person Throughput, and somewhat greater confidence than VMT or Delay.

In summary, the 1998 ODOT study determined that the greatest advantages of v/c over alternative performance metrics were its applicability to operational analysis of specific facilities and greater general confidence in its use. The ODOT study also recognized that other mobility metrics can be useful in selected contexts. Delay and Person Throughput, for example, would be better metrics for user benefits assessment, while VMT or VHT would be more appropriate metrics for evaluating air quality impacts.

3.2.2 Reliability Metrics

There is growing agreement on the need to include reliability metrics in examining highway performance (*NCHRP 2007; NTOC 2005*). Table 3.1 includes eight metrics related to reliability. Two of the metrics provide general and operational representations of non-recurring delay. Three additional metrics address travel time variability. The remaining three metrics focus on travel schedule reliability.

Non-recurring delay represents excess time lost beyond that due to recurring delay for a given day and time period. Schrank and Lomax (*2009*) estimate that non-recurring delay accounted for 54% of total personal delay among 439 urban areas in 2007. The relative importance of non-recurring delay also varies with v/c. At low v/c values, virtually all delay is attributable to non-recurring causes, while at high v/c values its relative contribution to total delay falls well below the average figure reported by Schrank and Lomax (*2009*). Regarding the relative importance of its various sources, Hallenbeck et al. (*2003*) found that lane-blocking incidents accounted for 10-35% of total non-recurring delay in the Puget Sound region. Thus, incident management programs could play an important part in reducing delay associated with non-recurring congestion.

The metric described as fluctuations in traffic volume measures the standardized variation in traffic volume for defined time periods. The main benefit from standardization (which yields a coefficient of variation) is in the clear interpretation of the metric across different types of facilities and over distinct time frames and traffic volumes.

The buffer index tends to increase with v/c, reflecting the increasingly uncertain delay consequences of the growth of recurring and non-recurring congestion. For example, Cambridge Systematics et al. (*2006*) present findings from a 4-city analysis showing the buffer index increasing in near-linear (but less than proportionate) fashion with increases in the travel time index. Thus, while the absolute size of the buffer index would increase with v/c, its size relative to expected travel time (i.e., the mean or median, depending on the specific metric) would decline.

The on-time performance metric is an important performance consideration in circumstances involving scheduled transportation services, such as transit and freight pick-up/delivery. Although less explicit, on-time performance is also relevant in personal auto travel, where commuters face penalties (sometimes directly) for failure to arrive at given work start times and where non-work travelers experience disutility for deviating from desired arrival times.

Incident management programs seek to reduce the time required to clear an incident and allow traffic to return to its normal flow. Incident response teams (IRTs) generally give highest priority to incidents that block travel lanes. IRTs also usually patrol during peak periods and respond to minor incidents when possible. Carson et al. (1999) evaluated Washington DOT's incident response program in the Puget Sound region. They estimated a 21-minute decline in duration for IRT-served incidents, which translated into estimated annual vehicle delay savings ranging from $3-9 million (as compared to annual program costs of about $700,000).

Research on non-recurring congestion has shown increasing interest in the role of weather, both in terms of its effects on speeds and in terms of its effects as a determinant of traffic incidents (*Dailey 2005*). Also, beyond the standard operational focus on incident management, there has been growing attention given to emergency management conditions (*NTOC 2005*).

3.2.3 Land Use/Urban Design Metrics

Among other objectives, OHP Policy 1B (*Land Use and Transportation*) promotes compact urban development. The land use and urban design metrics in Table 3.1 provide a means of empirically relating various characteristics of compact urban development to Policy 1F's mobility standards.

Population and employment density are the most basic indicators of compact urban development. Ewing and Cervero's (*2010*) meta-analysis includes these metrics, and they report their associated weighted VMT elasticities. Their reported per capita/household VMT elasticity for household/population density is -0.04, as derived from the nine studies included in their analysis. Thus, in this case, a 10% increase in household/population density results in an estimated -0.4% reduction in VMT per person/household. Alternatively, their reported elasticity for employment density is 0.00, based on six studies. This latter finding may reflect other research indicating that while the general dispersion of employment has lengthened commutes for many central urban residents, it has also shortened the commutes of suburban residents (*Gordon et al. 1989*).

As previously noted, mobility and accessibility are related through VMT. Ewing and Cervero (*2010*) report per capita/household VMT elasticities of job accessibility metrics for both transit and auto modes. For auto accessibility the elasticity is -0.20, while for transit accessibility the elasticity is -0.05. Accessibility to destinations by transit depends in part on the extent to which transit is accessible to travelers. Ewing and Cervero's (*2010*) reported per capita/household VMT elasticity with respect to transit access is -0.05.

Multiple use zoning, or land use mixing, facilitates travel by alternative modes and is expected to result in shorter trips. Ewing and Cervero's (*2010*) meta-analysis covers 10 studies employing entropy-based land use mix metrics. They report a weighted mean per capita/household VMT elasticity of -0.09 from the results of these studies.

Connectivity metrics reflect the extent to which travel distances between points can be minimized. The metric in Table 3.1 uses intersection density to represent connectivity, as examined by Chapman and Frank (*2004*). Alternatively, studies have employed metrics using street density to represent connectivity (*Hedel and Vance 2007; Reiff and Gregor 2005*). Six empirical studies employing either an intersection or street density metric were covered in Ewing and Cervero's (*2010*) meta-analysis. Their reported weighted mean per capita/household VMT elasticity from these studies was -0.12.

Ewing and Cervero (*2010*) observe that many of the VMT elasticities obtained in their meta-analysis are quite small, which implies that the land use and urban design features represented by the respective metrics in Table 3.1 have limited v/c consequences. However, they also emphasize that effective comprehensive planning usually produces changes across multiple land use and urban design metrics. They thus note that the VMT elasticity effect of comprehensive planning is additive across the affected metrics. Depending on the land use and urban design outcomes of implemented plans, this composite VMT elasticity could be large. For example, transit oriented development (TOD) combines a number of travel-reducing and alternative mode-favoring measures, including higher development density, mixed use zoning, good transit access, enhanced transit supply, and parking maximums. Cervero and Arrington (*2008*) recorded weekday vehicle trip generation (from cordon counts) in 17 TODs located in five metropolitan areas. Overall, their recorded trip generation rates were 44% lower that the rates reported in the ITE *Trip Generation* manual (*ITE 2003*). Their study included five Portland TODs, and trip generation rates for these developments were 41% below the ITE rate.

Parking availability and cost are strong determinants of mode choice, especially for work trips (*Cervero 2005; Strathman and Dueker 1996; Willson 1991*). Cities are slowly moving away from enforcing minimum parking requirements on new development in core areas in an effort to promote transit use and improve air quality (*Dueker et al. 1998; Kuzmiak et al. 2003*). Kain (*1994*) concludes that such policies and regulations ought to be in place before congestion pricing is considered.

Park and ride facilities dedicated to transit are often employed to attract heavy and light rail "choice" riders with longer commutes. Given the greater spacing between rail stations, park and ride lots allow commuters to access transit by auto where conditions for providing feeder access by bus are impractical or uneconomic (*Turnbull et al. 2004*). Park and ride facilities can also serve as a staging location for car or vanpooling activity. The main highway performance benefit of these facilities is the reduction in congestion on routes leading to rail destinations, typically urban core commercial centers. The propensity to choose commuter rail is adversely affected as lot utilization approaches saturation, and is also adversely affected by the pricing of lot use (*Turnbull et al. 2004*).

Similar to the TOD example, transportation demand management (TDM) programs commonly include features represented by multiple metrics. For example, TDM measures may extend to the adoption of parking maximums and market pricing of parking, extension of employee transportation benefits beyond employer-paid parking to provision of transit passes and bicycling facilities, and provisions for telecommuting and guaranteed rides (*Kuzmyak et al. 2010*). In combination, these TDM features have contributed to increased use of alternative modes and reductions in congestion.

3.2.4 Safety Metrics

Safety is an important transportation objective in its own right. Crash rates disaggregated by mode, type, severity, and road class are typically included among highway performance measures. Research shows that crash rates increase substantially as traffic flow approaches saturation (*Dickerson et al. 1998; Golob et al. 2004*). One would expect fatal/severe injury crash rates to be lower in congested than in free flow conditions (given reduced speeds), but the corresponding evidence is mixed (*Wang et al. 2009*). With respect to highway performance, higher crash rates contribute to an increase in the incidence of non-recurring congestion, thus worsening reliability.

Safety is also important for transit, although crash rates among transit modes are well below the rates for passenger and commercial vehicles (*APTA 2009*). Alternatively, transit rider surveys find that personal safety on vehicles and in the vicinity of stops and stations is an important customer concern (*Potts 2002*). Although it is generally accepted that the incidence of crime negatively affects the demand for transit (*Needle and Cobb 1997*), empirical studies documenting this relationship are lacking. Thus, the empirical relationship between this metric and v/c is uncertain.

3.2.5 Infrastructure Metrics

Given that highway capacity is directly represented in v/c, an increase in lane-miles can be expected to reduce v/c. However, capacity improvements can also increase subsequent traffic volumes at both the system and facility levels by releasing latent demand and by altering route choices. Cervero (*2002*) surveyed empirical studies of latent demand responses to capacity increases and found associated long run VMT elasticities ranging from .3 to .6.

Table 3.1 does not identify infrastructure metrics representing capacity improvements for site-specific facilities, such as intersections and interchanges. Clearly, such improvements enhance mobility, reliability and safety. However, individual metrics would be unable to adequately represent multiple capacity-related design elements of such facilities (e.g., ramp/overpass capacities, signalization, and access control features of interchanges). Generally, given specific design information about a facility improvement, a metric or set of metrics could be identified to represent a change in facility capacity. Thus, rather than attempt to identify a list of metrics that could potentially be employed across varied site-specific design contexts, we note that metrics exist to represent site-specific facility capacity changes.

Transit supply (capacity) can be represented by revenue hours or revenue miles of service. Generally, transit demand is more responsive to supply than to fare changes. Demand elasticities related to supply changes vary by transit mode, base level of service, area economic conditions, and operating/price conditions of non-transit modes. A literature survey by Evans et al. (*2004*) found transit supply elasticities ranging from .3 to 1.5. Thus, transit supply is inversely related to v/c.

Miles of striped bicycle lanes serve as one proxy for bicycle infrastructure capacity. Pucher et al. (*2010*) reviewed 19 empirical studies relating bicycle use to the supply of bicycle lanes. Results of these studies were mixed, with some reporting a significant positive relationship between capacity and use, and others finding no relationship. Given that a positive relationship exists, another issue concerns the extent to which increases in bicycle use substitute for the use of other transportation modes. If the principal substitute for bicycle use is transit, for example, the consequent effect on v/c would be negligible. Evidence of modal substitution effects in this context is lacking. For these reasons, the empirical relationship between bicycle lane miles and v/c is characterized in Table 3.1 as uncertain.

Deployment of ITS technologies has resulted in a variety of highway operations benefits, affecting commercial vehicle mobility (in preclearance and automatic vehicle location systems applications), incident management, traffic management (in signal control systems and ramp metering improvements), and traveler information (in real time navigation systems and in the reporting of traffic and other conditions). Traveler information can help to mitigate the effects of non-recurring congestion by influencing route choice and trip scheduling decisions. Mannering (*1989*) found that route choice decisions were highly sensitive to information about changes in relative travel times, while trip scheduling decisions were much less sensitive. His latter finding likely reflects the real and implicit penalties that travelers face in altering their travel schedules, especially for work-related trips (*Noland and Small 1995;Small 1982*).

A basic difference in ITS deployment in the transit industry is that vehicles are primarily being instrumented rather than facilities. Data from automatic vehicle location systems are used to produce more reliable transit schedules and are also used in real time applications, such as in broadcasts of predicted vehicle arrival times at stops and stations. Both the improvements in schedule reliability and reductions in customer waiting time uncertainty have positive consequences for transit demand and customer satisfaction (*Bates et al. 2001; Furth et al. 2006; Strathman et al. 2008*). Through the resulting increases in ridership, ITS applications in the transit industry have thus contributed to reducing v/c.

3.2.6 Energy/Environment Metrics

Both energy use and emissions are end consequences of VMT, and actions that have been taken to affect either metric have had varying effects on v/c. Nevertheless, these metrics have been included because they are considered to be among the best examples linking transportation performance measures to benchmarks, and, in turn, relating performance to economic sanctions and resource allocation decisions (*Stecher et al. 2010*).

With respect to energy efficiency, the corporate average fuel economy (CAFÉ) standards first authorized in the Energy Policy and Conservation Act of 1975 have, over the past three decades, established progressively higher efficiency benchmarks that must be met by auto manufacturers. Failure to meet the CAFÉ standard results in a penalty ($5.50 per vehicle per .1 mpg exceeding the standard) that the manufacturer must pay. Between 1975 and 2008 energy use per vehicle mile for automobiles and light trucks has fallen 39% and 42% respectively (*ORNL 2010*), at least partly in response to the CAFÉ standards. Also, given that emission of carbon dioxide (a primary greenhouse gas) is a direct function of fuel consumption, the CAFÉ standards have also produced climate benefits.

The CAFÉ standards have been criticized because they have had little effect on VMT trends (*Greene 1998*). Critics argue that energy efficiency improvements could have been achieved by increasing the gas tax and that, unlike CAFÉ standards, a gas tax would have also reduced travel demand. While Greene (*1998*) agrees with this argument in principle, he also observes that strong public resistance has made a gas tax increase (sufficient to achieve the same efficiency improvement) a much less viable alternative.

The Clean Air Act Amendments of 1990 set more rigorous transportation modeling requirements for areas that are out of compliance with EPA air quality standards. The amendments required the use of enhanced modeling to demonstrate that transportation improvement programs are facilitating progress toward compliance in nonattainment areas. Moreover, nonattainment areas must demonstrate progress toward compliance to qualify for federal transportation funds. Thus there is a strong economic incentive for affected improvement programs to emphasize a mix of VMT-reducing and congestion-relieving projects. Separately, the federally-sponsored Congestion Mitigation and Air Quality Improvement Program (which covers both maintenance and nonattainment areas) has also resulted in an emphasis on VMT-reducing transportation improvement projects to improve air quality (*TRB 2002*).

3.3 USE OF SUPPLEMENTAL METRICS: CONTEXTUAL ISSUES

The metrics presented in Table 3.1 vary across several dimensions--value basis, spatial and temporal resolution, and usefulness for different types of evaluation. Some metrics, such as the v/c ratio, are clearly appropriate for evaluating operational performance. Such metrics can be appropriately analyzed at the facility level. Viewed in isolation, however, they cannot directly account for the performance of other facilities and other travel modes. Other metrics, such as "accessibility to destinations," are clearly more appropriate for evaluating system performance and the achievement of system planning objectives. While such metrics employ system-level measurement and can directly consider multiple modes, they also can obscure potentially important facility level effects. Thus, there are obvious tradeoffs in metric perspectives. At one end, focusing on an individual facility may ignore the need to address system-wide objectives. At the other end, focusing on system-level performance may come at the detriment of ignoring performance on selected facilities.

Evaluating comprehensive plan amendments is particularly difficult because it can encounter the need to reconcile issues involving these two extremes. Plan amendments are typically proposed to advance system-oriented goals, such as economic development or compact development.

However, these amendments may have both system level and local effects on specific transportation facilities. Ideally, when evaluating plan amendments, a natural approach would be to develop a scoring system whereby metrics designed to represent system performance and system-planning goals could be weighed against metrics designed to represent facility performance, first and foremost v/c ratios, but potentially other facility-oriented metrics related to mobility, reliability and safety. Taken to its logical outcome, such a multi-objective multi-metric scoring system would require a set of weights and/or threshold values that would produce a composite score or rating. If this ideal scoring system were to yield a net detrimental rating, actions would need to be taken to mitigate the projected decline in composite performance.

3.3.1 Important Caveats

Three cautionary limitations should be considered in determining whether and how to use certain metrics in an evaluation process: (1) the problem of unbounded metrics; (2) the problem of linkages between a particular metric and other system elements (which may or may not be measured as part of an evaluation process); and (3) assignment of causality to outcomes.

The problem of unbounded metrics is most intuitively characterized by the assumption that "more is always better," which ignores the existence of diminishing marginal returns (benefits), or even the possibility of negative net benefits occurring. For example, provision of bike infrastructure such as bike-lane striping is generally assumed to be a positive attribute. Thus, an agency could propose striping miles-and-miles of bike lanes and claim this as a mitigating factor in a plan amendment projected to worsen v/c ratios on local facilities. In this instance, the presumption would be that more bike lanes would reduce auto trips and provide a safer bicycling environment; however, this metric provides no information on either of these purported outcomes. Mere provision of bike lanes does not guarantee a fixed, proportionate response in bike ridership, nor does it say anything about latent demand for bicycling or what proportions of trips would be diverted from autos, transit and walk modes. Moreover, there would be diminishing returns to striping bike lanes, particularly in areas where demand is likely to be low. Information on existing and potential demand would be necessary to determine the true effects of bike-lane striping. If a more thorough analysis revealed that most of the gains in bike ridership were likely to come at the expense of transit patronage rather than auto usage, there could actually be net negative benefits. Mode diversions and safety effects from the provision of bike lanes would need to be assessed separately. The same would be true for other metrics in which it is assumed that more is better, including freeway lane miles with ITS, total freeway lanes miles, and transit supply. Thus, metrics related to the provision of infrastructure capacity are insufficient measures of the real outcomes of interest, even though they might be an input to the calculation.

The linkage problem is one in which given metrics are inextricably tied to other processes and system elements, as is the case with transit-oriented development. These processes and elements could include the presence or absence of complementary land uses and transportation system elements, as well as socioeconomic and market factors. Some of the metrics found in Table 3.1 include land use mix, population and employment density, accessibility to destinations, accessibility to transit, street network connectivity, and bike and pedestrian network circuitousness. Each of these metrics is individually assumed to have a positive effect on auto travel reduction, and a greater amount of each is assumed to result in a greater reduction. Thus, they are also subject to the more-is-better way of thinking. There is also a concern that rates of trip reduction commonly ascribed in the literature to these individual factors were estimated under conditions in which there were strong complementary forces at work.

The degree to which, say, greater densities result in a reduction in auto travel also depends on the provision of attractive alternatives, both in terms of destinations and travel modes. For example, a city could propose re-zoning to accommodate a 20-story high-rise office tower with ground-floor retail in a suburban location that is not well-served by transit, claiming an offsetting density credit. Without the support of enhanced transit options, however, this type of development would not lead to a reduction in auto trips compared with lower-density development, quite the opposite in fact.

Similarly, mixed-use residential and commercial development may not provide much in the way of trip reduction if residents are unlikely to work or shop nearby or if the development is likely to attract many trips from elsewhere, all of which will depend on the type of retail, resident incomes, auto ownership levels, and the attractiveness of competing destinations. Further, a large residential-commercial mixed use development is more likely to be a significant regional attractor in a smaller city where its commercial component faces less competition, while the same development would likely have a more beneficial impact on local auto traffic in a larger metropolitan area where its market area is more localized.

The point of discussing the linkages problem is that certain metrics may represent necessary but insufficient conditions for claiming offsetting mobility credits. Indeed, given the complexity of the land use and transportation relationships under consideration, it would seem that any of the metrics listed in Table 3.1 under the land use category might prove to be an imprecise predictor of auto travel reduction across varied circumstances. Instead, it is recommended that metrics related to the travel-behavior-related outcomes desired from land use changes be measured directly, such as changes to auto trip-length distributions and shifts to non-auto modes.

The causality assignment problem is closely related to the linkage problem. A prime example of this would be metrics such as accessibility to employment or population (e.g., *Cervero 2005*), weighted by an impedance function of mode-specific travel times or by composite costs (i.e., log-sums). This is also an unbounded measure in which more is usually assumed to be better. Mathematically, an increase in accessibility can result from reduced travel costs or an increase in attractions (e.g., number of jobs); however, it tends to work out that an increase in attractors will have a larger effect on accessibility scores than a change in travel costs. Thus, a plan amendment could show an improvement in accessibility even if it would result in slightly greater travel times across multiple modes, just because more attractors have been added. This occurs because the marginal impact of each new attractor unit (e.g., job) is greater than the marginal impact of that job on travel costs. The job is counted in the attraction scores of every TAZ, whereas the trips produced by that job are diffused across the network and modes. This kind of ambiguity may be avoided when accessibility metrics are related to defined locations in which the magnitude of attractiveness is held constant while travel costs to reach these destinations is allowed to vary (e.g., *Reiff and Gregor 2005*).

Another example of mistaken causality relates to reliability, in which a lower score for certain metrics is usually assumed to be better. When a particular highway facility routinely reaches a saturation level, then by definition this can actually make the facility seem more reliable than under lower-demand driving conditions. That is, it can become reliably slow moving, and an improvement in reliability metrics, such as the coefficient of variation and the buffer index (which normalize travel time variability by average travel times) can mask real problems. Thus, a plan amendment that would put more traffic on an already saturated facility could actually show an improvement in these reliability scores compared with a baseline case, even though the v/c ratio would worsen. Under certain ranges of input values, metrics such as these that can provide misleading indicators of system or facility performance and therefore may be less reliable indicators of truly beneficial outcomes. Other metrics, however, such as the planning time index (which normalizes the 95th percentile travel time by free-flow times) are likely to provide a more stable measure and should be preferred on this basis.

3.3.2 Need for Modeling

One implication of the limitations discussed above is that supplemental performance metrics should reflect outcomes to traveler behavior, rather than concomitant conditions commonly associated with certain patterns of travel behavior. Secondly, there are important linkages between land use and transportation supply and demand, and these linkages conspire to change travel behavior. Thus, predicting travel behavior changes due to plan amendments requires careful consideration of known linkages. Network-based urban travel demand models offer the only obvious tool that can account for such complexity systematically and consistently to produce outcomes of interest for comparison with v/c ratios.

The third theme discussed in Section 3.3.1, that some metrics can produce ambiguous results under certain conditions, should serve to guide selection of outcome metrics by favoring those metrics that offer stable, unambiguous interpretations. Simulations using a travel demand model can help to identify which metrics provide consistent and stable interpretations.

Lastly, a distinction needs to be made between using a travel demand model to explore effects and trade-offs among supplemental performance metrics, and using such a model to support regulatory decisions. The present project is oriented toward the former objective. Hypothetically, while the latter objective is potentially achievable, it would require further consideration of issues related to the standardization of model structures and modeling protocols. Consideration would also need to be given to the treatment of local circumstances where a transportation demand model does not exist.

3.3.3 Facility Utilization and Network Efficiency

Efficient utilization of transportation facilities, with respect to both baseline and projected conditions, should also be part of the discussion of supplemental metrics. All else being equal, a plan, project or policy that promotes efficient utilization of existing assets, be they highway, transit or non-motorized facilities, should be viewed favorably and could offset to some degree the negative view of high roadway v/c ratios. The way this might occur in a plan amendment context would be a situation in which there is area-wide congestion and the proposed change would shift traffic patterns such that roadway v/c ratios closest to the subject site are made a little worse, while v/c ratios in nearby congested parts of the network are improved. If total network travel time is made better in the aggregate compared with the base case, then a plan amendment would lead to an efficiency improvement if it promotes more consistent utilization of existing assets. From a least-cost planning perspective this may be interpreted as load balancing across facilities.

By focusing only on locations where v/c worsens while ignoring locations where v/c has improved, plan amendment evaluations may not recognize changes that yield net benefits to the system as a whole. Ideally, a network-wide efficiency metric would document net performance changes for both state and local transportation facilities. Systematic network-based travel demand modeling would be needed to predict the underlying shifts in travel patterns, which are ultimately expressed by the metric of total network vehicle travel time.

Network efficiency evaluation could be extended to a multi-modal framework by measuring changes in total network travel time across all modes. From a least-cost planning perspective, this approach would consider load balancing across modes. The key here would be to determine whether a projected outcome will result in a more efficient multi-modal utilization pattern, and the most direct way to measure that would be changes in person hours of travel.

3.4 SUMMARY DISCUSSION

The literature review has identified a set of transportation performance metrics that could potentially serve as supplements to the v/c metric defining the OHP mobility standards. A brief appraisal of the metrics has been provided, focusing mainly on reported evidence of the empirical relationship between these metrics and v/c, the current mobility standards metric. More general considerations related to the use of the supplemental metrics in evaluating facility and system performance are also discussed. Subsequent work will include selection of supplemental metrics for further analysis using a travel demand model.

Several general conclusions can be drawn from this review. First, the literature shows that there has been a substantial commitment to transportation performance measurement at the state and federal levels in the United States. The list of metrics used or suggested is extensive. Yet, there is also evidence that performance measures are often not directly or clearly related to outcomes that are important to transportation policy makers and the public. Thus, transportation performance measures have sometimes been found to be failing with respect to accountability. In the present case, v/c represents the outcome of interest and it will be necessary to clearly establish empirical relationships to this outcome for given metrics to serve as supplements. Apart from serving stakeholder accountability, clear empirical linkages between v/c and supplemental metrics is needed to ensure legal defensibility of ODOT decisions under the TPR.

Second, in selecting v/c to represent the OHP's mobility standards, ODOT evaluated a number of metrics (including some covered in this review) against such criteria as consistency, data availability, forecastability, transparency/understandability, modal neutrality, and complementarity with other OHP policies. It also anticipated a need for flexibility. Generally, the metrics included in the present review have the ability to reinforce the performance of v/c against these evaluation criteria. The metrics' most useful contribution, however, may be in facilitating greater flexibility in implementing the OHP mobility policy. This seems particularly evident with respect to the potential contributions of the land use, urban design, and alternative mode metrics, for which empirical evidence of mobility outcomes is fairly strong and for which modeling opportunities appear promising.

This literature review has focused on supplemental metrics that could potentially serve OHP Policy 1F (*Highway Mobility Standards*). In selected instances, the metrics also relate to other OHP policies, including Policy 1A (*State Highway Classification System*), Policy 1B (*Land Use and Transportation*), Policy 1C (*State Highway Freight System*), and Policy 1G (*Major Improvements*). Thus, the usefulness of the supplemental metrics presented in this review will, in part, depend on their contributions to various OHP policies. For example, reliability metrics may provide important information in assessing the effects of given actions on Policy 1C.

One of the potential benefits of the use of supplemental metrics in implementing the plan amendment provisions of the TPR will lie in their ability to serve as a bridge linking Policy 1F and other OHP policies. This bridging role can be realized by gaining a better understanding of the functional relationships among metrics. Thus, an important purpose of subsequent modeling activity in this project will be to examine and document these functional relationships. Such effort should be distinguished from the need to identify performance metrics that specifically address each OHP policy. This latter need has been the focus of previous work (*Reiff and Gregor 2005*), which identified a large inventory of possible metrics and analyzed a selected subset.

Lastly, returning to Brown's (*1996*) observation that the most successful performance measurement systems limit their attention to a "vital few" indicators, a case could likely be made for the need to maintain an extensive portfolio of metrics to supplement v/c. However, it should be a goal to make the size of the portfolio as small as possible. Maintaining a limited number of supplemental metrics would help to ensure that the resulting performance measurement system would still reasonably satisfy the criteria that previously favored v/c as the preferred metric, and would also help to avoid a "trivial many" outcome.

4.0 ANALYSIS OF MOBILITY METRICS

The objective of this chapter is to demonstrate the potential for using various mobility metrics that might provide insight into the extent to which a large-scale land use change proposal meets selected goals expressed in the OHP. The intent is not to specify a single set of metrics that would apply in all cases. Rather, the aim is to explore the information content of these various metrics, how they co-vary with changes in inputs and spatial scale, and their ability to "tell a story" about the transportation performance impacts of a proposed land use change.

It is expected that the results of this analysis will be used to inform the selection of alternative mobility metrics by the appropriate policy boards or as a component of the transportation system planning process. Further, while the methods developed to derive and assess the metrics are model-based, it envisioned that they could be applied using tools that do not necessarily require the use of models. The final section of this chapter will provide recommendations for implementation of the analytical methods used to construct these metrics, some of which do not require the analyst to run a full-scale travel demand model.

4.1 METHODOLOGY

The approach followed to studying the selected mobility metrics is to perform a model-based case study on a land use change scenario that has actually been previously evaluated by ODOT. This has the advantage of providing a realistic context within which to systematically evaluate alternative metrics. By utilizing behaviorally-based travel demand models, we have the ability to rapidly test alternative input assumptions and to obtain measurable outcomes.

The case study selected for analysis, the Northgate commercial center in Medford, Oregon was recommended by ODOT because it was centrally located within the urban area, well-served by public transit, and close to an interstate freeway interchange. Northgate was proposed as a mixed non-residential development, composed of office, retail and a small amount of industrial uses. In addition, the proposed development included a trolley service that would provide internal circulation within the site, the idea being to promote travel within the site and not on the surrounding roadway network. As described below, a set of nine metrics is selected and tested through four model scenarios:

- 2010 Baseline
- 2010 Northgate
- 2025 Baseline
- 2025 Northgate

The analysis compares the outcomes obtained for each metric between no-build and build scenarios, and between opening year (2010) and future-year (2025) scenarios. Thus the modeling rationale is to predict the impacts of the proposed development both now and in the more distant future and to isolate those impacts from the natural growth that would occur in the urbanized area over time. In addition to these comparisons, sensitivity analyses are performed in which one of the build scenarios (2025 Northgate) is modeled under varied land use input assumptions, moving the location of the project within the study area and varying its magnitude.

4.2 SELECTION OF METRICS

The overarching goal in selecting metrics for further analysis is to provide empirically grounded, reliable support for considering mobility metrics. This requires a set of metrics that encompass policies directly or indirectly related to mobility in the OHP, yet be fairly few in number to avoid redundancy and potentially ambiguous interpretation. Accordingly, the metrics presented in this chapter have been selected using criteria most likely to achieve those aims and are limited to a "vital few" indicators, with some metrics supporting multiple policy objectives. Since roadway v/c ratios have been the basis for administering the OHP's mobility policy, v/c is included in the set of metrics selected and will be the basis for comparison with other metrics.

4.2.1 Criteria

The criteria used for the selection of metrics were based on a review of literature on mobility performance measures as well as communication with this project's technical advisory committee (TAC).The selection criteria are as follows:

- The metric must provide evidence of a change in travel activity that relates directly to one or more OHP policies, or the goals and policies typically found in an adopted transportation system plan (TSP).
- The metric must provide evidence of a change in travel activity that can be empirically linked in theory, if not empirically, to a stimulus resulting from a particular change in land use, socio-economic composition, or transportation system supply characteristics. A theoretical linkage may be demonstrated through a validated regional travel modeling system in which a variation in the input under consideration leads to a change in the output metric under consideration.
- The metric should be robust. It should provide consistently plausible, interpretable results over the range of potential input values.
- Each metric in the set of metrics should provide information on a distinct aspect of travel activity and, ideally, complement other metrics. This is important not only for avoiding redundancy and potentially conflicting interpretations of outcomes, but also for representing as many relevant policy perspectives as possible.
- Each metric should have the ability to be forecast using well-established methods and readily available, consistently measured and applied input data. Forecasting methods and input data include those commonly used in urban and regional travel demanding modeling systems and in traffic impact assessment practices.

- The set of metrics should incorporate measured changes in travel activity across all travel modes and travel markets, including private auto, public transit, pedestrian and bicycle, and commercial truck travel.
- The set of metrics should include both measurements of facility-specific performance and measurements of network and area-wide performance. Facility-specific metrics are important for operational analysis, whereas network and area-wide metrics are important for evaluating effects on potentially competing policy objectives and for impacts across multiple modes.
- The set of metrics should not include measurements of related non-travel activity measurements, such as direct measurement of local or regional economic impacts, environmental impacts, or safety impacts. While economic, environmental and safety impacts are often of vital public interest, such impacts require a different and additional set of analysis tools, assumptions, and expertise beyond those likely to be employed in a land use plan amendment review process. However, the set of metrics should provide a general indication of whether travel outcomes will make a positive or negative contribution toward economic productivity, the natural environment, and safety.

4.2.2 Description of Selected Metrics

In consideration of the criteria discussed above as well as the recommendations of the TAC, the following metrics were selected for further study. The list below describes each metric and the logic behind its selection.

Network-wide V/C

Given the central focus of v/c in the land use change review process, as currently formulated, it is important to consider how v/c ratios change between scenarios network-wide. Typically, traffic impact analyses that are commissioned by municipalities will consider only facilities that lie within that municipality's boundaries, as was the case in the 2006 TIA prepared for the City of Medford (described below). ODOT may request that other facilities within their jurisdiction also be evaluated, but this is typically limited to interstate and state highways. Further, the engineering focus of TIAs tends to be on facilities that are expected to provide a degraded level of service under a proposed project, ignoring facilities that might actually improve relative to baseline conditions.

Thus changes to v/c ratios are examined throughout the entire modeled region, with the motivation being to determine whether the facilities considered in the TIA are the only ones in the region that exhibit significant changes in v/c, or whether other locations in the region would also experience significant impacts. An additional objective is to look for compensatory effects—whether there are links in the network where v/c actually improves due to the redistribution of traffic engendered by the land use change.

Total Vehicle Hours/Miles of Travel

The total amount of time that vehicles spend on the network is an important metric from the perspective of total delay experienced by all drivers on the regional highway network. Total vehicles-miles traveled (VMT) is a closely related metric, also examined below; however, VHT has more explanatory power due to this ability to represent system-level delay. In addition, OHP goals to reduce vehicle emissions are directly related to vehicle-hours-traveled (VHT) on roadway networks. VHT is a system-wide metric that accounts of the travel time of all passenger and commercial vehicles on the network. The amount of time that individual travelers spend in transit vehicles is also considered, more from the standpoint of congestion-induced delay than from emissions, since it is assumed that transit vehicle run times are fixed by their schedules.

Total network travel time for vehicles on the highway network is related to v/c in the sense that the more links in the network that have high v/c ratios, the greater will be the delay and increased time on the network. On a system-wide level, however, while v/c on some facilities may increase for a particular scenario, that may be offset by lower v/c on other facilities, with the potential for a net reduction in VHT. From an efficiency perspective, if a particular project or plan were to result in better overall network travel time, then it may be preferred even if individual facilities are adversely affected. This of course does not rule out mitigation where egregious level-of-service conditions exist.

Person Hours of Travel Time

From a multimodal perspective, it is important to consider not just vehicle travel times, but also the total travel time experienced by all persons, irrespective of travel mode. This metric addresses the total travel welfare of all users of the system and has the potential to reveal compensatory effects. It differs from vehicle trips because it counts the travel time of drivers and passengers separately. In addition, total person hours of travel (PHT) accounts for the time spent by individuals walking, bicycling and using public transit. For example, it might be possible for auto travel times to increase while transit, bike and walk travel times are decreasing due to the project providing better accessibility to non-auto modes. PHT relates to v/c at a system-wide level to the extent that facilities with higher v/c ratios will promote longer travel times. One drawback to the computation of PHT in a travel demand modeling system is that it difficult to account for truck trips and trips with one more end outside of the study area, because occupancies for these trips are unknown. Thus, in this study, PHT only represents resident travel within the study area in private vehicles. Commercially-based truck trips and external trips are, however, represented in the VHT metric.

Trip Length Distributions

If a proposed land use change were expected to result in shorter trip distances, the predicted change in trip-length distribution (TLD) should reflect this. Since it is possible that trip-lengths might have a differential impact by mode, we chose to examine TLDs by mode, as well. Plans that aim to provide a more mixed and compact spatial arrangement of land uses would be expected to result in shorter trip lengths. TLD is a direct measure of that change. In addition, knowing TLD changes helps determine the extent to which a change in network-level VHT or PHT is due to a change in the frequency, destinations, or modes of travel.

Mode Shares

If a proposed land use plan change were expected to shift auto trips to transit, walk or bike modes, then the predicted change in mode shares should reflect this. While VHT and PHT provide evidence of changes to total travel times, they do not explain the structural factors leading to change, which could be due to a change in the frequency of trips, the locations of trips (trip lengths), the mode of travel, or more realistically, some combination of the three. By examining mode shares, we can answer part of the question. Moreover, mode shares are a direct measure of the degree to which a plan is likely to achieve OHP goals promoting the use of non-SOV modes.

Regional Accessibility to Employment/Shopping Opportunities

One of the chief arguments in favor of land use changes that promote economic development is that they will provide opportunities for employment. In some cases, a plan change may reflect a geographic redistribution of employment, but not necessarily a change in total regional employment. To the extent that the redistribution results in more efficient travel patterns, net regional accessibility to employment may still increase.

Regional accessibility is typically defined at the zonal level, measuring the ability to reach employment opportunities in all other zones, which is a function of both the number of jobs in other zones and travel time and cost impedances that would be experienced in traveling to these other zones. The farther away from the origin zone, the less attractive is each marginal unit of employment. This is calculated separately for each mode. For example, the accessibility of Zone *i* to employment would be written as:

$$A_i^{emp} = \sum_{j \in J} E_j * f\left(c_{ij}\right)$$

Where E_j is the number of employees in Zone j, and $f\left(c_{ij}\right)$ is an impedance function related to the cost of travel between i and j. The impedance cost, c_{ij} could be calculated from inter-zonal travel distances, travel times by a single mode, or some composite utility. Thus, the ability to reach employment opportunities from Zone i is discounted by the cost of travel from Zone i to all other zones.

This study adapts the estimated accessibility utilities in the Portland Metro modeling system (Kim 2008, 16-17) for both home-based work and home-based shopping purposes to represent the mode-specific impedances for accessibility to jobs and accessibility to shopping opportunities, respectively. Metro's accessibility formulas are simpler and more intuitive than those found the in the RVMPO model system. The resulting impedance functions used in this study were as follows:

Access to Total Employment (Jobs)

Auto:

$$f\left(c_{ij}\right) = \exp(-.03608 * InVehicleTime - .09956 * WalkTime)$$

Transit:

$$f\left(c_{ij}\right) = \exp(-.03608 * InVehicleTime - .09956 * WalkTime - .0576 * InitialWait - .04002 * TransferWait)$$

Walk:

$$f\left(c_{ij}\right) = \exp(-.09956 * WalkTime)$$

Access to Retail Employment (Shopping Opportunities)

Auto:

$$f\left(c_{ij}\right) = \exp(-.0215 * InVehicleTime - .1033 * WalkTime)$$

Transit:

$$f\left(c_{ij}\right) = \exp(-0215 * InVehicleTime - .1033 * WalkTime - .06847 * InitialWait - .0524 * TransferWait)$$

Walk:

$$f\left(c_{ij}\right) = \exp(-.1033 * WalkTime)$$

The treatment of regional accessibility to shopping opportunities is similar to that of access to total employment, the difference being the focus on retail employment as a proxy for shopping opportunities. This is important because it focuses more on off-peak travelers and reflects the interests of both workers and non-workers in meeting daily needs.

Accessibility calculations of this kind are somewhat confounding, because the simple addition of employment to a region will increase accessibility, with the additional travel costs of such added employment having a proportionally smaller impact. To test this further (as described later in the sensitivity tests), a land use change scenario is created in which a Northgate development will be built as proposed in the same TAZs, but then an equivalent amount of employment is subtracted from other TAZs throughout the region. This produces an *Alternative Northgate* scenario with the same total employment as the base scenario. The idea is to demonstrate how the redistribution of land uses around the region might affect regional accessibility as well as other metrics. It also portrays a situation in which it is assumed that the growth attributed to Northgate would have occurred somewhere else in the region, an assumption that could be made in a comprehensive plan.

Local Accessibility to Employment/Shopping (20-minute neighborhood)

This is a similar concept to regional accessibility, but expressed differently and perhaps more simply. Here, the ability of a household in each zone to reach job and shopping opportunities within 20 minutes travel time is calculated for three primary modes: auto, transit and walk.

Travel times are derived from the inter-zonal times predicted by the regional model. Jobs and shopping opportunities are represented as total and retail employment, respectively.

This metric was included to explore the “20-minute neighborhood” concept, a popular paradigm among proponents of "smart growth" policies. This metric assumes that all employment and retail shopping is equally attractive, provided it be reached within 20 minutes travel time. It could prove useful in evaluating other concentrated growth scenarios, such as the “regional centers” concept included in Portland Metro’s long-range growth management plans.

4.3 DESCRIPTION OF STUDY AREA

In this section, the study area is described along with the traffic-impact study (TIA) that was conducted for the proposed Northgate project in Medford (*JRH Transportation Engineering 2006*). The TIA was undertaken in conjunction with a review of the project under the TPR.

4.3.1 Northgate Centre Development Proposal

The Northgate Centre project was proposed as a mixed industrial-retail-office project in central Medford, Oregon. The project site encompassed multiple parcels, some of which were separated by major arterials. Figure 4.1 presents an aerial photo of the study area in which purple pentagons represent the approximate location of the project. Figure 4.2 shows street and highway names in study area. The orange triangles in the figures represent the locations that ODOT analyzed in its 2006 evaluation.

The bulk of the project was bounded by N. Central Avenue to the west; E. McAndrews Road to the southeast; Court Street (OR 99) to the east; and N. Pacific Highway (OR 99) to the north. Another portion of the project, a business park, was located on the west side of Central Avenue, north of OR 238. The proposed project included a 219,300 square foot office park, which could accommodate both professional services and light industrial uses; 417,500 square feet of new retail shopping space; and a 167,000 square foot business park, which could accommodate some combination of general and light industrial uses. Construction of the project necessitated a zone change from industrial to other commercial use.

Importantly, the project was bisected by Rossanley Drive (OR 238), which effectively separated office and retail uses, causing some to question whether it really qualified as a “mixed use” development for the purpose of evaluating its internal-trip-capture rate. Another feature of the project was a proposed free trolley service that would serve as an internal circulator for the project site. The trolley would follow Central Avenue and cross OR 238 at an exclusive at-grade crossing, which provided some credence for the argument that the site would capture many of its trips internally and generate fewer trips on adjacent roadways than would otherwise be expected from a non-mixed-use site.

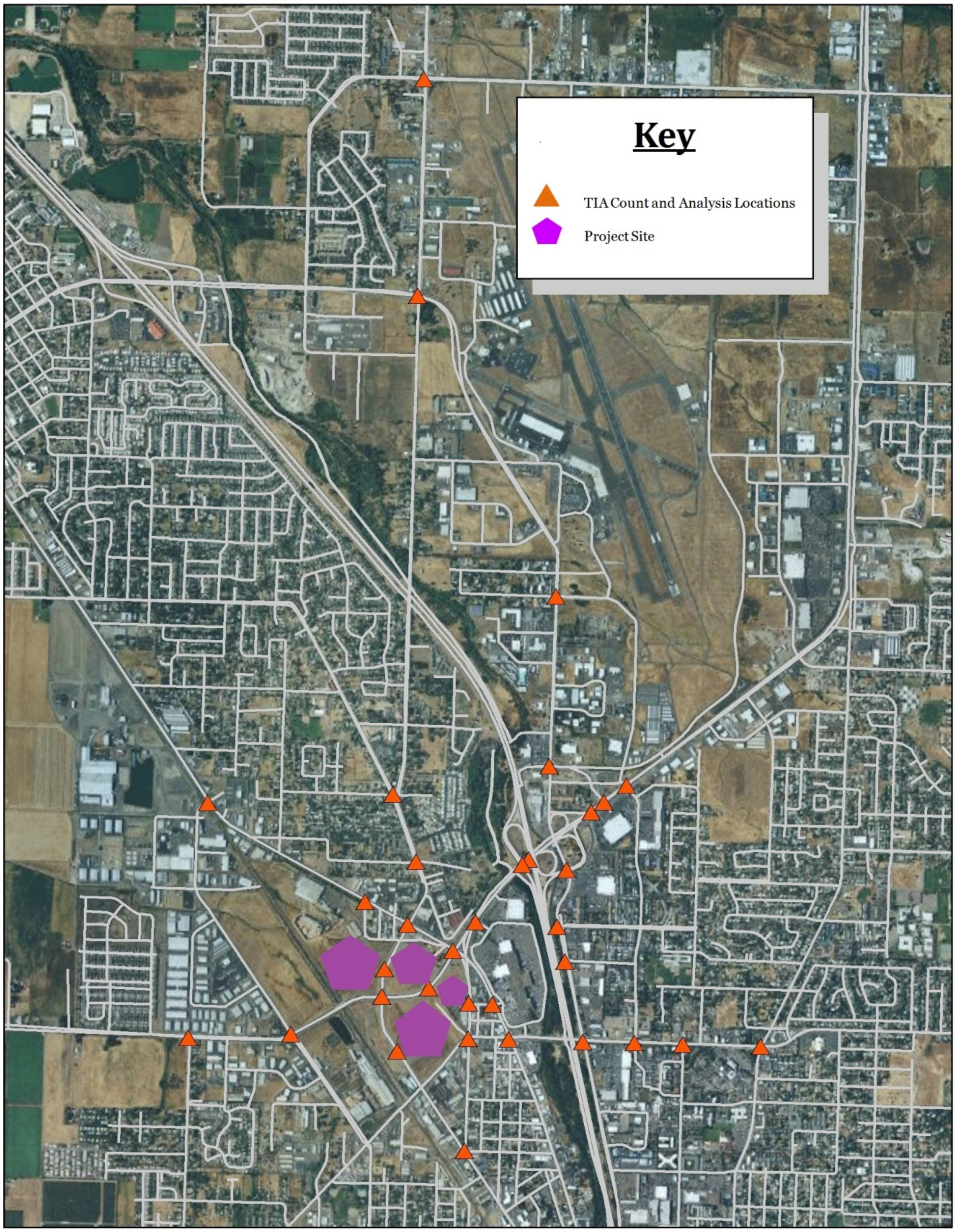

Figure 4.1: Project Site with Locations of Intersections and Other Access Points Analyzed in the 2006 TIA

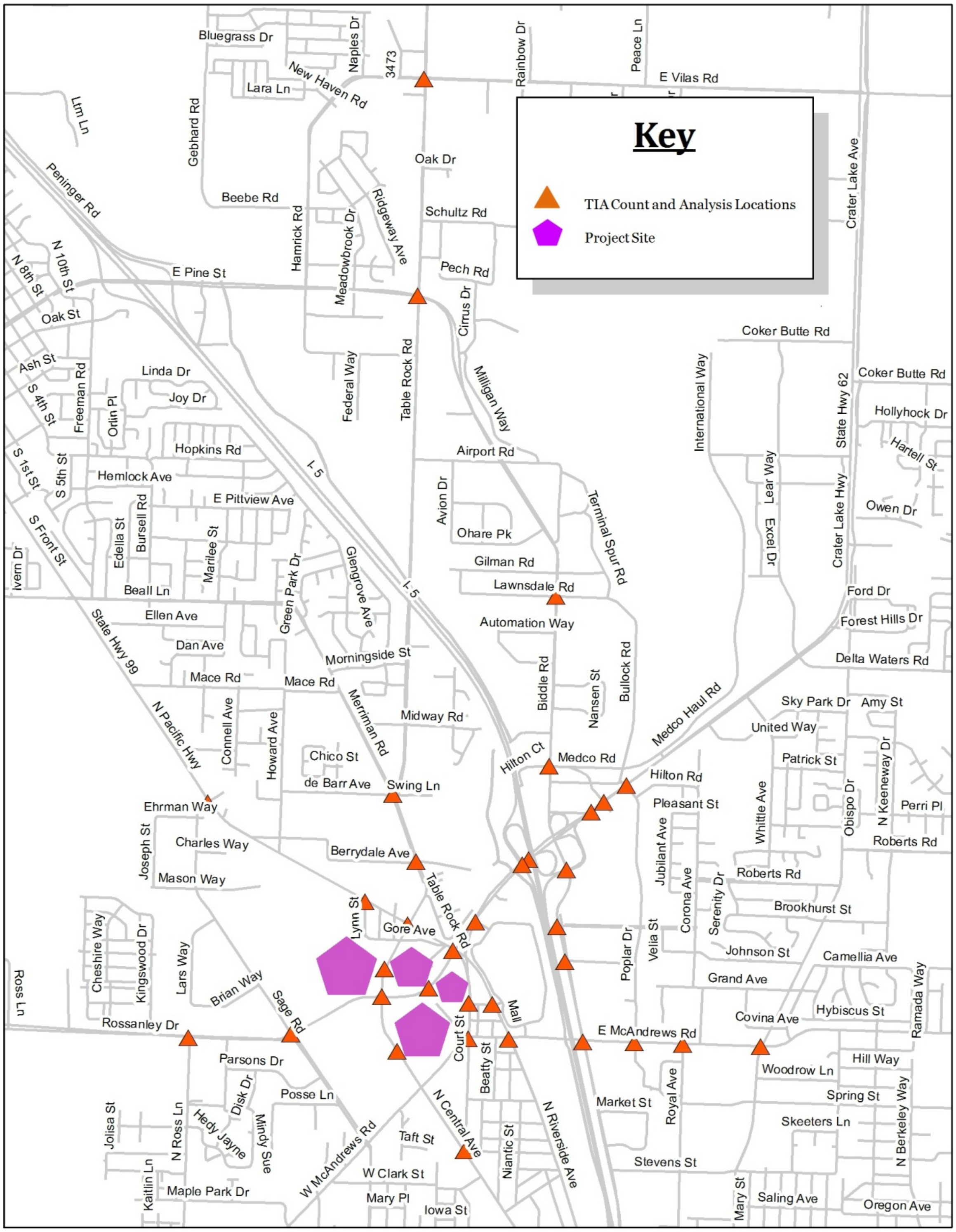

Figure 4.2: Project Site with Locations of Intersections and Other Access Points Analyzed in the 2006 TIA

4.3.2 Summary of Findings from the 2006 Traffic Impact Study

In accordance with the TPR, the City of Medford commissioned a TIA. The TIA focused on 29 signalized and 5 un-signalized intersections surrounding the project site, following recommendations from ODOT. The TIA used the OHP mobility standards of .85 for state-level highways and .90 for district-level highways. In addition, the City of Medford specified LOS D ratings or better as the threshold for all new facilities at the time of project opening. These standards were applied to each turning movement at intersections, considering left-, through- and right-turning volumes. The Medford MPO’s regional travel model, at that time called RVCOG, was used to produce background volumes for both baseline and build scenarios. The way in which v/c ratios were evaluated was to apply the percent change in approach volumes predicted by the model to hourly traffic counts, rather than using the modeled volumes directly. This procedure is consistent with ODOT guidelines.

The TIA found that one signalized intersection and one un-signalized intersection would exceed the OHP mobility standards in both the 2010 no-build and build scenarios. In addition, the TIA found that one un-signalized intersection would exceed the standard in the build scenario only for 2010. For the 2025 analysis, four signalized intersections and two un-signalized intersections were found to exceed the ODOT mobility standards in both no-build and build scenarios, while two signalized intersections and one un-signalized intersection would exceed the standard in the build scenario only.

The implications of these findings were that the developer would either need to provide mitigation or scale back the development to the point where it did not make intersections that were already in violation of the standard worse. Intersections that were not in violation in the baseline scenario but which exceeded the standard in the build scenario would likewise require mitigation or a reduced project in order to satisfy mobility standards. The TIA recommended a comprehensive set of geometric design and intersection control measures that would mitigate problem intersections for the 2025 build scenario.

4.4 DESCRIPTION OF RVMPO MODEL

The regional travel demand modeling system used in this analysis is maintained by the Rogue Valley Metropolitan Planning Organization (RVMPO). The model used in the original (2006) analysis was a slightly different version of the software, but used the same study area land use inputs and network. For this analysis, ODOT's Transportation Planning and Analysis Unit (TPAU) prepared a model setup utilizing versions of the model coding and database that are more compatible with their current modeling platform.

4.4.1 Program Platform

The RVMPO model system consists of two integrated components. The demand components are coded in "R," an open-source statistical programming language, and follow ODOT's "JEMnR" model structure. JEMnR (jointly estimated model in R) is a best-practice trip-based model structure that was developed by ODOT, based on a 1994 household survey by Portland Metro, for use in MPOs around the state. JEMnR's individual components are described in more detail below.

The network supply and matrix data structures are embedded in the commercial software "EMME/2," developed by INRO of Montreal, Canada. For this analysis, a more current version of the same modeling system was used, EMME/3. The original EMME/2 databanks were converted to the more modern EMME/3 format, but all of the original macros used to execute EMME matrix manipulations and network assignments steps were fully backwards-compatible with EMME/2 and required no modification.

The RVMPO model was peer-reviewed in 2008. The version of the model used for this study is "Version 2." Version 2 differs from the first version, which was used in the original Northgate analysis. ODOT developed Version 2 to improve its specification of utility functions for destination and mode choice. After first using Version 1, the study team chose to use Version 2, because it produced mode share results that were more in line with expectations.

The main components of the RVMPO JEMnR model include pre-generation, accessibility calculations, trip generation, distribution, mode choice, and traffic assignment steps. The R scripts interact directly with EMME/3 through an"emme2" library, written in R, and developed by ODOT. JEMnR sends EMME/3 commands to execute EMME macros that create travel time skims and trip tables, and execute highway and transit assignments. JEMnR imports the assignment results and updated travel time skims and uses them to control an iterative feedback process. The feedback process converges to a solution in which the travel times used in the trip distribution and mode choice steps are consistent with those resulting from the network assignment steps. Additional details on model components may be found in the RVMPO model documentation (*Rogue Valley Metropolitan Planning Organization 2008*).

For this analysis it is important to mention that the trips generated in the model are based on the cross-classification model used in JEMnR and its rates, which are based on the number of household and jobs in each TAZ. This is different from the trip rates generated in a TIA, which are based on the size of a specific building type and land use, with rates provide by equations found in the Institute of Transportation Engineers *Trip Generation* manual.

The RVMPO model runs one PM peak period network assignment for highways and one for transit. In addition, the model also runs one 24-hour assignment for highways and one for transit.

4.4.2 Network and Zone System

The RVMPO model network and zone system was provided by ODOT. For the base year, it consists of 759 traffic analysis zones (TAZ), 8671 links and 3016 nodes. Importantly, the modeled networks for 2010 and 2025 reflect facilities that already exist or that were approved in the RVMPO's TSP as of 2006, without the Northgate project. The modeled networks for the baseline and the build alternatives are the same for the same model year, thus only the land use inputs change.

The region is served by the Rogue Valley Transportation District, which, for this analysis, is shown to operate eight bus lines in the region. In addition, it is worth noting that bicycle and pedestrian facilities are not represented separately from highway facilities in the model network. Rather, bicycle and pedestrian travel are assumed to follow roadway network links, with travel time for these two modes a static function of distance.

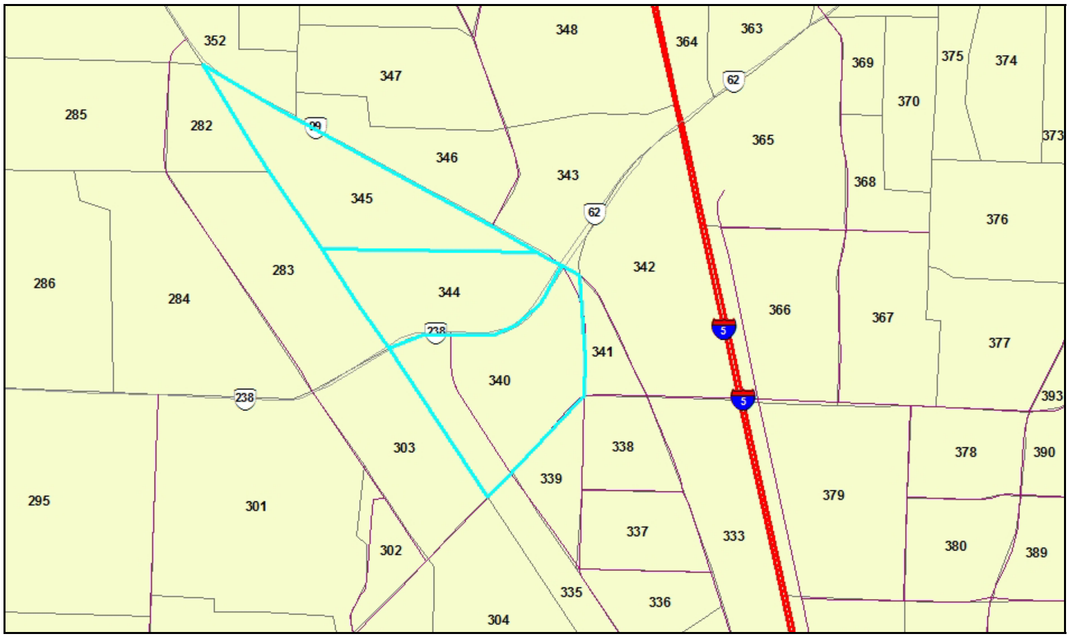

Figure 4.3: Three Modeled Study Area Zones Comprise the Northgate Project

The Northgate site covers three TAZs: 340, 344 and 345, which are outlined in blue in Figure 4.3. The coverage area of the model includes the Cities of Eagle Point, Central Point, Medford, Jacksonville, Phoenix, Talent and Ashland, all located along the Interstate 5 corridor. Figure 4.4 shows the model coverage area, with the TAZs representing the Northgate site highlighted in blue, and Figure 4.5 shows the structure of the travel demand modeling network.

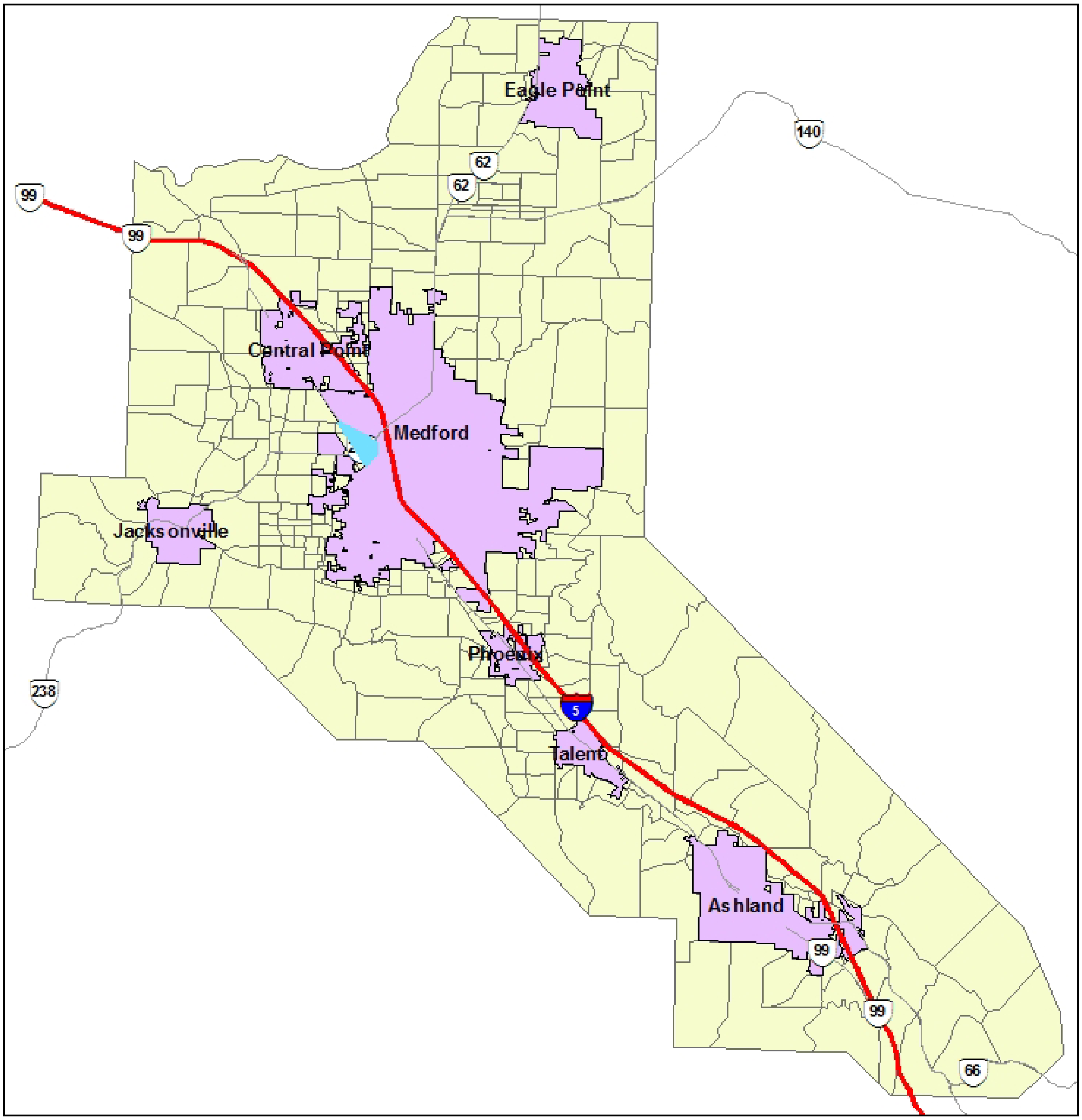

Figure 4.4: RVMPO Region

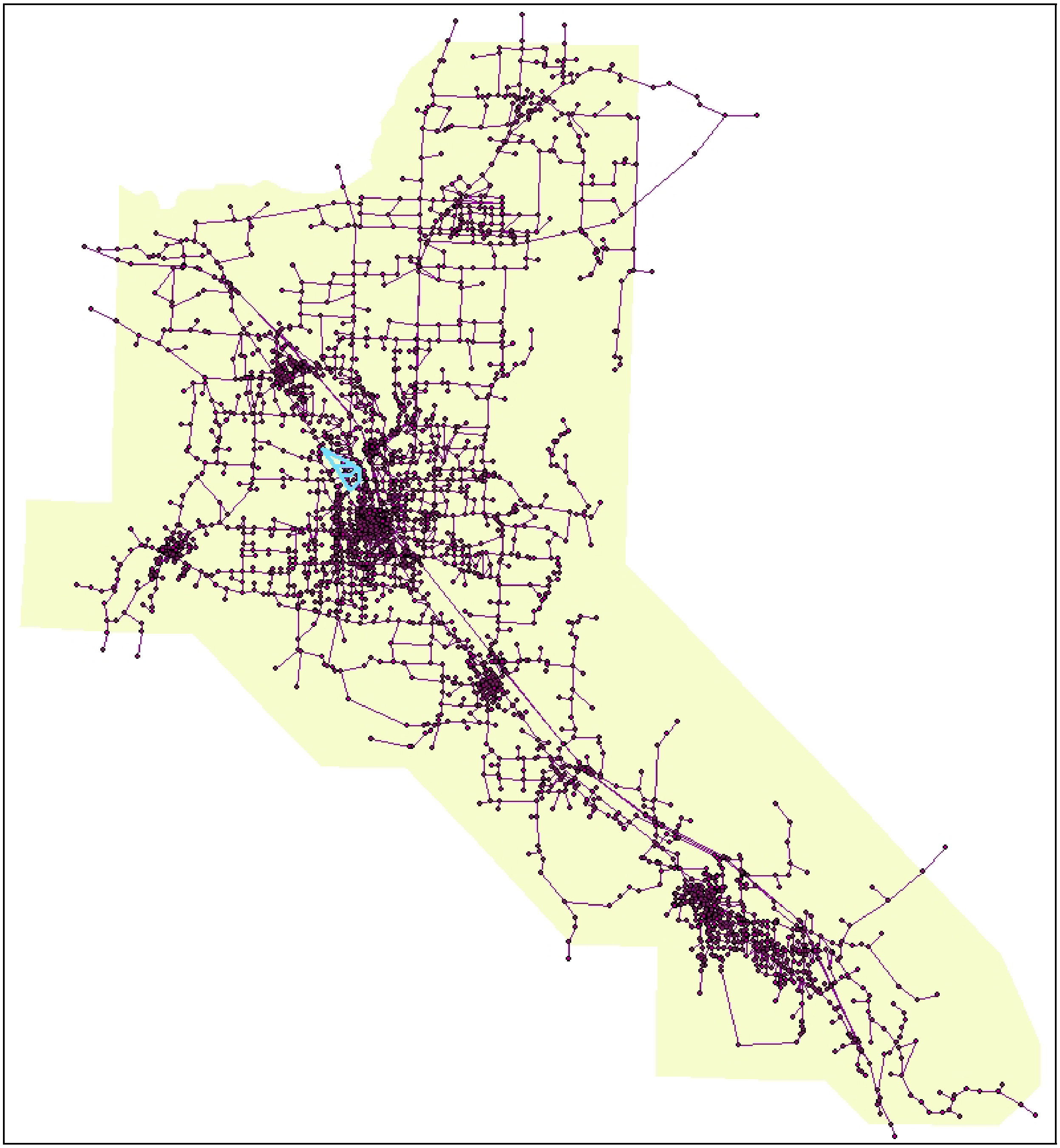

Figure 4.5: RVMPO Model Link and Node Structure

4.5 MODELED SCENARIOS

For the 2006 TIA, the comparison was one in which changes to land use in the three TAZs comprising the Northgate project site were modified to reflect employment that would occur with the Northgate project. This was compared with land use that was expected without the Northgate project. Two scenario years were created: 2010 the proposed year that the project would open, and 2025, a fifteen-year growth scenario. These same land use input and model-year assumptions are adopted for the present analysis.

A fundamental assumption in the TIA was that the employment attributed to the Northgate project was added to the total employment for the area, with a small amount of manufacturing employment removed from one of the TAZs. This means that the Northgate scenarios had 1,878 more jobs in the 2010 scenario and 1,794 more jobs in the 2025 scenario. One alternative for the baseline scenario would be to redistribute the jobs attributed to Northgate to other TAZs around the region, such that the total employment in the baseline scenario matched the total employment in the Northgate scenario under the assumption that the growth would have occurred somewhere in the region anyway. A second alternative would be to let the baseline scenario remain as is, but to modify the Northgate scenario such that the extra employment from Northgate is subtracted from other TAZs in order to obtain the same total employment as the baseline scenario, again the assumption being that the growth would have occurred somewhere else without the project.

For the initial analysis of 2010 and 2025 scenarios, neither of these alternatives is pursued in order to remain consistent with the TIA (which assumed the project would provide additional employment growth). It is common practice in TIAs to simply add a project's contributions to regional employment rather than to assume it would be redistributed from elsewhere. In other land use change evaluations, it is likely that a municipality may make similar assumptions, particularly in more rural areas and small towns where a large development may represent a large proportional gain.

In other cases in which a municipality is contemplating the adoption of a comprehensive plan amendment for growth management purposes, as opposed to a specific development proposal, redistribution of growth may be one stated objective (as is often the case with transit oriented development). In such cases, one would expect land use scenario inputs to reflect this type of redistributed growth. In order to reflect such assumptions, a 2025 Northgate Conserved Growth scenario is created in which the employment gain in the three TAZs representing the project is subtracted from other TAZs around the region, such that the total regional employment remains the same as in the 2025 Baseline scenario. The subtractions were drawn from other TAZs in proportion to existing employment in those TAZs of the same industry type as Northgate. The conserved growth scenario results are included as one of the sensitivity tests.

4.5.1 Baseline 2010

The 2010 Baseline scenario was prepared using an allocation of (then) future land use prepared by RVMPO for the year of project opening. The households and employment in each zone represent what would have occurred without the project. The total population for the region was projected to be 172,216, and the total employment for the region was projected to be 72,581. The households, population and employment in each of the project area zones are shown in Table 4.1 below. The travel model network should be consistent with known facilities for 2010.

Table 4.1: 2010 Baseline Scenario Households, Population and Employment for the Project Area

			Employment						
TAZ	Total Hhld.	Total Pop.	Total	Manuf'g.	Wh'lsale Trade	Retail Trade	Finance	Services	Other
340	0	0	505	337	0	68	100	0	0
344	0	0	0	0	0	0	0	0	0
345	4	9	228	164	7	40	6	11	0
Sum	4	9	733	501	7	108	106	11	0

4.5.2 Northgate 2010

The 2010 Northgate scenario starts from the baseline scenario for that same year and maintains the same network facilities. The land use inputs for the three TAZs that comprise the Northgate project were modified as follows:

- 888 new service jobs were added to TAZs 340, 344 and 345.
- 131 new finance jobs were added to TAZs 340, 344 and 345.
- 1,185 new retail jobs were added to TAZs 340 and 345.
- 326 manufacturing jobs were removed from TAZ 345.

The net allocation of these additions and subtractions is shown in Table 4.2. The Northgate project is projected to add 1,878 jobs over the 2010 Baseline scenario, increasing total regional employment by 2.6 percent. No changes are made to households or population.

Table 4.2: 2010 Northgate Scenario Households, Population and Employment for the Project Area

			Employment						
TAZ	Total Hhld.	Total Pop.	Total	Manuf'g.	Wh'lsale Trade	Retail Trade	Finance	Services	Other
340	0	0	1,255	0	0	957	107	191	0
344	0	0	722	0	0	0	100	622	0
345	4	9	634	175	7	336	30	86	0
Sum	4	9	2,611	175	7	1,293	237	899	0

4.5.3 Baseline 2025

The 2025 Baseline scenario was prepared using an allocation of future land use prepared by RVMPO for the year of project opening. The households and employment in each zone represent what would have occurred without the project. The total population for the region was projected to be 203,473, and the total employment for the region was projected to be 82,984. This represents an 18 percent increase in population and a 14 percent increase in employment over the 2010 Baseline scenario. Note that it was assumed that the households and populations for the TAZs comprising the Northgate site remained the same as in 2010, whereas total employment in these same zones was project to increase by 84 jobs. The population and employment in each of the study area zones are shown in Table 4.3. The travel model network should be consistent with existing and financially committed facilities for 2025.

Table 4.3: 2025 Baseline Scenario Households, Population and Employment for the Project Area

			Employment						
TAZ	**Total Hhld.**	**Total Pop.**	**Total**	Manuf'g.	Wh'lsale Trade	Retail Trade	Finance	Services	Other
340	0	0	581	354	0	121	105	0	0
344	0	0	0	0	0	0	0	0	0
345	4	9	236	172	7	40	6	11	0
Sum	4	9	817	526	7	161	111	11	0

4.5.4 Northgate 2025

The 2025 Northgate scenario starts from the baseline scenario for that same year and maintains the same network facilities. The land use inputs for the three TAZs that comprise the Northgate project were modified as follows:

- 888 new service jobs were added to TAZs 340, 344 and 345.
- 26 new finance jobs were added to TAZs 340, 344 and 345.
- 1,132 new retail jobs were added to TAZs 340 and 345.
- 351 manufacturing jobs were removed from TAZ 345.

The net allocation of these additions and subtractions is shown in Table 4.4. The Northgate project is projected to add 1,794 jobs over the 2025 Baseline scenario, slightly less than the increment in jobs attributed to Northgate in the 2010 scenarios. These numbers reflect the expected region-wide losses and gains in employment by industry type, as projected by an economist working for the project's developers, and represent a 2.1 percent increase in total regional employment over the 2025 Baseline scenario. No changes are made to households or population.

Table 4.4: 2025 Northgate Scenario Households, Population and Employment for the Project Area

			Employment						
TAZ	**Total Hhld.**	**Total Pop.**	**Total**	Manuf'g.	Wh'lsale Trade	Retail Trade	Finance	Services	Other
340	0	0	1,255	0	0	957	107	191	0
344	0	0	722	0	0	0	100	622	0
345	4	9	634	175	7	336	30	86	0
Sum	4	9	2,611	175	7	1,293	237	899	0

4.5.5 General Model Assumptions and Results

Application of the RVMPO Model to each of the land use scenarios, using the network files applicable to each scenario year, will produce a uniform set of outputs that reflect the internal structure of the model system. The model system's internal structure incorporates important assumptions that affect the way in which it responds to land use inputs.

4.5.5.1 Important Assumptions

While a detailed analysis of model variable specifications is beyond the scope of this study, there are a few inherent assumptions that need to be acknowledged.

Households and population are not affected by the Northgate proposal – This assumption was made in the preparation of the TAZ (land use) input file. Thus, the number of households and population remain unchanged between scenarios. An alternative assumption would have been that the new jobs represented in the Northgate proposal would attract additional households to the region. Given the size and nature of the development, the assumption of no new households was likely warranted.

Employment in the region is not affected by the change in the number of jobs brought about by the Northgate proposal – Given the same number of households and persons in the region, there was no change made to the number of workers per household in the preparation of the land use input files. An alternative assumption would have been to assume that the Northgate proposal would have added jobs to the region that would have been filled by area residents.

Trip generation is entirely "production-constrained" – In the parlance of travel demand modeling, a production-constrained trip-generation model is one in which the total number of trips generated is a function of household generation rates, and is not influenced by the number of regional "attractors" (e.g., employment and retail opportunities). Household trip production rates are a function of household attributes, such as the number of persons, automobile availability, income, number of workers, and presence of children. In some trip-based model systems, certain trip purposes (primarily work and school) are attraction-constrained, meaning the total number of trips generated for those purposes are based on rates developed from the attraction end of the trip. In both production- and attraction-constrained systems, however, the location and magnitude of attractors does influence the spatial distribution of trips between TAZs. The implication of trip generation being production-constrained is that the model system is not sensitive to induced demand. The impact on this study is that, for the same year, the total number of trips generated is the same for both Baseline and Northgate scenarios.

Non-motorized trips are insensitive to congestion effects – The level of service experienced by pedestrians and bicyclists is not reflected in the model system design. Walk and bicycle mode utilities are expressed as a function of just one variable, distance along eligible links in the roadway network, and are not affected by traffic congestion or any other factors. To the extent that other, motorized modes are projected to experience better or worse travel times, the walk and bike mode shares may increase or decrease by comparison. In addition, to the extent that a change in land use provides more opportunities for pedestrians and bicyclists, walk and bike trips may also increase.

Truck trips are fixed, not modeled – The RVMPO model system treats truck trips, as well as inter-regional auto trips, as fixed, trip-table inputs. Accordingly, the model system does not reflect any change in truck trip origins or destinations due to the Northgate scenario. Accordingly, the interests of truckers are represented only in the changes to vehicle hours/miles of travel, but their trips are not distinguishable from auto trips. This is a potential weakness in the tool as specified, one that is handled in other model systems through a special truck model component and multi-class highway assignment methods. TIAs handle this by assuming a certain percentage of project site vehicle flows being truck traffic based on historical percentages of background traffic and site characteristics.

Mode availability restrictions – The RVMPO model system, like most travel demand modeling systems, makes certain assumptions about the availability of certain travel modes. Listed below are the availability restrictions placed on individual modes within the study region.

- Drive alone – only available to households with at least one car
- Drive with passenger – only available to households with at least one car
- Auto passenger – no restrictions
- Bus by walk access – only available if both trip ends are within 0.25 mile of a bus stop
- Bus by park-and-ride access – only available if destination trip end is within 0.25 mile of a bus stop
- Bike – only available for trips with distance less than ten miles
- Walk – only available for trips with distance less than five miles

Mode choice structure – The RVMPO model system utilizes a multinomial logit model structure in mode choice. The implications of this model form are that alternate modes are considered to be equally competitive with one another. For example, this would mean that an improvement in the level of service of bus transit-walk access would have the same proportional impact on the propensity to walk, bike, drive, or park-and-ride. Arguably, one might expect that bus transit-walk access and walking modes would be close substitutes, or perhaps bus walk-access and bus-park-and-ride. In some model systems, mode choices are structured so that alternatives that are viewed as closer substitutes are grouped together and thus a change in level-of-service for grouped alternatives will have a greater effect on mode shares within the group than on alternatives outside the group.

4.5.5.2 What to Look for in Model Results

The RVMPO model structure, including the assumptions discussed above, work to produce a set of expected responses to changes in land use input assumptions. The following general model results are to be expected in the analysis of results:

- The total number of trips generated will not change between Baseline and Northgate scenarios for the same analysis year.
- The spatial distribution of trips between TAZs in the region will change, with households making shorter or longer trips, depending on the location of attractors (jobs and retail opportunities) and the cost of travel (travel time) to these locations.
- Different travel modes will be affected differently. The new spatial arrangement of land uses in the region will improve or reduce access to job and retail opportunities more for some modes than others. This may show up as shorter/longer travel times by certain modes, shifts in mode share, and changes to accessibility measures that are different for different modes.
- The model system is insensitive to commercial truck travel. Truck trips are indistinguishable from auto trips at the network level and therefore are not singled out in any of the analyses.
- Bicycle trips and park-and-ride trips represent a relatively small share of travel in the RVMPO region; therefore, their results should be interpreted with caution.
- The new distribution of trips between TAZs and, to some degree, shifts in mode share will result in changes to the volume and direction of traffic flows on the highway network, resulting in changes to v/c ratios network-wide.

The impacts of land use changes will be greater closer to the project site, and will diminish farther away from the site. This sensitivity is explored in detail below. Similarly, system-level impacts, such as VMT and VHT, will reflect the net effect of increases and decreases throughout the model region and are likely to show the least change between scenarios.

4.6 ANALYSIS OF MODEL RESULTS BY METRIC

In this section, the results of the alternative mobility metrics as applied to the case study scenarios are presented. The section is organized such that the results for each metric are examined across the scenarios. A synthesis of what may be learned by considering the evidence provided by all of the metrics is presented later. As described below, for zone-based metrics the results are presented at four different levels of spatial focus, based on the location of origin and destination zones relative to the project site.

4.6.1 Geographic Focusing

It was anticipated that metrics representing a system-level phenomenon, such as trip lengths, mode shares, person hours of travel, and regional accessibility, would show different effects at different levels of spatial focus. For example, one would expect to see a greater proportional impact on mode shares for trips with an origin or destination in one of the three study area zones, compared to trips with neither end in a study area zone. Also, one would expect that trips closer to the study area would be affected more than trips further away due to the larger anticipated changes in network level of service closer to the study area. At the regional scale, one might expect to see very little residual effect of the project.

To test this, four districts of varying size were created in the RVMPO model region to study the impact of the North Gate development on both a more local and regional scale. The district boundaries were chosen through trial-and-error during the initial investigation of metric results. The smallest district, District 1, contains only the RVMPO TAZs that comprise the actual site of development; the second smallest district, District 2, contains TAZs that are within about 1 mile of the development site; the second largest district, District 3, contains TAZs that are within about 4 miles of the development site; and the largest district, District 4, contains all TAZs in the RVMPO model region. The district areas are concentric and inclusive, such that outer districts contain all of the TAZs within each inner district. Figure 4.6 shows the study districts.

The way in which the districts are used to organize outputs is as follows:

- If either the origin or the destination of a trip belonged to one of the TAZs on the map shown as District 1, then the trip was considered to belong to District 1.
- If either the origin or the destination of a trip belonged to one of the TAZs on the map shown as District 2, inclusive of District 1, then the trip was considered to belong to District 2.
- If either the origin or the destination of a trip belonged to one of the TAZs on the map shown as District 3, inclusive of Districts 1 and 2, then the trip was considered to belong to District 3.
- All trips were considered to be part of District 4. For example, a trip with a trip end in District 1 will also be included in the tabulations for Districts 2, 3 and 4.

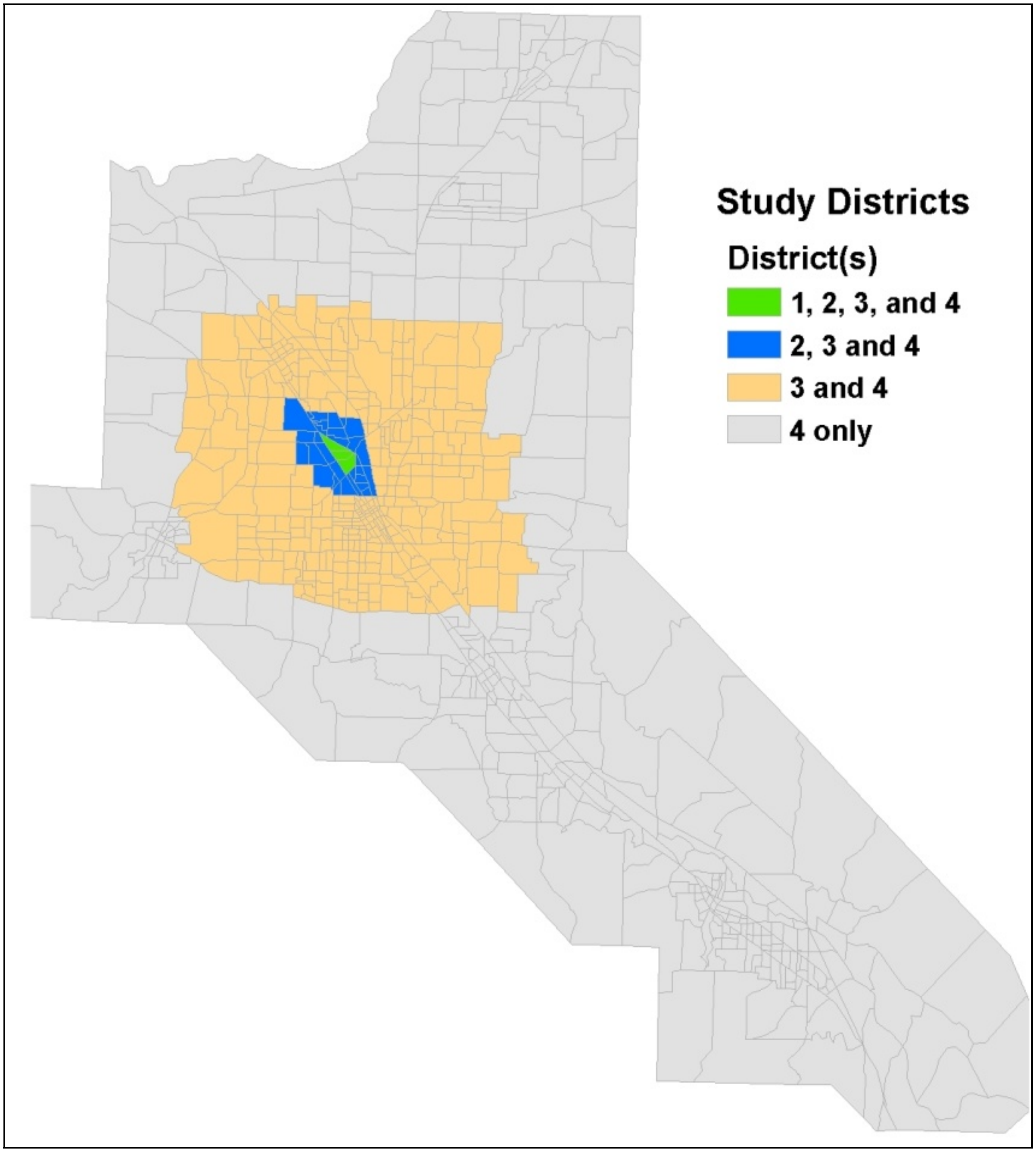

Figure 4.6: Concentric Study Districts Representing Four Levels of Geographic Focus

4.6.2 Metric-by-Metric Comparison

The remainder of this section focuses on one metric at a time, comparing the results between Baseline and Northgate scenarios for both 2010 and 2025.

4.6.2.1 Network-wide V/C Changes

Changes in link v/c ratios between the Base and Northgate scenarios were studied to identify network locations where traffic congestion was affected. The v/c ratio was calculated for each link of the peak period assigned networks for the Base and Northgate scenarios, and then the absolute difference of the Northgate and Base v/c ratios was computed (Northgate less Base) and mapped. Figure 4.7 presents the 2010 change in v/c ratios, and Figure 4.8 presents the 2025 change in v/c ratios.

The abundance of positive change (indicated by warm colors) indicates a marked increase in congestion near the Northgate. Although there are few arterial approaches to the Northgate site that show an increase in congestion, in the 2010 scenarios the development does not appear to have much of a systematic effect beyond the immediate vicinity of the site. In the 2025 scenarios, v/c changes are noticeable a bit further from the project site, and it appears that some links actually show improved v/c ratios (shown in light blue) in the Northgate scenario compared with the baseline. Improvements would likely be due to some traffic being diverted towards Northgate that would otherwise be headed to and from other commercial areas.

The most substantial v/c changes appear to be contained within the first two study districts shown in Figure 4.6. Interestingly, if one compares the extent of the changes in Figures 4.7 and 4. 8 to the locations of study intersections in the TIA (Figure 4.2), there is a remarkable correspondence between the geographic extent of the chosen TIA study sites and the facilities that the current study indicates will experience impacts. It is not clear from the TIA documentation how the study sites were chosen, but it may be that a travel demand model was used to identify potential problem locations.

It should be mentioned that there are two network links shown on the right side of the network map, quite far away from the project site, that seem to change dramatically in both 2010 and 2025 scenarios, switching between large positive and negative changes in v/c. This may be an anomaly, possibly due to poor network coding, which causes those particular links to oscillate between assignment iterations.

It is also important to note that these v/c ratios were not compared with the v/c ratios originally developed for the 2006 TIA. There are several differences between this and that earlier analysis, such as differences in demand model variables and utility coefficient due to the change from Version 1 to Version 2 of the RVMPO model. The TIA also considered assumed turning movement volumes, by direction, at intersections in the vicinity of the project site, whereas this study considers v/c changes along the links leading up to the intersection. Since the TIA analysts used travel demand model outputs at the link level to factor-up turning movement volumes at the intersections for each approach, the method used here is consistent with the TIA methodology.

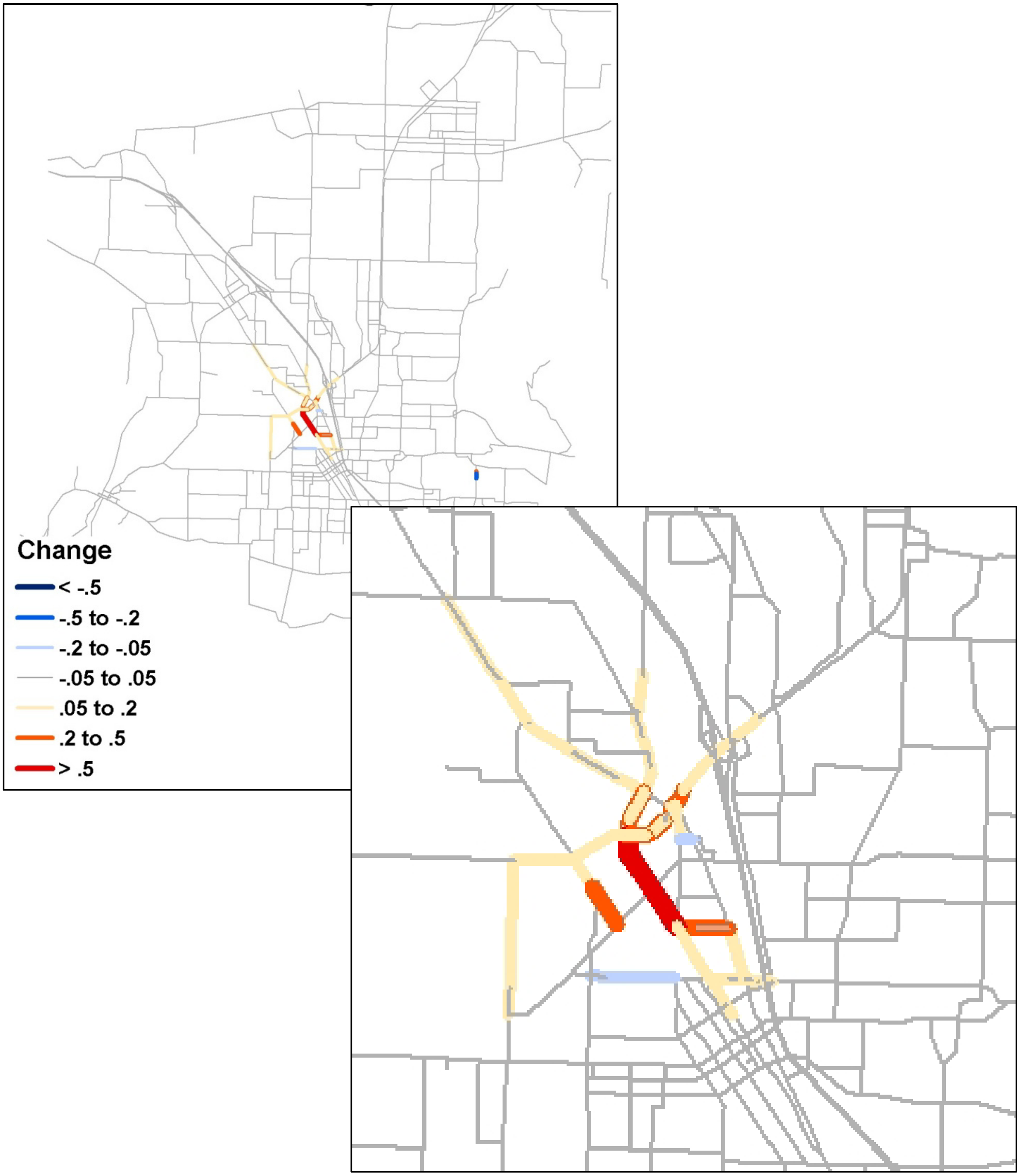

Figure 4.7: Absolute Changes in V/C between 2010 Baseline and 2010 Northgate Scenarios

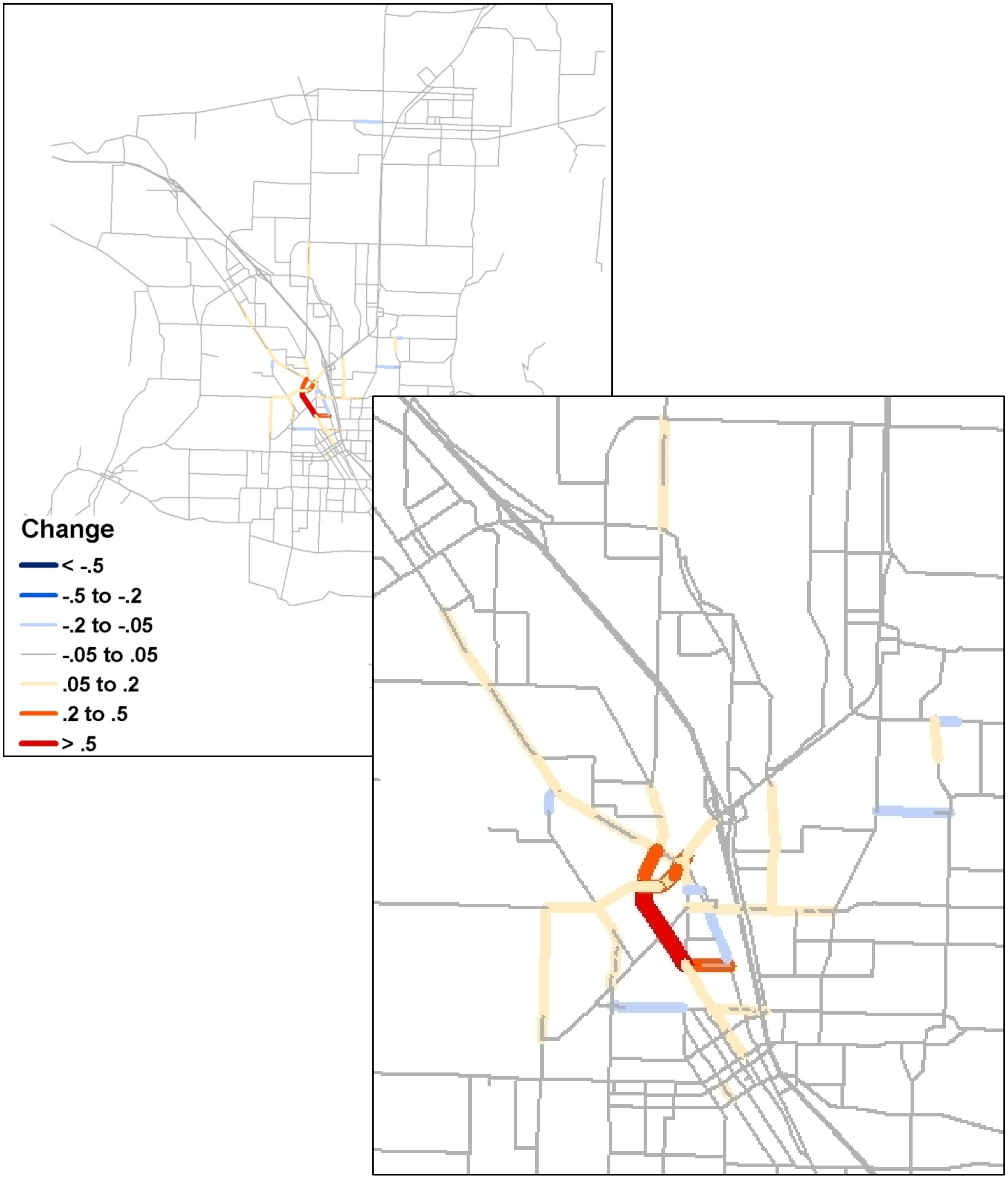

Figure 4.8: Absolute Changes in V/C Between 2025 Baseline and 2025 Northgate Scenarios

4.6.2.2 Total Network Travel Time and Distance

Total assigned auto and transit network times and distances were tabulated for the Baseline and Northgate scenarios. Although VHT is the metric under consideration, VMT is closely related and, together, they provide a good indication of network-wide travel speeds. These results are shown in Table 4.5. While there is general growth in both VHT and VMT between 2010 and 2025 due to the expected increase in population, there appears to be no substantial impact on auto and truck travel times and distances due to the Northgate project when viewed at the regional level.

There is a small, but noticeable decrease in transit trip miles and travel times. The 2010 and 2025 Northgate scenarios have less assigned transit miles and hours, which may result from having fewer and/or shorter trips than in the Baseline scenario. Consideration of additional metrics, such as trip-lengths and mode shares, can help untangle these results.

It is also interesting to note that the average speed of auto and truck trips represented in the model is essentially unchanged between Baseline and Northgate scenarios and even between 2010 and 2025 model years. This may indicate that the network changes anticipated by ODOT and represented (through the TSP) in the 2025 network are well-matched to the level and distribution of demand for that year.

Table 4.5: Changes to Total Network Travel Distance and Time: 2010 & 2025 Baseline vs. Northgate Scenarios

	2010			2025		
	Baseline	**Northgate**	**% Change**	**Baseline**	**Northgate**	**% Change**
Auto/Truck Vehicle Miles (VMT)	1,742,599	1,750,526	0%	2,109,860	2,118,955	0%
Auto/Truck Vehicle Hours (VHT)	67,232	67,552	0%	80,681	81,061	0%
Transit Trip Miles	3,629	3,520	-3%	4,049	3,945	-3%
Transit Trip Hours	3,152	2,992	-5%	3,600	3,450	-4%

4.6.2.3 Total Person Hours of Travel Time

Whereas network travel times and distances represent vehicle usage of the highway system, a measure that more directly reflects the experience of individual travelers is person hours of travel (PHT). As previously mentioned, PHT calculations do not include commercial truck trips or private auto trips that leave the region or enter from outside. This would be expected to yield results that differ by model of travel. In order to examine how this measure might impact individuals differently around the region, the geographic-focusing study districts were applied. The results for 2010 and 2025 are shown in Tables 4.6 and 4.7, respectively.

As might be expected, trips with at least one end in the Northgate site (represented by District 1) are projected to increase by an order of magnitude over the Baseline scenario, in both the 2010 and 2025 scenarios. As one zooms out to trips within District 2 (trips within one mile of the site), there is still a substantial increase in the amount of travel

(36-37%). When zooming out to the District 3 level (trips within four miles of the site) the change shrinks to about one percent. Finally, at the District 4 level(all trips in the region) there is virtually no impact on PHT by all modes. These results are remarkably consistent between 2010 and 2025 scenarios, which again reflect the finely tuned balanced between demand and network supply created for the RVMPO 2030 TSP.

Table 4.6: Changes to Total Person Hours of Travel Time (PHT): 2010 Baseline vs. Northgate Scenarios

2010	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	40	1,235	6,397	9,352	399	1,444	6,230	9,076	889%	17%	-3%	-3%
Bike	4	113	646	917	42	139	647	913	886%	24%	0%	0%
Walk to Bus	8	262	1,491	2,202	88	307	1,450	2,141	1010%	18%	-3%	-3%
PnR Bus	0	17	137	170	0	16	130	162	0%	-7%	-5%	-5%
Drive Alone	200	3,570	20,581	27,676	1,857	4,880	20,995	27,939	829%	37%	2%	1%
Drive w Pasg.	150	3,358	17,142	22,803	2,028	4,784	17,502	22,971	1251%	42%	2%	1%
Passenger	164	3,753	18,321	24,425	2,313	5,339	18,622	24,477	1311%	42%	2%	0%
All	567	12,307	64,716	87,544	6,728	16,910	65,576	87,680	1088%	37%	1%	0%

Table 4.7: Changes to Total Person Hours of Travel Time (PHT): 2025 Baseline vs. Northgate Scenarios

2025	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	50	1,272	7,329	11,134	404	1,491	7,167	10,854	708%	17%	-2%	-3%
Bike	5	120	742	1,067	43	147	744	1,064	703%	23%	0%	0%
Walk to Bus	11	269	1,615	2,433	90	316	1,578	2,377	726%	18%	-2%	-2%
PnR Bus	0	17	145	184	0	16	139	177	0%	-6%	-4%	-4%
Drive Alone	251	3,823	23,851	32,397	1,915	5,159	24,278	32,666	662%	35%	2%	1%
Drive w Pasg.	204	3,581	19,826	26,762	2,096	5,052	20,212	26,945	929%	41%	2%	1%
Passenger	225	3,999	21,136	28,682	2,393	5,641	21,470	28,751	962%	41%	2%	0%
All	747	13,081	74,645	102,660	6,941	17,823	75,588	102,834	830%	36%	1%	0%

These scenarios likewise indicate a differential effect by mode. Specifically, within Districts 1 and 2 there is a proportionally greater increase in the amount of auto travel compared with pedestrian and transit travel. Region-wide percentage decreases in pedestrian and transit travel show up at District 3 and 4 levels. In addition, there are larger percentage gains in the amount of travel by multiple-occupancy auto models, compared with drive alone. This is likely due to the large gains in retail and service employment in the project TAZs, which are likely to attract a larger share of shopping and personal service-related trips in the Northgate scenario than in the baseline scenario. Such trips tend to have a higher average auto occupancy than, say, commute trips. It should be noted that park-and-ride is shown in the tables as having zero PHT, because the model predicted that less than one daily trip would choose this mode for trips starting or ending in District 1.

4.6.2.4 Average Person Trip Travel Times

While VMT, VHT and PHT may be used to estimate the total amount of travel, expressed as distance or time, examination of average trip travel times provides additional information upon which to evaluate the impacts of a land use change. Tables 4.8 and 4.9 show the average person-trip travel times, by mode, for the 2010 and 2025 scenarios, respectively. The results of the two model years are very similar.

Table 4.8: Changes to Average Person Trip Travel Time (in minutes): 2010 Baseline vs. Northgate Scenarios

2010	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	26.5	21.0	13.6	11.9	25.9	22.3	14.1	12.2	-2%	6%	3%	2%
Bike	11.0	10.5	9.6	8.6	8.9	10.1	9.6	8.7	-20%	-4%	0%	0%
Walk to Bus	16.4	25.9	22.6	20.7	15.8	22.2	22.3	20.6	-4%	-14%	-1%	-1%
PnR Bus	0.0	21.7	21.7	23.2	0.0	21.9	21.7	23.3	0%	1%	0%	0%
Drive Alone	5.8	5.5	5.9	5.5	5.3	5.5	5.9	5.6	-9%	0%	0%	1%
Drive w Pasg.	5.9	5.9	6.2	5.9	5.6	5.8	6.2	6.0	-6%	-1%	0%	0%
Passenger	5.6	5.6	5.9	5.7	5.2	5.5	5.9	5.7	-6%	-2%	0%	0%
All	6.2	6.2	6.5	6.2	5.7	6.1	6.5	6.2	-8%	-3%	0%	0%

Table 4.9: Changes to Average person Trip Travel Time (in minutes): 2025 Baseline vs. Northgate Scenarios

2025	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	28.0	21.6	13.4	11.5	26.6	22.9	13.8	11.7	-5%	6%	3%	2%
Bike	11.1	10.6	9.7	8.6	9.1	10.3	9.7	8.6	-18%	-4%	0%	0%
Walk to Bus	16.5	25.8	22.4	20.7	16.2	22.5	22.2	20.6	-2%	-13%	-1%	0%
PnR Bus	0.0	21.1	21.0	22.5	0.0	21.2	21.0	22.6	0%	1%	0%	0%
Drive Alone	5.8	5.5	5.9	5.5	5.3	5.5	5.9	5.6	-8%	0%	0%	0%
Drive w Pasg.	6.0	5.9	6.2	5.9	5.6	5.9	6.2	5.9	-6%	-1%	0%	0%
Passenger	5.7	5.7	5.9	5.7	5.3	5.6	5.9	5.7	-6%	-2%	0%	0%
All	6.2	6.3	6.5	6.2	5.7	6.1	6.5	6.2	-8%	-3%	0%	0%

Despite an increase in the amount of travel, Tables 4.8 and 4.9 depict an overall decrease in average travel times for Districts 1 and 2. Together with the increases in total PHT for the Districts closest to the site, this suggests the model depicts travel time savings in the Northgate scenario that would induce travelers to shift their trips to the Northgate TAZs. This appears to be true for all modes in District 1 and all but the walk mode in District. 2. Bike trips in Districts 1 and 2 and Transit trips within District 2 appear to benefit most by reduced travel times to and from the Northgate site.

Walk trips are projected to have longer average travel times for trips with at least one end in Districts 2, 3 and 4. The likely reasons for this is that the new employment and retail opportunities represented by the Northgate project provide more attractive walk trip destinations for certain TAZs, enough to induce a shift in demand to the walk mode, meaning people are willing to walk farther to the Northgate site because it has more to offer.

4.6.2.5 Trip Length Distributions

Whether average trip lengths are actually affected by the Northgate project can be confirmed by examining the distribution of trips by distance, expressed in miles. The frequency distributions of trip lengths for the 2010 Baseline and Northgate scenarios are shown in Figure 4.9. The four charts are ordered by study district. The top-two charts show Districts 1 and 2, from left to right respectively, and the bottom-two charts show Districts 3 and 4, from left to right respectively. The frequencies of the Baseline scenario are indicated by the blue bars and the frequencies of the Northgate scenario are symbolized by the green bars.

Overall, trip lengths in the RVMPO model are shorter than might be expected in other regions, which is partially a function of the model structure, and partially a function of the linear shape of the region (which combines several smaller cities, each with their own travel sub-market). Nevertheless, these figures show that trips closer to the Northgate project study area (Districts 1 and 2) are likely to be shorter in length, but that the differences in trip lengths diminish as one considers the larger geographic areas. A nearly identical distribution resulted from the 2025 scenario, as shown in Figure 4.10.

Information on average trip lengths by travel mode is also provided in Tables 4.10 and 4.11 for the 2010 and 2025 scenarios, respectively. These tables show overall average trip distances decreasing in District 1 by 12-13 percent, decreasing by two percent overall in District 2, unchanged in District 3, and actually increasing by about one percent overall in District 4. The results for 2010 and 2025 are very similar. They are also similar to the percentage changes in travel times shown in Tables 4.8 and 4.9, including the breakdown by mode.

Taken together, examination of trip lengths and travel times, suggest that the Northgate project would result in shorter trip distances and travel times closer to the site, while trips further away might actually lengthen in an effort to reach the site. This is partially the result of the re-distribution of trips towards the project site, and partially a shift in mode shares. Further examination of the change in mode shares is addressed below.

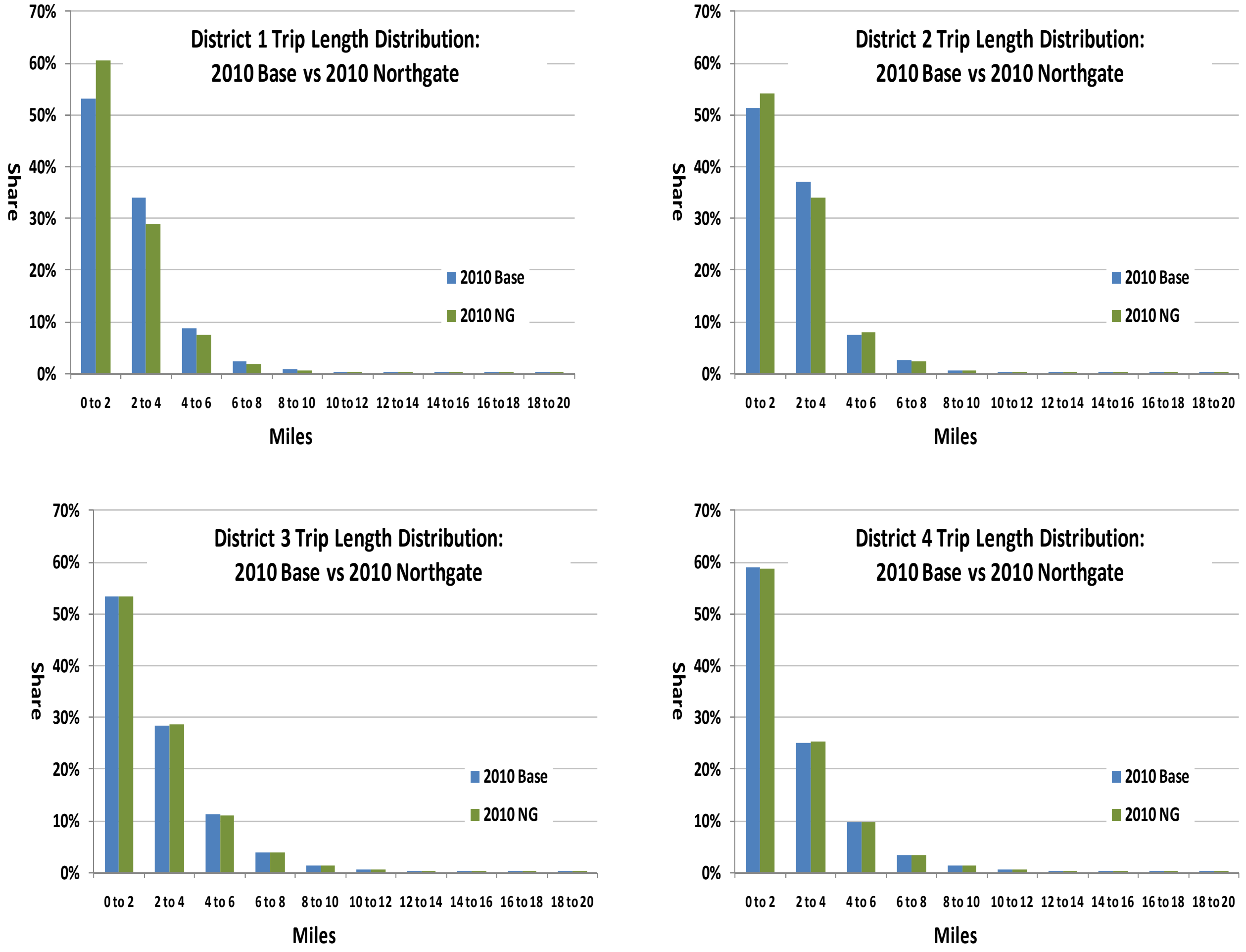

Figure 4.9: Trip-length distributions (in miles) for the 2010 Baseline and Northgate scenarios

Table 4.10: Changes to Average Trip Distances (in miles): 2010 Baseline and Northgate Scenarios

2010	Baseline by Study District				Northgate by Study District				Percent Change			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	1.3	1.1	0.8	0.7	1.3	1.1	0.8	0.7	-2%	6%	3%	2%
Bike	1.8	1.7	1.6	1.4	1.5	1.7	1.6	1.4	-20%	-4%	0%	0%
Walk to Bus	1.3	1.5	1.5	1.5	1.3	1.5	1.5	1.5	0%	-5%	1%	1%
PnR Bus	0.0	2.4	2.6	2.7	0.0	2.4	2.6	2.7	0%	0%	0%	1%
Drive Alone	2.8	2.7	2.9	2.7	2.5	2.7	2.9	2.7	-12%	0%	1%	1%
Drive w Pasg.	2.3	2.3	2.5	2.3	2.1	2.2	2.5	2.3	-11%	-3%	0%	1%
Passenger	2.1	2.1	2.3	2.1	1.8	2.0	2.3	2.1	-11%	-4%	-1%	0%
All	2.4	2.3	2.5	2.3	2.1	2.3	2.5	2.3	-13%	-2%	0%	1%

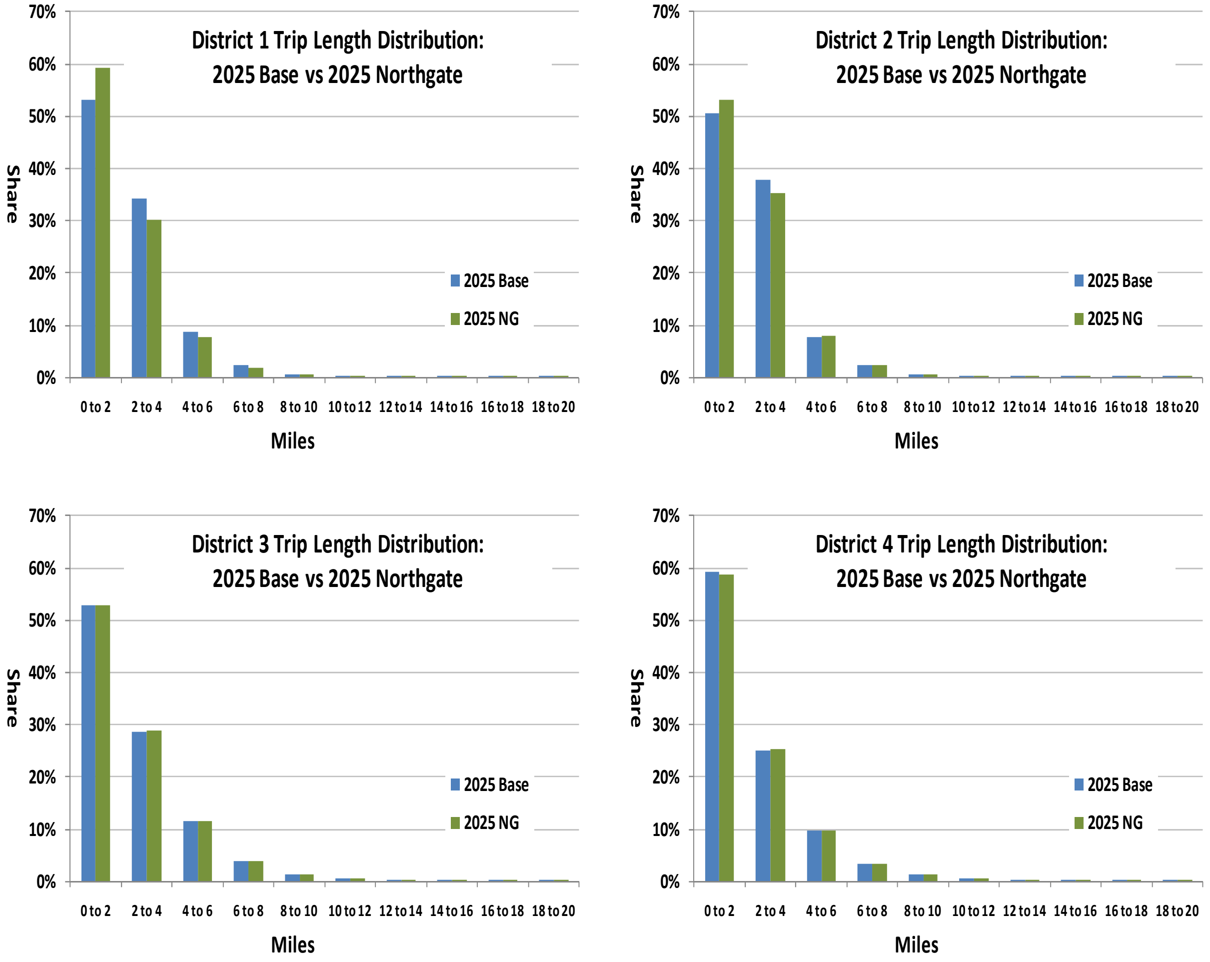

Figure 4.10: Trip-Length Distributions (in miles) for the 2025 Baseline and Northgate Scenarios

Table 4.11: Changes to Average Trip Distances (in miles): 2025 Baseline and Northgate Scenarios

2025	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	1.4	1.1	0.8	0.7	1.3	1.2	0.8	0.7	-4%	6%	2%	2%
Bike	1.8	1.8	1.6	1.4	1.5	1.7	1.6	1.4	-18%	-4%	0%	0%
Walk to Bus	1.3	1.5	1.5	1.5	1.3	1.5	1.6	1.5	0%	-5%	1%	1%
PnR Bus	0.0	2.4	2.6	2.6	0.0	2.4	2.6	2.6	0%	0%	0%	1%
Drive Alone	2.8	2.7	2.9	2.7	2.5	2.7	2.9	2.7	-11%	-1%	1%	1%
Drive w Pasg.	2.3	2.3	2.5	2.3	2.1	2.3	2.5	2.3	-10%	-3%	0%	1%
Passenger	2.1	2.1	2.3	2.1	1.9	2.1	2.3	2.1	-10%	-4%	0%	0%
All	2.4	2.3	2.5	2.3	2.1	2.3	2.5	2.3	-12%	-2%	0%	1%

4.6.2.6 Mode Shares

The changes in total person hours of travel and average trip times and distances by mode indicate that a shift in mode shares may play a role. The predicted changes in mode shares that would result from the Northgate proposal for scenario years 2010 and 2025 are shown below in Tables 4.12 and 13, respectively.

Table 4.12: Changes to Mode Shares: 2010 Baseline and Northgate Scenarios

2010	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	2%	3%	5%	6%	1%	2%	4%	5%	-21%	-22%	-7%	-5%
Bike	0%	1%	1%	1%	0%	0%	1%	1%	-5%	-9%	-1%	-1%
Walk to Bus	1%	1%	1%	1%	0%	0%	1%	1%	-10%	-3%	-3%	-2%
PnR Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	-35%	-7%	-5%
Drive Alone	38%	33%	35%	35%	30%	32%	35%	35%	-21%	-3%	0%	0%
Drive w Pasg.	28%	29%	28%	27%	31%	30%	28%	27%	12%	2%	1%	0%
Passenger	32%	34%	31%	30%	37%	35%	31%	30%	17%	3%	0%	0%
All	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%

Table 4.13: Changes to Mode Shares: 2025 Baseline and Northgate Scenarios

2025	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	1%	3%	5%	6%	1%	2%	4%	6%	-16%	-21%	-6%	-4%
Bike	0%	1%	1%	1%	0%	0%	1%	1%	-2%	-9%	-1%	-1%
Walk to Bus	1%	1%	1%	1%	0%	0%	1%	1%	-16%	-4%	-3%	-2%
PnR Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	-33%	-6%	-4%
Drive Alone	36%	33%	35%	35%	30%	32%	35%	35%	-18%	-3%	0%	0%
Drive w Pasg.	28%	29%	28%	27%	31%	30%	28%	27%	9%	2%	1%	0%
Passenger	33%	34%	31%	30%	37%	35%	31%	30%	13%	3%	0%	0%
All	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%

Both years show similar changes between Baseline and Northgate scenarios. While all modes show more travel going to Districts 1 and 2 in the PHT scenarios, it is clear that the drive-with-passenger and passenger modes gain shares for trips within a mile of the project site. As hypothesized, the likely reason for this shift is that the Northgate site offers shopping opportunities that were not present in the Baseline scenario, when the primary reason for travel to these zones was for work in manufacturing jobs. Since shopping and related activities more often involve other household members than commute trips, the trips being produced and attracted to District 1 are more likely to involve multiple occupancy vehicles in the Northgate scenario. However, spread over the entire region (as shown in District 4) there is no change in shares between drive-alone and the two multiple occupancy modes.

For trips within Districts 1 and 2, non-multiple-occupancy auto modes actually lose shares, even though they all gain in terms of total trips and PHT. At the regional level, which is reflected in the District 4 columns, mode shares remain relatively stable between scenarios, with some decreases to the already-small mode shares of the transit and non-motorized modes.

As a point of reference, Tables 4.14 and 4.15 show the actual number of projected trips, by mode, for the 2010 and 2025 scenarios, respectively. These results confirm that in the Northgate scenario a significant portion of trips are shifted to District 1 and, to a lesser extent, District 2, while total trips remain unchanged for the entire region (District 4).

Table 4.14: Changes to the Number of Trips by Mode: 2010 Baseline and Northgate Scenarios

2010	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	91	3,529	28,213	47,027	926	3,879	26,588	44,570	914%	10%	-6%	-5%
Bike	23	646	4,023	6,375	281	830	4,025	6,328	1126%	28%	0%	-1%
Walk to Bus	29	607	3,960	6,374	336	830	3,908	6,240	1057%	37%	-1%	-2%
PnR Bus	0	46	381	439	0	43	360	417	0%	-8%	-5%	-5%
Drive Alone	2,085	39,174	210,283	299,262	21,188	53,613	213,718	300,467	916%	37%	2%	0%
Drive w Pasg.	1,517	34,186	165,945	230,153	21,850	49,358	169,486	231,215	1341%	44%	2%	0%
Passenger	1,754	39,995	186,013	257,112	26,433	58,113	189,678	257,505	1407%	45%	2%	0%
All	5,499	118,183	598,817	846,742	71,014	166,666	607,763	846,742	1191%	41%	1%	0%

Table 4.15: Changes to the Number of Trips by Mode: 2025 Baseline and Northgate Scenarios

2025	**Baseline by Study District**				**Northgate by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	107	3,526	32,773	58,103	911	3,902	31,147	55,538	749%	11%	-5%	-4%
Bike	29	676	4,599	7,455	282	861	4,598	7,403	881%	27%	0%	-1%
Walk to Bus	40	625	4,320	7,053	333	843	4,266	6,919	742%	35%	-1%	-2%
PnR Bus	0	47	416	491	0	44	396	470	0%	-7%	-5%	-4%
Drive Alone	2,622	41,628	243,231	351,213	21,708	56,383	246,798	352,448	728%	35%	1%	0%
Drive w Pasg.	2,044	36,158	191,229	270,611	22,377	51,725	194,983	271,714	995%	43%	2%	0%
Passenger	2,384	42,185	213,363	301,944	27,020	60,773	217,293	302,377	1033%	44%	2%	0%
All	7,225	124,845	689,931	996,869	72,633	174,530	699,481	996,869	905%	40%	1%	0%

4.6.2.7 Regional Accessibility to Jobs/Shopping Opportunities

As discussed above, changes to mode shares, trip lengths and person-hours of travel may reflect, at their root, changes in accessibility to activity opportunities that are brought about by a land use change. Accordingly, it makes sense to represent accessibility directly. Although there are a variety of methods for calculating accessibility, this study uses a continuous function based on the ability to reach activity opportunities from each TAZ in the study area. The formulas used (see Section 4.2.2) generally hold that accessibility increases with the number of attractors in other zones (e.g., employment), discounted by the impedance cost of travel to those zones, with cost represented by travel times. This study considers access to jobs (total employment) and shopping opportunities (retail employment by proxy). Travel impedance is differentiated among auto, transit, and walking modes.

To put accessibility in context, an important consideration is the number of households or persons that are affected, or who benefit by increased accessibility. For example, while two zones may experience the same percentage gain in accessibility to jobs, this gain means more to an origin zone with 500 households than a zone with just 15 households, because more persons are likely to benefit.

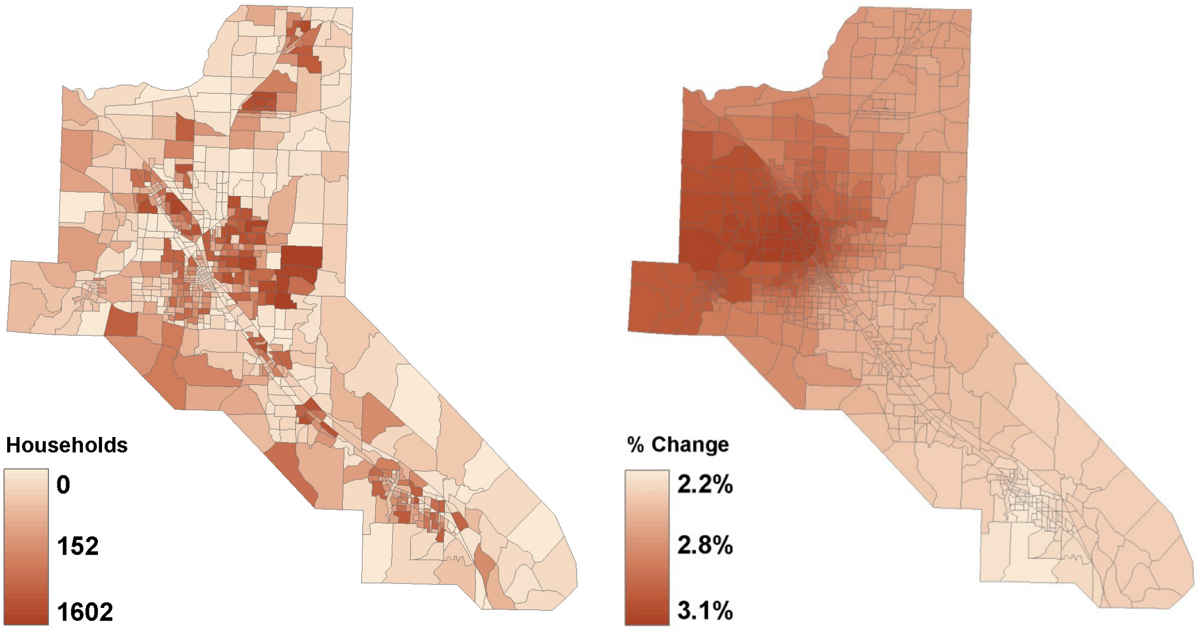

Figure 4.11: 2010 Total Households (left) and 2010 Percent Change in Regional Accessibility to Employment by Auto (right) Resulting From the Proposed Northgate Project

The relevance of this consideration is illustrated in Figure 4.11, in which the number of households in each TAZ is depicted on the map at left and the changes in regional accessibility to employment for the 2010 Northgate scenario are depicted on the map to the right. Darker shades of red indicate greater numbers of households and larger percentage changes in accessibility. Figure 4.11 suggests that areas closest to the project site will experience the greatest improvement in accessibility, with the TAZs to the west of the project site benefiting more than the TAZs to the east. This may be a consequence of better roadway connectivity to the project's TAZs, which are located on the west side of I-5. Accessibility gains are still evident further south in the region, along the I-5 corridor, but tend to diminish with travel time and distance. That the entire region experiences accessibility gains is due to the assumption that Northgate would add new jobs to the region, not just a redistribution of the same number of jobs. Further, as can be seen in the left-hand map showing 2010 households, the TAZs that are likely to gain the most in terms of increased accessibility are not necessarily the ones with the most households.

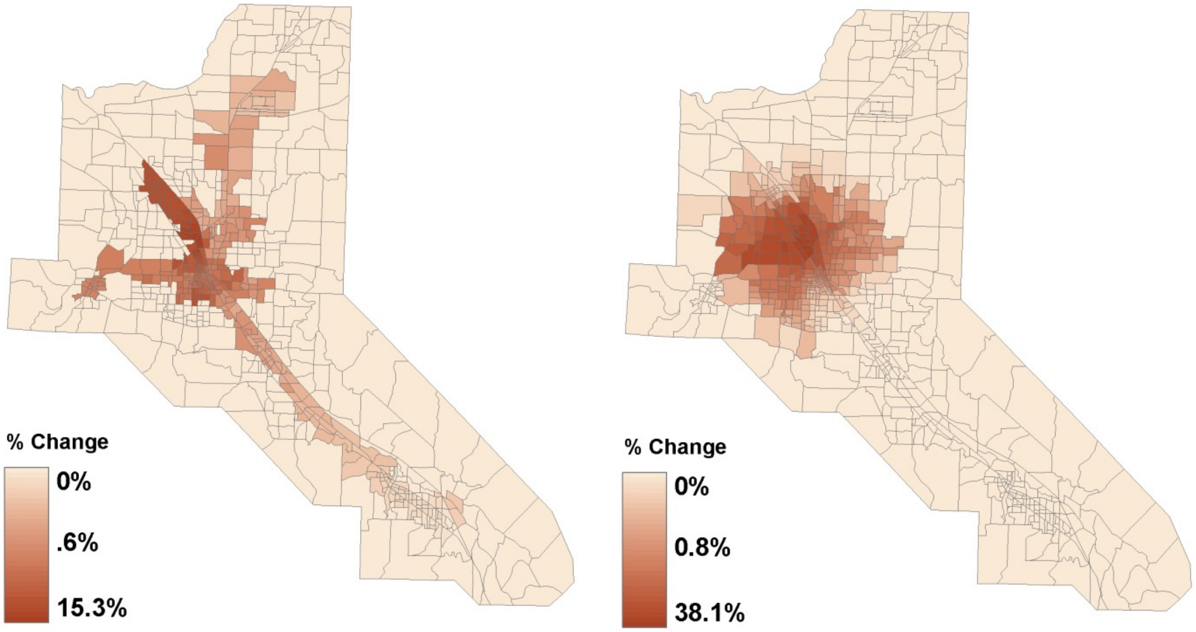

Figure 4.12: 2010 Percent Change in Regional Accessibility to Employment by Transit (left) and by Walk (right) Resulting From the Proposed Northgate Project

Figure 4.12 shows regional transit and walk mode accessibility changes for the 2010 Northgate scenario. These show noticeably different patterns from the scenario's auto accessibility changes. Transit accessibility clearly corresponds to the location of bus routes, even extending down to Ashland at the southern end of the study region. Changes in walk accessibility are more concentrated within 3-4 miles of the Northgate site. It should also be noted that the scales shown on the two maps in Figure 4.12 differ from each other and differ considerably from the auto accessibility map. While it would be possible to rescale these maps in such a way to use the same monochromatic gradation for each mode, the auto accessibility map would not show as much variation, making patterns more difficult to discern. If regional accessibility were to be used as a mobility measure, however, the actual numbers would be used.

Variations on accessibility calculations might consider access to retail employment as a proxy for shopping opportunities. Figure 4.13 shows mode-specific accessibility calculations for access to retail employment. The basic patterns are very similar to accessibility to total employment, probably due to the ubiquity of retail employment; however, the magnitude of changes, as reflected in the map keys, is substantially greater.

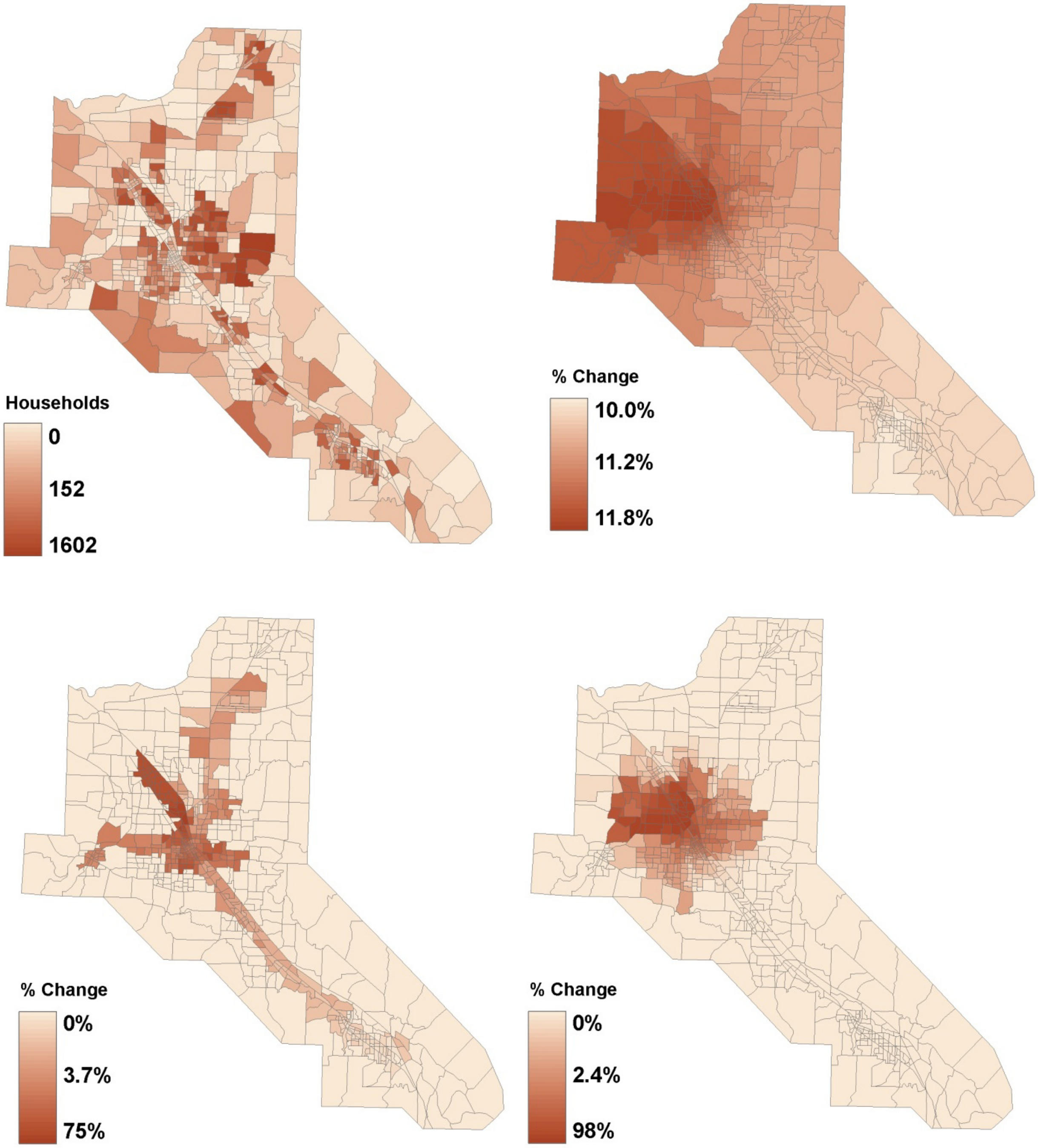

Figure 4.13: 2010 Households (upper left); Percent Change in Regional Accessibility to Retail Employment by Auto (upper right), by Transit (lower left), and by Walk (lower right) Resulting from the Proposed Northgate Project

The calculation of regional accessibility for the 2025 scenario follows a very similar pattern to that of the 2010 calculations. The spatially uniform growth rate assumed for the region contributes to this outcome, which would not be necessarily true for in other regions. Figure 4.14 shows the 2025 households and changes in auto accessibility to employment for comparison with Figure 4.11.

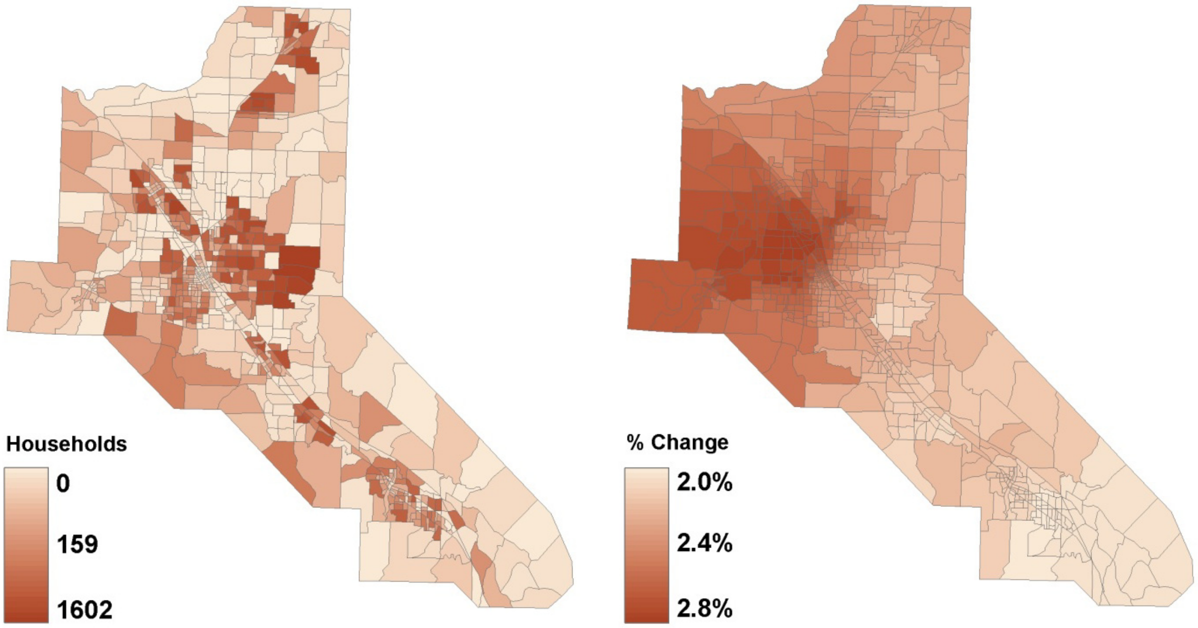

Figure 4.14: 2025 Total Households (left) and 2025 Percent Change in Regional Accessibility to Employment by Auto (right) Resulting from the Proposed Northgate Project

4.6.2.8 Local Accessibility (20-Minute Neighborhood)

The 20-minute neighborhood concept may provide a more intuitive measure of regional accessibility than unbounded continuous functions. In reviewing an initial set of plotted maps showing this metric, the study team observed that the impact patterns basically followed district boundaries. This is due in part to the fact that the measure assumes that all attractors (e.g., employment) are equally attractive, provided they are within 20 minutes travel time from the origin TAZ. Table summaries by study district would better capture the nature of this metric.

The impacts of the Northgate project on local accessibility for the 2010 and 2025 scenarios are shown in Table 4.16. Viewed in this way, the patterns are fairly clear. The auto mode has the quickest travel times and hence produces the largest 20-minute radius. Because much of the study region can be traversed by car in 20 minutes, the percentage change in local accessibility covers this wide area. Hence, the additional employment attributed to Northgate represents a small proportion of total employment (3 percent gain), and there is very little difference between study districts. When considering just retail employment, however, the percentage gain in accessibility by auto is greater(9-12 percent), starting from a lower base number.

Table 4.16: Changes in Local Accessibility (20-Minute Neighborhood): Baseline vs. Northgate Scenarios

	Mode	2010 Study District				2025 Study District			
		1	2	3	4	1	2	3	4
Work	Auto	3%	3%	3%	3%	3%	3%	3%	3%
	Transit	19%	19%	1%	1%	17%	16%	1%	1%
	Walk	122%	24%	2%	2%	109%	22%	2%	1%
Retail	Auto	12%	12%	12%	11%	10%	10%	10%	9%
	Transit	40%	64%	9%	7%	37%	58%	7%	6%
	Walk	210%	44%	7%	6%	183%	40%	6%	5%

For the slower transit and walk modes, the 20-minute neighborhood is proportionally smaller. This means that they start with a smaller baseline accessibility, and the added employment provided by the Northgate project improves local accessibility close to the project site (in District 1 and to a lesser extent in District 2). Farther out (in Districts 3 and 4) accessibility by auto actually enjoys a larger percentage gain than transit and walk modes, owing to its ability to cover a larger area within 20 minutes.

4.7 SENSITIVITY TESTS

The comparisons between baseline scenario and a build scenario, discussed above, would be typical for a land use change subject to review by ODOT. Although this is based on an actual case, there are many other plausible scenarios that might yield different results, or at least portray the metrics in a different light.

In order to consider a wider range of land use change scenarios, a set of three "what if" sensitivity tests is developed, with the basic objective of providing a better understanding of how each metric would perform under different circumstances. While a number of sensitivity tests were contemplated (such as changes to model system parameters and the transportation network) it was thought that changes to the land use inputs themselves would offer the most useful basis for examining the range of applicability of the various metrics. These tests are described below. A summary of lessons learned from these sensitivity tests concludes this section.

4.7.1 Relocating the Project to a Fringe Area

The Northgate project was centrally located within the City of Medford in an area well-served by transit and highway interchanges. For these reasons, it makes a good test case for land use change that seeks to redevelop under-utilized parts of an urban core. Other land use changes, however, particularly ones in more rural settings or on the urban fringe, would be expected to have different impacts on the transportation system. In order to examine the selected metrics under such circumstances, the original Northgate 2025 scenario was "relocated" to the northern fringe of the Medford region.

4.7.1.1 Description of Test

As shown in Table 4.17, the employment that was added to TAZs 340, 344 and 345 in the original 2025 Northgate scenario was moved to TAZ 160. Employment in the three original Northgate TAZs was restored to Baseline values. As shown in Figure 4.15, TAZ 160 appears in green at the northern edge of the study area, well outside Medford and even Central Point. Similar to the original analysis, four concentric study districts were created to facilitate analysis.

Besides being on the urban fringe, TAZ 160 was chosen because it had nearby freeway access and, in the baseline case, some industrial employment, similar to the original development scenario. TAZ 160 is also similar in area to the sum of the three original TAZs. An important difference from the Northgate site is a lack of transit service.

Table 4.17: TAZ Inputs to the 2025 Fringe Growth Scenario

TAZ 160	**Total Hhld.**	**Total Pop.**	**Employment**						
			Total	Manuf'g.	Wh'lsale Trade	Retail Trade	Finance	Services	Other (Mining)
Baseline	31	103	68	37	0	0	0	0	31
Northgate	31	103	2,176	0	0	1,132	126	888	30

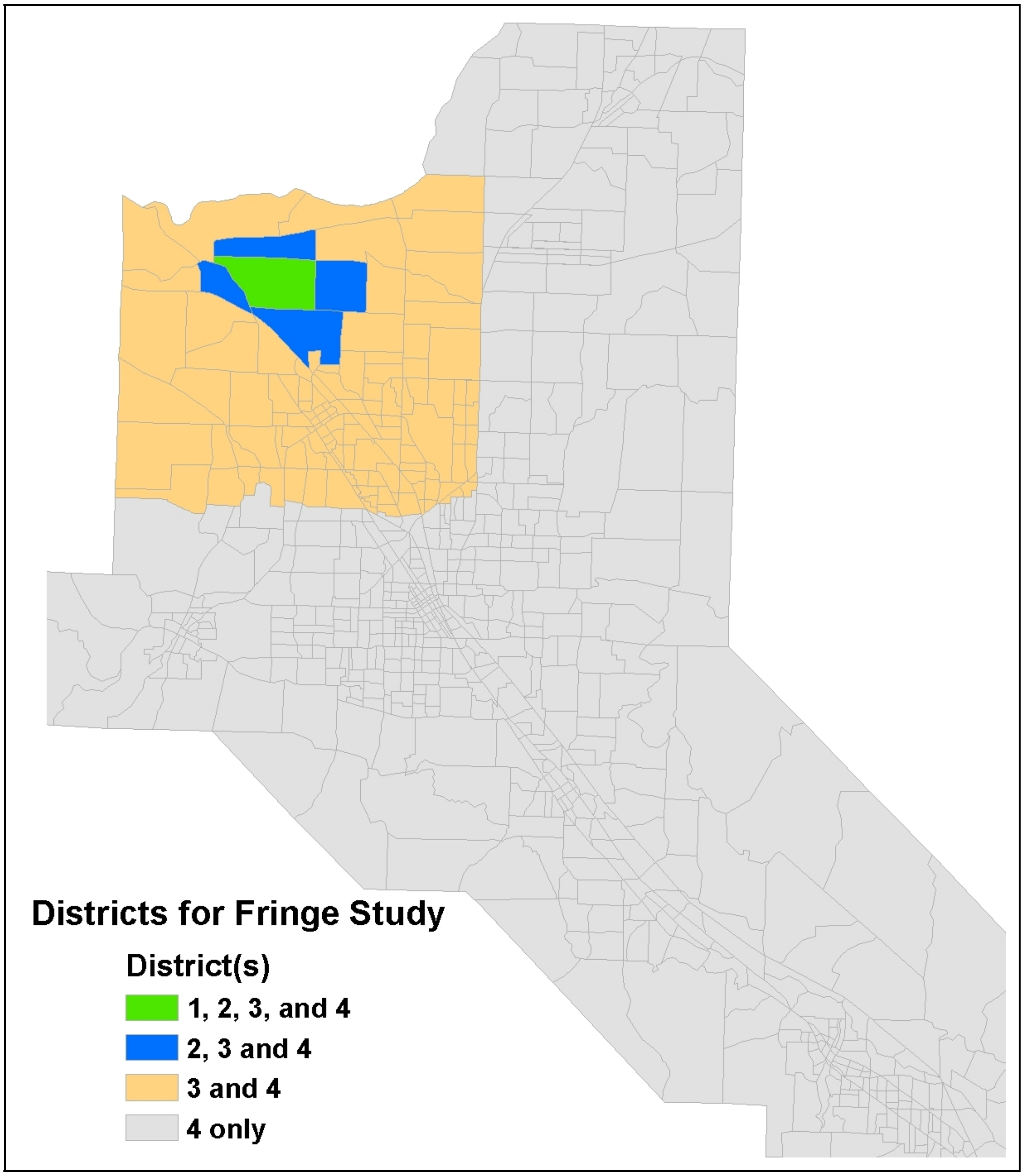

Figure 4.15: Location of TAZ 160 (in green) and the Study Districts Created for the Fringe Growth Sensitivity Test

4.7.1.2 Analysis of Model Results

The Fringe Growth scenario yielded results that differ substantially from the original Northgate scenario across nearly all metrics. While some of these results are to be expected as a consequence of the project's move to a new location, others point to the more rural character of the urban fringe site and its lack of transit service. As before, findings are presented by metric.

Network-wide V/C Changes

As depicted in Figure 4.16, the 2025 Fringe Growth scenario is projected to have a substantially smaller effect on regional v/c ratios, compared with the original Northgate scenario. The only noteworthy changes are at the I-5 interchange and roadways immediately adjacent to the site. One reason that these v/c changes are relatively small, compared with the original scenario, is that the Fringe Growth site is sufficiently far enough away from the bulk of the population in the region that is not attracting as many trips as were projected for the original site. In addition, the facilities nearest the site on the map have sufficient capacity to absorb the additional demand.

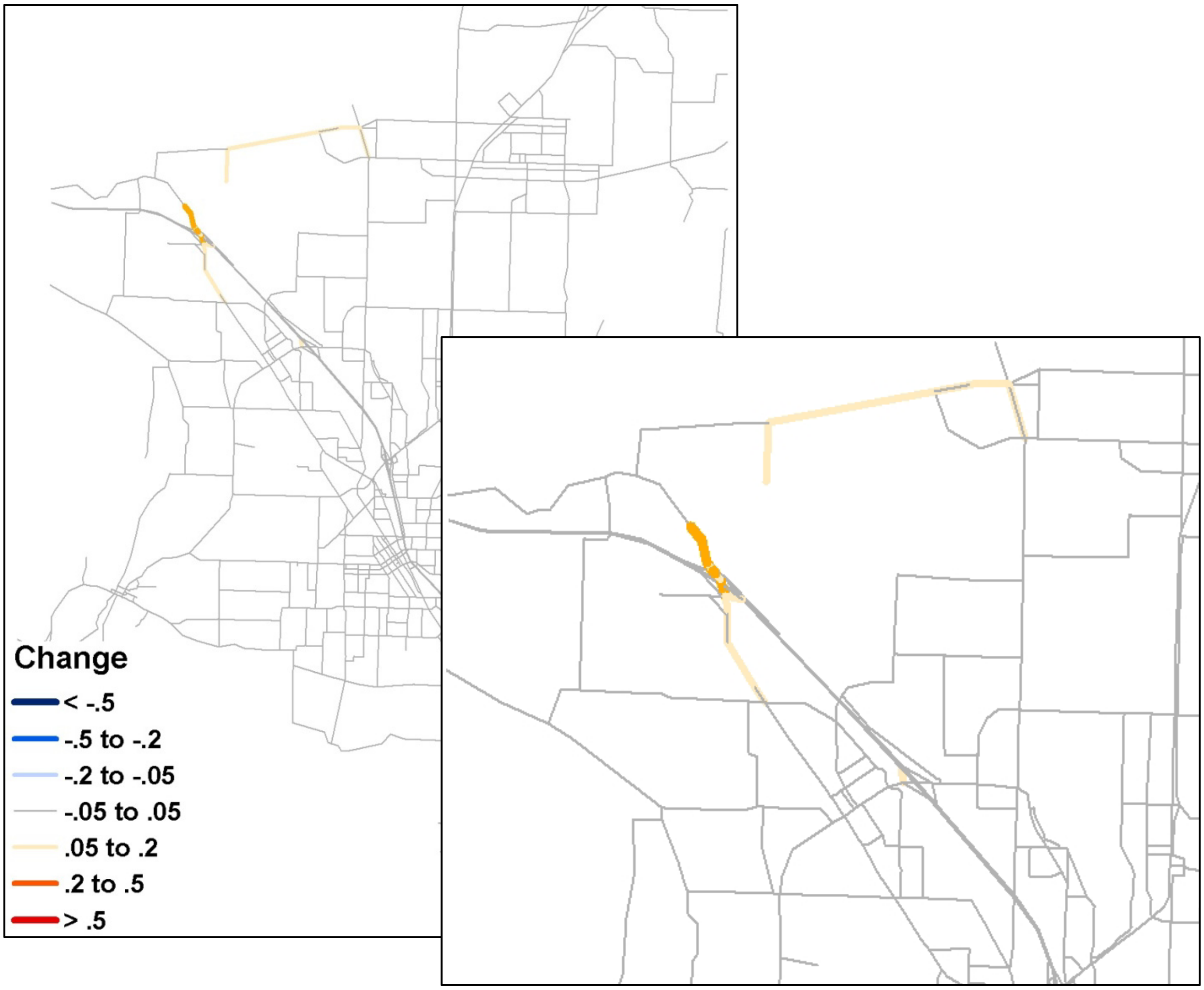

Figure 4.16: Absolute Changes in V/C Between 2025 Baseline and 2025 Fringe Growth Scenarios

Total Network Travel Time and Distance

Given the relatively modest impact on regional v/c ratios, as discussed above, it is not surprising that the Fringe Growth scenario also yields relatively little change in total region network travel distance and time. Table 4.18 indicates that the Fringe Growth scenario would result in little increase in regional Auto/Truck VMT or VHT, while producing slightly lower but noticeable reductions in transit trip miles and hours. Given the lack of transit service to the site, this is not surprising.

Table 4.18: Comparison of Changes in VMT and VHT for 2025 FringeGrowth Scenario

2025	Baseline	Original Northgate	Fringe Growth	Original % Change	Fringe % Change
Auto/Truck Vehicle Miles (VMT)	2,109,860	2,118,955	2,113,035	0%	0%
Auto/Truck Vehicle Hours (VHT)	80,681	81,061	80,710	0%	0%
Transit Trip Miles	4,049	3,945	3,999	-3%	-1%
Transit Trip Hours	3,600	3,450	3,521	-4%	-2%

Total Person Hours of Travel Time

A more dramatic outcome of the Fringe Growth scenario emerges when looking at total person hours of travel by mode and study district. Bearing in mind that the study district boundaries have been “redrawn” to emanate from TAZ 160 (as shown in Figure 4.15) it is apparent that the lack of activity and travel in that part of the region provides the analysis of change in PHT with a low starting point. As depicted in Table 4.19, there are no non-auto trips projected for TAZ 160 (District 1) in the Baseline scenario, and relatively few in total, even zooming out to District 3 (about 4 miles from the project site). Thus, changes across all modes that add trips to these areas and thereby increase PHT results in large percentage changes. At the full-regional level (represented by District 4) it is evident that the Fringe Growth scenario would result in small but significant reductions in PHT by non-auto modes, while increasing PHT by auto modes slightly.

Table 4.19: Changes to Total Person Hours of Travel Time: 2025 Baseline vs. Fringe Growth Scenarios

2025	Baseline by Study District				Fringe Growth by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	0	3	1,668	11,134	292	1,392	7,072	10,732	0%	40771%	324%	-4%
Bike	0	2	243	1,067	31	137	736	1,061	0%	6657%	203%	-1%
Walk to Bus	0	0	286	2,433	81	310	1,571	2,364	0%	0%	450%	-3%
PnR Bus	0	0	31	184	0	16	138	176	0%	0%	341%	-4%
Drive Alone	34	130	9,159	32,397	1,446	4,726	24,034	32,747	4117%	3530%	162%	1%
Drive w Pasg.	17	76	7,321	26,762	1,582	4,576	19,876	26,915	9113%	5958%	171%	1%
Passenger	15	66	7,707	28,682	1,804	5,095	21,050	28,694	11991%	7654%	173%	0%
All	67	277	26,415	102,660	5,237	16,251	74,477	102,689	7689%	5770%	182%	0%

The region-wide PHT results are similar to those obtained for the original Northgate scenario, but with slightly lower PHT by non-auto modes. Thus, the difference between locating a large development closer to an urban center and locating it on the urban fringe is most apparent in the results closest to the site. PHT can be misleading, however, because what appears to be a substantial change at the local level may be due to a low starting point and end up having little impact on local facilities, as previously shown in the analysis of v/c.

Average Person Trip Travel Times

The average person trip times by mode for the Fringe Growth scenario are shown in Table 4.20. Across all modes, the Fringe Growth scenario produces substantially lower average trip travel times in study districts close to the site. This is not because congestion has been relieved, but rather because the scenario has provided closer employment and shopping alternative for persons living in those TAZs, where there were next to none before. Thus nearby residents are making much shorter trips, because they no longer have to travel to Medford to meet basic needs. Because the network has a large amount of unused capacity at the northern edge of the study region, there is also little congestion to pose significant problems. As one zooms out to the full region level (District 4), these changes appear to be non-existent, with the exception of a 1 percent increase in drive alone travel times and a 1 percent decrease in walk travel times.

Table 4.20: Changes to Average Person Trip Travel Time: 2025 Baseline vs. Fringe Growth Scenarios

2025	**Baseline by Study District**				**Fringe Growth by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	47.5	31.0	14.9	11.5	29.4	23.0	13.8	11.4	-38%	-26%	-8%	-1%
Bike	23.8	20.2	11.8	8.6	9.2	10.4	9.8	8.6	-61%	-49%	-17%	0%
Walk to Bus	-	-	27.4	20.7	16.0	22.7	22.3	20.6	0%	0%	-19%	0%
PnR Bus	-	-	24.1	22.5	36.9	21.1	21.0	22.6	0%	0%	-13%	0%
Drive Alone	9.4	8.6	6.5	5.5	5.4	5.5	5.9	5.6	-42%	-36%	-8%	1%
Drive w Pasg.	10.3	9.5	6.8	5.9	5.7	5.9	6.3	5.9	-44%	-38%	-8%	0%
Passenger	10.1	9.3	6.5	5.7	5.4	5.6	6.0	5.7	-47%	-40%	-8%	0%
All	9.8	9.1	6.9	6.2	5.8	6.2	6.5	6.2	-41%	-32%	-6%	0%

Trip Length Distributions

An examination of trip length distributions substantiates the assertion that the Fringe Growth scenario is providing travelers in the northern part of the study region with closer destinations. The frequency distribution of trip lengths for the 2025 Baseline and Fringe Growth scenarios are shown in Figure 4.17. Compared with the original Northgate scenario, the figures depict more obvious changes in which much shorter trips are being made by persons traveling to and from TAZs in Districts 1, 2 and 3 in the Fringe Growth scenario, compared with the trip lengths attributed to these zones in the Baseline scenario. Table 4.21 shows the average trip lengths are spread somewhat uniformly across all modes.

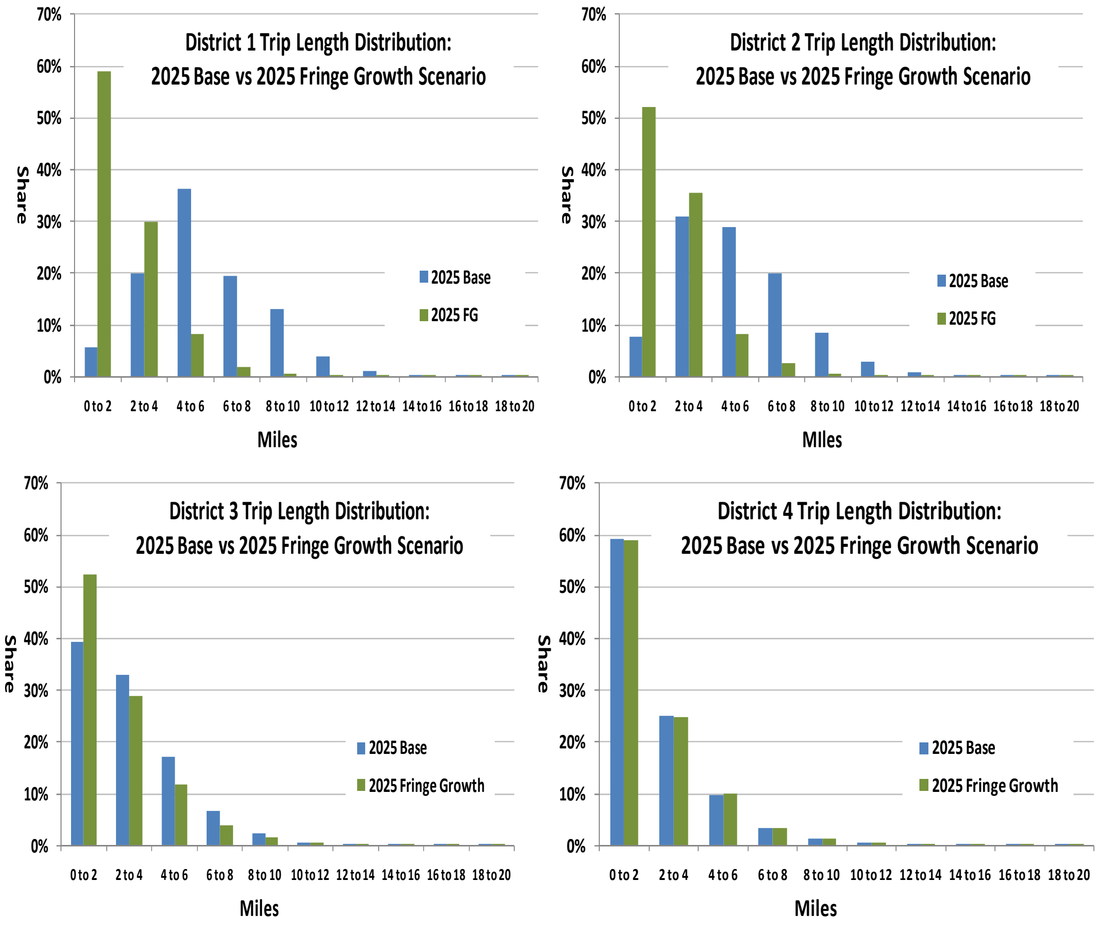

Figure 4.17 Trip Length Distributions (in miles) for the 2025 Baseline and Fringe Growth Scenarios

Table 4.21: Changes to Average Trip Distances (in miles): 2025 Baseline vs. Fringe Growth Scenarios

2025	Baseline by Study District				Fringe Growth by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	2.5	1.7	0.8	0.7	1.5	1.2	0.8	0.7	-40%	-30%	-8%	1%
Bike	4.0	3.4	2.0	1.4	1.5	1.7	1.6	1.4	-61%	-49%	-17%	0%
Walk to Bus	-	-	1.8	1.5	1.3	1.5	1.6	1.5	0%	0%	-12%	1%
PnR Bus	-	-	3.9	2.6	2.7	2.4	2.6	2.6	0%	0%	-33%	0%
Drive Alone	5.7	5.2	3.5	2.7	2.6	2.7	3.0	2.7	-55%	-48%	-15%	1%
Drive w Pass	5.7	5.1	3.0	2.3	2.1	2.3	2.5	2.3	-63%	-55%	-16%	1%
Pass	5.5	5.0	2.8	2.1	1.9	2.1	2.3	2.1	-66%	-58%	-17%	0%
All	5.6	5.1	3.0	2.3	2.2	2.3	2.5	2.3	-62%	-54%	-17%	1%

At the regional level (District 4), the Fringe Growth scenario has increased overall trip lengths by about 1 percent. The main likely reason for this increase is that the urban fringe location of Northgate project and its scale are large enough to attract demand from the entire region, diverting some trips from other less attractive TAZs that might actually be closer.

Mode Shares

Information on the effect of the Fringe Growth scenario on mode shares is presented in Tables 4.22 and 4.23, which show changes to mode shares and to the actual number of trips by mode, respectively. Both tables make it clear that the project would have large impacts in Districts 1-3 (within about 4 miles of the site) with large percentage gains in trips across all modes. In terms of mode shares, however, non-auto modes are non-existent within Districts 1 and 2 in the base case, and make modest gains in the Fringe Growth case. Zooming out to the full-regional level, the net effects of the Fringe Growth scenario are slight reductions in the share of non-auto modes for the region. This is to be expected since, as previously explained, the new development's location in TAZ 160 is projected to draw trips from around the region. It is also located where transit is largely unavailable.

Table 4.23 also contains an additional important piece of information. The total trips attracted to Districts 1 and 2 are 53,823 and 156,947, respectively. In contrast, the original 2025 Northgate scenario attracted 72,633 trips to its District 1 and 174,530 to District 2. Put another way, locating the project at the northern fringe of the study region would be projected to attract 26 percent fewer trips than if the project were built in its more central original location. Further, there would be 10 percent fewer trips attracted to the District within one mile of the site. This difference is likely due to the relative remoteness of the Fringe Growth scenario location and its lack of non-auto travel options.

Table 4.22: Changes to Mode Shares: 2025 Baseline and Fringe Growth Scenarios

2025	**Baseline by Study District**				**Fringe Growth by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	0%	0%	3%	6%	1%	2%	5%	6%	0%	537%	54%	-3%
Bike	0%	0%	1%	1%	0%	1%	1%	1%	29%	52%	23%	-1%
Walk to Bus	0%	0%	0%	1%	1%	1%	1%	1%	0%	0%	127%	-3%
PnR Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	70%	-5%
Drive Alone	54%	50%	37%	35%	30%	33%	35%	35%	-44%	-35%	-4%	0%
Drive w Pasg.	24%	26%	28%	27%	31%	30%	28%	27%	26%	12%	-1%	0%
Passenger	22%	23%	31%	30%	37%	35%	31%	30%	73%	49%	0%	0%
All	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%

Table 4.23: Changes to the Number of Trips by Mode: 2025 Baseline and Fringe Growth Scenarios

2025	**Baseline by Study District**				**Fringe Growth by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	0	7	6,702	58,103	597	3,626	30,811	56,430	0%	54939%	360%	-3%
Bike	1	6	1,238	7,455	206	791	4,530	7,404	16896%	13030%	266%	-1%
Walk to Bus	0	0	626	7,053	304	820	4,237	6,870	0%	0%	577%	-3%
PnR Bus	0	0	78	491	0	44	394	468	0%	0%	406%	-5%
Drive Alone	219	905	85,059	351,213	16,006	51,114	242,736	352,231	7198%	5551%	185%	0%
Drive w Pasg.	100	478	64,674	270,611	16,636	46,341	190,290	271,454	16490%	9604%	194%	0%
Passenger	89	423	70,903	301,944	20,074	54,212	211,172	302,012	22568%	12729%	198%	0%
All	410	1,817	229,279	996,869	53,823	156,947	684,171	996,869	13033%	8536%	198%	0%

Regional Accessibility to Employment

The motivation for travel to TAZ 160 from around the region is represented in the regional accessibility metric. As shown in Figure 4.18, the Fringe Growth scenario boosts regional auto accessibility by 2-to-3.4 percent region-wide, and more so closer to the project site.

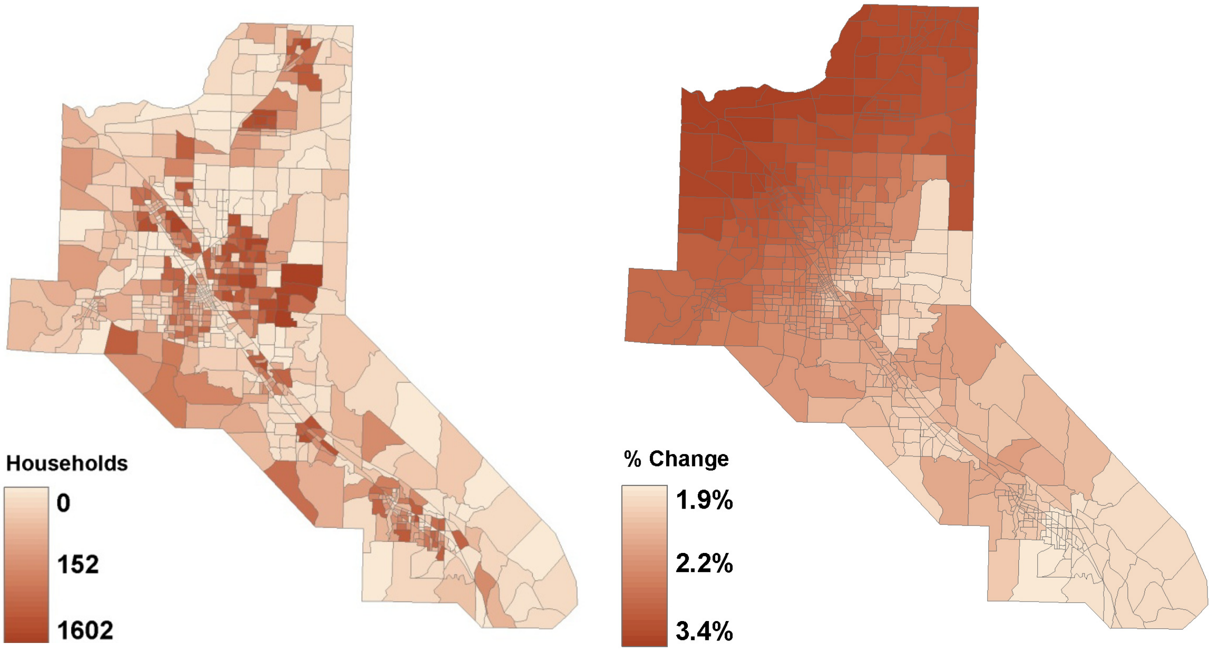

Figure 4.18: 2025 Total Households (left) and 2025 Percent Change in Regional Accessibility to Employment by Auto (right) Resulting From the Fringe Growth Scenario

Comparing this map with the map showing the location of households in 2025, it is apparent that the areas expected to gain the most in terms of access to employment tend to be more lightly populated, with the exception of Eagle Point in the far northeastern part of the region, gains a lot by the project. Interestingly, east Medford appears to gain little in terms of accessibility; however, this percentage change also reflects the fact that it already enjoys more access to employment opportunities than the rest of the region.

Examination of accessibility by transit and walk modes provides a distinct contrast. As shown in Figure 4.19, changes in accessibility by walking are high in terms of percentage gains immediately adjacent to TAZ 160. However, this is a lightly populated area, so the number of households benefitting is small. In addition, the analysis of changes in accessibility by transit showed no change across the region, given that the site does not have a direct transit connection. For this reason, a map of changes in accessibility by transit is not provided. For the sake of completeness, it should be mentioned that accessibility to retail employment (shopping opportunities) would provide results that look substantially the same as those shown in Figures 4.18 and 4.19, but with higher percentage values.

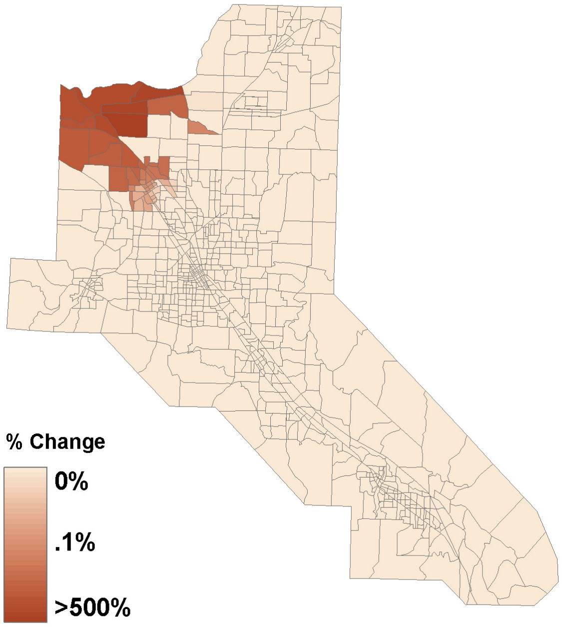

Figure 4.19: 2025 Percent Change in Regional Accessibility to Employment by Walking Resulting from the Fringe Growth Scenario

Local Accessibility (20-Minute Neighborhood)

Examination of local accessibility measures for the Fringe Growth scenario provides somewhat odd, albeit predictable results. Table 4.24 shows the results for both access to work and retail opportunities within a 20-minute time buffer of each TAZ. These results show no changes to transit accessibility, consistent with the regional measures discussed above. Local accessibility by auto increases fairly consistently across the region, but is greater closer to the site. Local accessibility by walking has a very large percentage increase within Districts 1 and 2 (within 1 mile of the site), with a more modest gain when viewed from the perspective of District 3 (within 4 miles). The net effect at the regional level (District 4) is a 2 percent increase.

Table 4.24: Changes in Local Accessibility (20-Minute Neighborhood): Baseline vs. Fringe Growth Scenarios

	Fringe Growth	Study District			
	Mode	*1*	*2*	*3*	*4*
Work	**Auto**	4%	4%	3%	2%
	Transit	-	-	-	-
	Walk	+999%	+999%	4%	0%
Retail	**Auto**	12%	11%	10%	7%
	Transit	-	-	-	-
	Walk	-	+999%	11%	2%

4.7.2 Scaling Up the Project

The original Northgate project inputs represented a set of land use inputs based on an actual development proposal. Examination of individual metrics revealed sensitivities to this particular set of inputs that varied by distance from the project site. Beyond four miles from the project site, impacts attenuate rapidly. If the project were actually smaller in magnitude, it is likely that many of the metrics would show even smaller differences from the baseline scenario in fairly predictable ways. If the project were much larger in magnitude, however, one would expect much more pronounced differences between baseline and build scenarios. These differences also might reveal different patterns, compared to the original Northgate scenario. In order to evaluate what the impacts of a much larger development might be, perhaps one that may be out of scale with the surrounding transportation network infrastructure, two scenarios were constructed in which the employment attributed to the Northgate project is multiplied by factors of two and five. While these scenarios might seem unlikely for the Medford study area, they are plausible for larger urban regions where higher densities are more common.

4.7.2.1 Description of Test

Additional employment was added to each industry sector for the three Northgate site TAZs. No changes were made to the roadway network in either scenario. The two scenarios are labeled as “Northgate 2X” and “Northgate 5X” to indicate the multiplicative factor applied to the original Northgate scenario. The land use inputs for the three Northgate TAZs for the “2X” scenario are shown in Table 4.25. This scenario adds 3,943 new jobs to the region for 2025, representing a 4.7 percent increase in total regional employment over the Baseline scenario.

The land use inputs for the three Northgate TAZs for the “5X” scenario are shown in Table 4.26. This scenario adds 10,390 new jobs to the region for 2025, representing a 12.5 percent increase in total regional employment over the Baseline scenario.

Table 4.25: 2025 Northgate “2X” Scenario Households, Population and Employment for Project Area

			Employment						
TAZ	Total Hhld.	Total Pop.	Total	Manuf'g.	Wh'lsale Trade	Retail Trade	Finance	Services	Other
340	0	0	2,284	0	0	1,793	109	382	0
344	0	0	1,444	0	0	0	200	1,244	0
345	4	9	1,032	178	7	632	54	161	0
Sum	4	9	4,760	178	7	2,425	363	1,787	0

Table 4.26: 2025 Northgate “5X” Scenario Households, Population and Employment for Project Area

			Employment						
TAZ	Total Hhld.	Total Pop.	Total	Manuf'g.	Wh'lsale Trade	Retail Trade	Finance	Services	Other
340	0	0	5,371	0	0	4,301	115	955	0
344	0	0	3,610	0	0	0	500	3,110	0
345	4	9	2,226	187	7	1,520	126	386	0
Sum	4	9	11,207	187	7	5,821	741	4,451	0

4.7.2.2 Analysis of Model Results

In this analysis, the original Northgate 2025 scenario was used as the basis for comparison with the 2X and 5X scenarios. The geographic focusing uses the same study districts employed for the original Northgate scenario (see Figure 4.6).

Network-wide V/C Changes

The impact of the 2025 Northgate 2X and 5X scenarios on the model network is depicted in Figures 4.20 and 4.21, respectively. Both maps show more links with increases in v/c than in the original 2025 Northgate scenario, and the 5X scenario causes more links to turn red, orange and yellow than the 2X scenario. These changes are happening farther away from the project site. This should not be a surprise given the amount of new employment added. However, it should be noted that the total number of regional trips in the model system is the same as in the original 2025 Northgate scenario. The reason for this, as explained in Section 4, is that the RVMPO model system is production based and therefore insensitive to the possibility of induced demand.

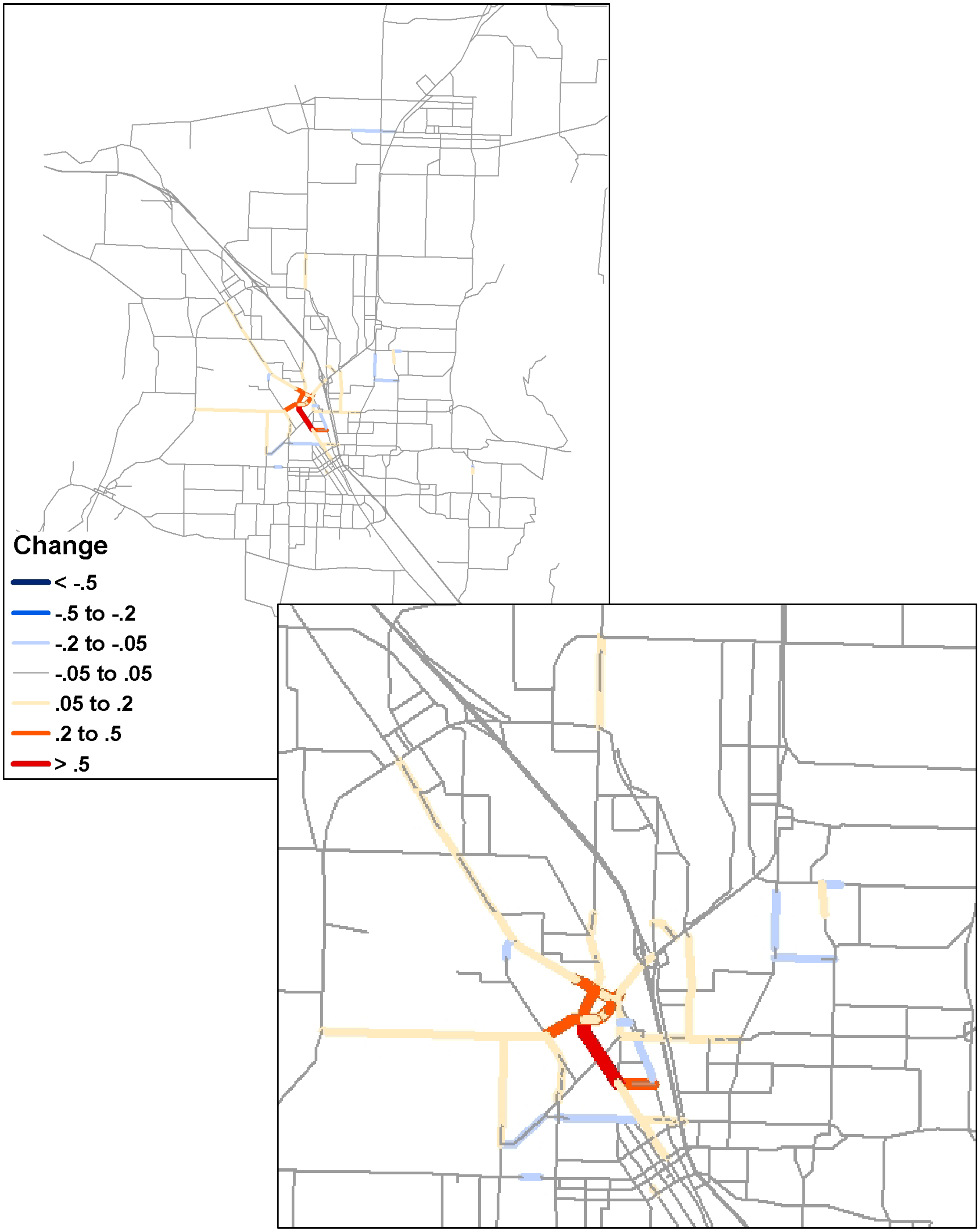

Figure 4.20: Absolute Changes in V/C between 2025 Baseline and 2025 Northgate “2X” Scenarios

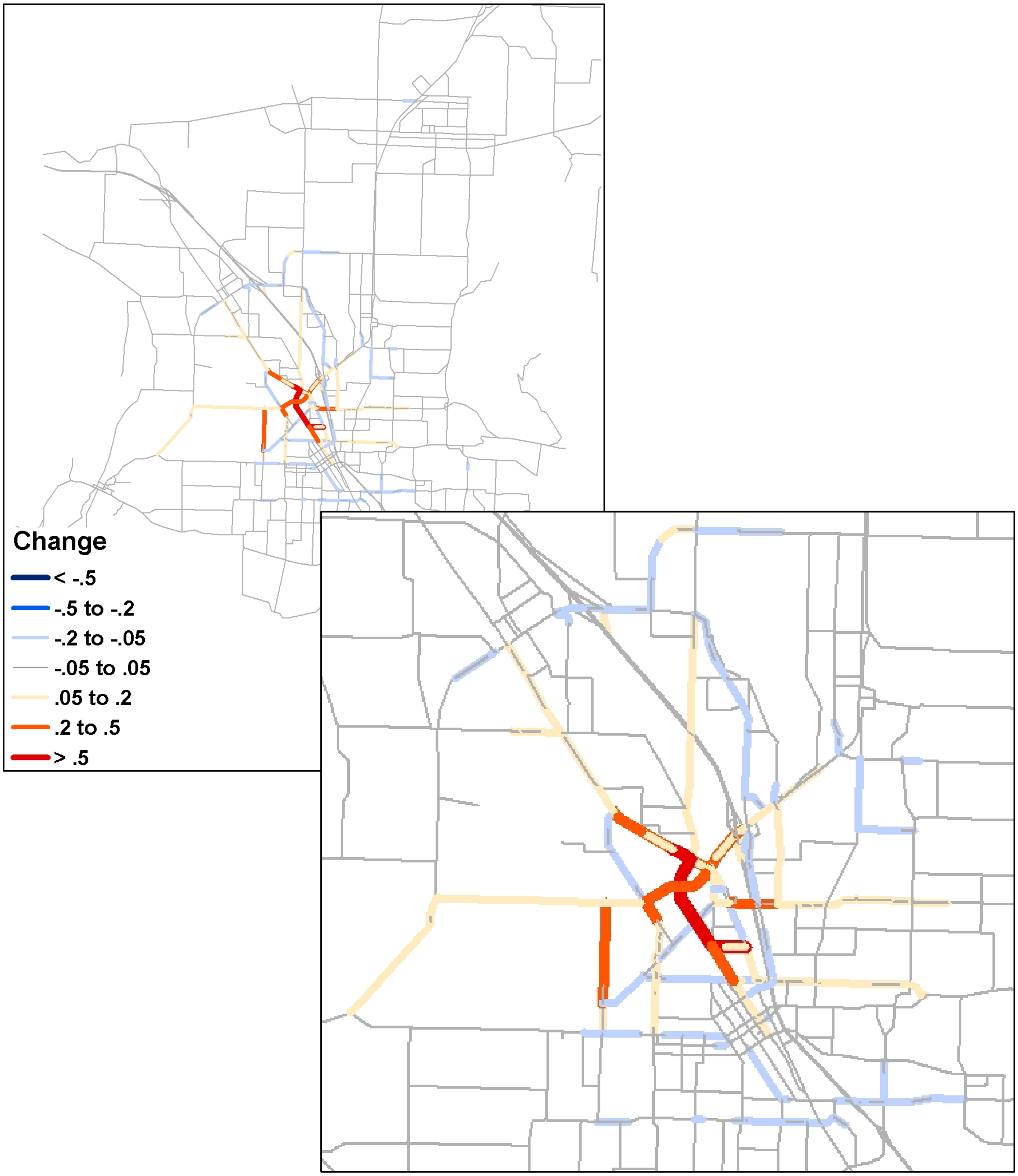

Figure 4.21: Absolute Changes in V/C between Baseline and 2025 Northgate “5X” Scenarios

Households thus do not generate any new trips. What the model does do, however, is redistribute demand spatially and among modes. Thus, it is possible to obtain more vehicle trips if there is a shift to from non-auto to auto, or from multiple-occupancy to single-occupancy auto. Figures 4.20 and 4.21 also show several new links turning blue, meaning that v/c ratios have actually decreased in those locations. More blue links show up in the 5X scenario than in the 2X scenario. Again, this is a result of a shift in destinations, which is more pronounced in the 5X scenario.

Total Network Travel Time and Distance

Total network travel time and miles traveled increase in rather predictable ways in both 2X and 5X scenarios, compared with both the baseline and the original Northgate scenario (see Table 4.27). Even though total trips are the same, the project attracts more trips from farther away in the region. In contrast, there are substantially fewer total person-trip miles and hours in these scenarios. As in the original Northgate scenario, there appears to be a diversion of trips from transit to auto modes.

Table 4.27: Change to Total Network Travel Distance and Time: 2025 Baseline vs. Northgate "2X" & "5X" Scenarios

2025	Baseline	Original Northgate	Northgate 2x	Northgate 5x	Original % Change	2X % Change	5X % Change
Auto/Truck Vehicle Miles (VMT)	2,109,860	2,118,955	2,121,320	2,128,652	0%	1%	1%
Auto/Truck Vehicle Hours (VHT)	80,681	81,061	81,133	81,401	0%	1%	1%
Transit Trip Miles	4,049	3,945	3,905	3,731	-3%	-4%	-8%
Transit Trip Hours	3,600	3,450	3,400	3,169	-4%	-6%	-12%

Total Person Hours of Travel Time

Examining person hours of travel by mode, it is apparent that as the project size increases there is a shift in PHT to trips originating at and destined to District 1 and, to a lesser extent, to District 2. This can be seen in Tables 4.28 and 4.29 for the Northgate 2X and 5X scenarios, respectively. When aggregating up to the District 3 level, there appears to be little impact on total PHT.

Table 4.28: Total Person Hours of Travel Time: 2025 Baseline vs. Northgate "2X" Scenarios

2025	Baseline by Study District				Northgate 2X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	50	1,272	7,329	11,134	505	1,553	7,088	10,718	908%	22%	-3%	-4%
Bike	5	120	742	1,067	53	155	743	1,061	898%	29%	0%	-1%
Walk to Bus	11	269	1,615	2,433	96	315	1,553	2,343	783%	17%	-4%	-4%
PnR Bus	0	17	145	184	0	15	136	173	0%	-9%	-7%	-6%
Drive Alone	251	3,823	23,851	32,397	2,384	5,546	24,404	32,741	848%	45%	2%	1%
Drive w Pasg.	204	3,581	19,826	26,762	2,552	5,413	20,295	26,973	1153%	51%	2%	1%
Passenger	225	3,999	21,136	28,682	2,896	6,030	21,541	28,750	1185%	51%	2%	0%
All	747	13,081	74,645	102,660	8,486	19,027	75,759	102,760	1036%	45%	1%	0%

Table 4.29: Total Person Hours of Travel Time: 2025 Baseline vs. Northgate “5X” Scenarios

2025	Baseline by Study District				Northgate 5X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	50	1,272	7,329	11,134	972	1,850	6,792	10,207	1842%	45%	-7%	-8%
Bike	5	120	742	1,067	103	192	739	1,047	1837%	60%	0%	-2%
Walk to Bus	11	269	1,615	2,433	162	344	1,462	2,215	1387%	28%	-9%	-9%
PnR Bus	0	17	145	184	1	14	124	159	0%	-19%	-15%	-14%
Drive Alone	251	3,823	23,851	32,397	4,802	7,563	25,038	33,103	1810%	98%	5%	2%
Drive w Pasg.	204	3,581	19,826	26,762	4,936	7,313	20,670	27,039	2323%	104%	4%	1%
Passenger	225	3,999	21,136	28,682	5,471	8,016	21,743	28,553	2328%	100%	3%	0%
All	747	13,081	74,645	102,660	16,447	25,292	76,566	102,324	2102%	93%	3%	0%

Tables 4.28 and 4.29 also provide evidence that the demand being shifted toward Districts 1 and 2 is more likely to be auto than not. At the regional level, District 4 results show net losses in PHT by walk, bike and transit modes, while auto modes gain. This suggests that trips that were previously made locally (e.g., shopping) are now being attracted to the Northgate site. Thus, the larger the number of attractors at Northgate (i.e., 2X; 5X), the greater the pull.

Average Person Trip Travel Times

Calculation of average trip times for these same modes provides much the same picture. Overall, average trip travel times decrease within about one mile of the project site, as shown in Tables 4.30 and 4.31 for the 2X and 5X scenarios, respectively. Interestingly, bike and walk modes benefit the most since trips originating in Districts 1 and 2 previously had fewer options. At the District 2 level, however, walk trips lengthen in travel time because more person are choosing to walk farther, attracted by what Northgate has to offer. These effects are further amplified in the 5X scenario (shown in Table 4.31), which shows significantly shorter average trip times for all modes except park-and-ride. At the regional level, District 4 average travel times show almost no change, with small increases for walk, drive along, and park-and-ride.

Table 4.30: Changes to Average Person Trip Travel Time (in minutes): 2025 Baseline vs. Northgate “2X” Scenarios

2025	Baseline by Study District				Northgate 2X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	28.0	21.6	13.4	11.5	24.4	22.6	13.9	11.8	-13%	5%	4%	2%
Bike	11.1	10.6	9.7	8.6	9.0	10.1	9.7	8.6	-19%	-5%	0%	0%
Walk to Bus	16.5	25.8	22.4	20.7	16.4	22.4	22.2	20.6	-1%	-13%	-1%	0%
PnR Bus	0.0	21.1	21.0	22.5	43.0	21.4	21.1	22.6	0%	1%	0%	1%
Drive Alone	5.8	5.5	5.9	5.5	5.2	5.5	5.9	5.6	-9%	-1%	0%	1%
Drive w Pasg.	6.0	5.9	6.2	5.9	5.6	5.8	6.2	5.9	-7%	-2%	0%	0%
Passenger	5.7	5.7	5.9	5.7	5.3	5.5	5.9	5.7	-7%	-3%	0%	0%
All	6.2	6.3	6.5	6.2	5.7	6.1	6.5	6.2	-9%	-3%	0%	0%

Table 4.31: Changes to Average Person Trip Travel Time (in minutes): 2025 Baseline vs. Northgate "5X" Scenarios

2025	Baseline by Study District				Northgate 5X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	28.0	21.6	13.4	11.5	22.3	22.3	14.3	12.1	-20%	3%	7%	5%
Bike	11.1	10.6	9.7	8.6	8.2	9.3	9.6	8.6	-26%	-12%	-1%	0%
Walk to Bus	16.5	25.8	22.4	20.7	16.7	20.9	22.2	20.7	1%	-19%	-1%	0%
PnR Bus	0.0	21.1	21.0	22.5	44.0	21.9	21.3	22.9	0%	4%	1%	2%
Drive Alone	5.8	5.5	5.9	5.5	5.2	5.4	5.9	5.6	-10%	-2%	0%	1%
Drive w Pasg.	6.0	5.9	6.2	5.9	5.4	5.6	6.1	5.9	-10%	-5%	-1%	0%
Passenger	5.7	5.7	5.9	5.7	5.0	5.3	5.8	5.6	-12%	-7%	-2%	-1%
All	6.2	6.3	6.5	6.2	5.5	5.8	6.4	6.2	-12%	-7%	-1%	0%

Trip Length Distributions

Compared with the original Northgate scenario, examination of the trip-length distributions produced in the 2X and 5X scenarios reveals a shortening of trip lengths within Districts 1 and 2, with Scenario 5X trip lengths showing greater variation than Scenario 2X. As shown in Figure 4.22, trip lengths become longer when aggregated to the level of Districts 3 and 4, to the point where they become essentially indistinguishable from the Baseline scenario.

Average trip distances by mode essentially mirror the patterns discussed above for average travel times by mode. Average trip distances are shown in Tables 4.32 and 4.33 for the 2X and 5X Scenarios, respectively. Shorter trips are being made with one mile of the site (Districts 1 and 2); however, there are more long trips being made from farther away in the region. At the regional level, the net impact is about a one percent gain in average trip lengths, with larger percentage increases in average trip length for the non-auto modes. These mode-specific effects are slightly greater in the 5X scenario than the 2X scenario.

Table 4.32: Changes to Average Trip Distance (in miles): 2025 Baseline vs. Northgate "2X" Scenarios

2025	Baseline by Study District				Northgate 2X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	1.4	1.1	0.8	0.7	1.2	1.1	0.8	0.7	-12%	5%	3%	2%
Bike	1.8	1.8	1.6	1.4	1.5	1.7	1.6	1.4	-19%	-5%	0%	0%
Walk to Bus	1.3	1.5	1.5	1.5	1.3	1.5	1.6	1.5	-1%	-5%	1%	1%
PnR Bus	0.0	2.4	2.6	2.6	2.7	2.4	2.6	2.7	0%	0%	1%	1%
Drive Alone	2.8	2.7	2.9	2.7	2.5	2.7	2.9	2.7	-11%	-1%	1%	1%
Drive w Pasg.	2.3	2.3	2.5	2.3	2.1	2.2	2.5	2.3	-10%	-3%	0%	1%
Passenger	2.1	2.1	2.3	2.1	1.9	2.0	2.3	2.1	-11%	-5%	-1%	0%
All	2.4	2.3	2.5	2.3	2.1	2.3	2.5	2.3	-12%	-3%	0%	1%

Table 4.33: Changes to Average Trip Distance (in miles): 2025 Baseline vs. Northgate “5X” Scenarios

2025	Baseline by Study District				Northgate 5X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	1.4	1.1	0.8	0.7	1.1	1.1	0.8	0.7	-18%	4%	6%	4%
Bike	1.8	1.8	1.6	1.4	1.4	1.6	1.6	1.4	-26%	-12%	-1%	0%
Walk to Bus	1.3	1.5	1.5	1.5	1.3	1.4	1.6	1.5	0%	-7%	3%	3%
PnR Bus	0.0	2.4	2.6	2.6	2.8	2.4	2.7	2.7	0%	0%	2%	3%
Drive Alone	2.8	2.7	2.9	2.7	2.5	2.6	2.9	2.7	-12%	-2%	1%	2%
Drive w Pasg.	2.3	2.3	2.5	2.3	2.0	2.1	2.4	2.3	-15%	-8%	-1%	0%
Passenger	2.1	2.1	2.3	2.1	1.7	1.9	2.2	2.1	-18%	-12%	-3%	-1%
All	2.4	2.3	2.5	2.3	2.0	2.2	2.5	2.3	-16%	-7%	0%	1%

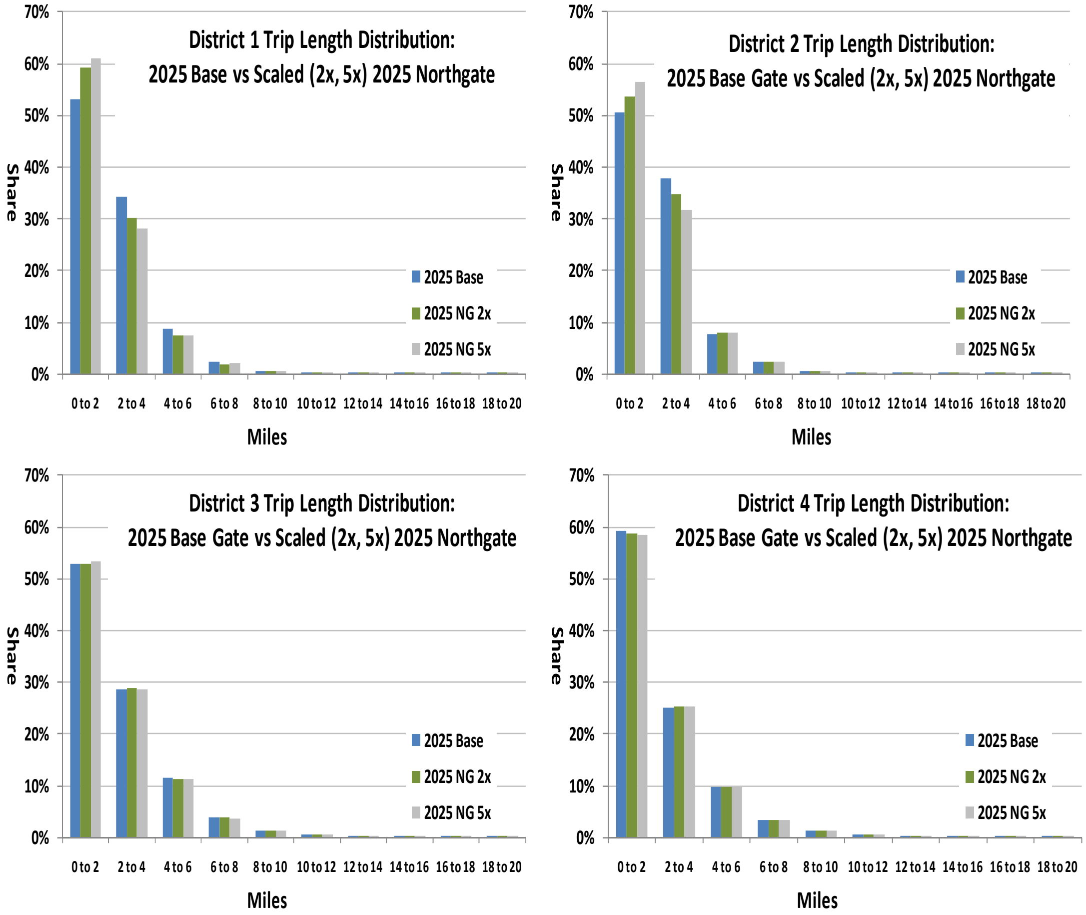

Figure 4.22: Trip Length Distributions (in miles) for the 2025 Baseline and Northgate “2X” & “5X” Scenarios

Mode Shares

The impacts of the Northgate 2X and 5X scenarios on mode shares are summarized in Tables 4.34-4.37. Tables 4.34 and 4.36 show mode shares for the 2X and 5X scenarios, respectively. Tables 4.35 and 4.37 show the actual number of trips by mode for these scenarios. In general, the results show that while more trips are being made to TAZs within Districts 1 and 2 by all modes, a larger share is being made by auto, with the largest percentage gains going to the passenger and drive-with-passenger modes. As in the previous scenarios, this appears to be the result of the large proportion of retail employment at the project site and the fact that shopping trips often tend to involve multiple household members.

Further, the actual number of trips being made by the non-auto modes, especially transit, is very low in the Baseline scenario, suggesting that the level of service may not be particularly attractive. Consequently, it is not surprising that a larger number of new trips use other modes.

Zooming out to the full region, District 4 values indicate a net decrease in mode share for all non-auto modes, with the largest percentage losses being walk and park-and-ride mode shares. While park-and-ride may be disregarded due to its small representation in the Baseline model, the reduction in walk trips seems to be a more solid outcome. The shift in trips away from previous locations and to the Northgate site may thus represent a shift away from neighborhood shopping.

Table 4.34: Changes to Mode Shares: 2025 Baseline and Northgate "2X" Scenarios

2025	**Baseline by Study District**				**Northgate 2X by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	1%	3%	5%	6%	1%	2%	4%	5%	-7%	-23%	-8%	-6%
Bike	0%	1%	1%	1%	0%	0%	1%	1%	-1%	-10%	-2%	-1%
Walk to Bus	1%	1%	1%	1%	0%	0%	1%	1%	-28%	-10%	-5%	-3%
PnR Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	-40%	-9%	-7%
Drive Alone	36%	33%	35%	35%	30%	32%	35%	35%	-16%	-3%	0%	0%
Drive w Pasg.	28%	29%	28%	27%	31%	30%	28%	27%	8%	2%	1%	1%
Passenger	33%	34%	31%	30%	37%	35%	31%	30%	12%	3%	1%	0%
All	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%

Table 4.35: Changes to the Number of Trips by Mode: 2025 Baseline and Northgate "2X" Scenarios

2025	**Baseline by Study District**				**Northgate 2X by Study District**				**Percent Change**			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	107	3,526	32,773	58,103	1,241	4,115	30,622	54,572	1057%	17%	-7%	-6%
Bike	29	676	4,599	7,455	355	917	4,597	7,383	1136%	36%	0%	-1%
Walk to Bus	40	625	4,320	7,053	352	844	4,192	6,815	789%	35%	-3%	-3%
PnR Bus	0	47	416	491	1	42	386	459	0%	-10%	-7%	-7%
Drive Alone	2,622	41,628	243,231	351,213	27,279	60,882	248,080	352,962	940%	46%	2%	0%
Drive w Pasg.	2,044	36,158	191,229	270,611	27,490	55,783	196,055	272,065	1245%	54%	3%	1%
Passenger	2,384	42,185	213,363	301,944	33,057	65,518	218,488	302,613	1287%	55%	2%	0%
All	7,225	124,845	689,931	996,869	89,776	188,101	702,421	996,869	1143%	51%	2%	0%

Table 4.36: Changes to Mode Shares: 2025 Baseline and Northgate "5X" Scenarios

2025	Baseline by Study District				Northgate 5X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	1%	3%	5%	6%	1%	2%	4%	5%	-2%	-32%	-17%	-13%
Bike	0%	1%	1%	1%	0%	0%	1%	1%	6%	-12%	-3%	-2%
Walk to Bus	1%	1%	1%	1%	0%	0%	1%	1%	-41%	-24%	-12%	-9%
PnR Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	-62%	-19%	-15%
Drive Alone	36%	33%	35%	35%	31%	32%	35%	36%	-15%	-3%	0%	1%
Drive w Pasg.	28%	29%	28%	27%	31%	30%	28%	27%	8%	3%	1%	1%
Passenger	33%	34%	31%	30%	36%	35%	31%	30%	10%	4%	1%	0%
All	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%

Table 4.37: Changes to Number of Trips by Mode: 2025 Baseline and Northgate "5X" Scenarios

2025	Baseline by Study District				Northgate 5X by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	107	3,526	32,773	58,103	2,619	4,976	28,411	50,692	2341%	41%	-13%	-13%
Bike	29	676	4,599	7,455	757	1,236	4,631	7,326	2531%	83%	1%	-2%
Walk to Bus	40	625	4,320	7,053	581	987	3,950	6,433	1368%	58%	-9%	-9%
PnR Bus	0	47	416	491	1	37	349	417	0%	-22%	-16%	-15%
Drive Alone	2,622	41,628	243,231	351,213	55,459	83,888	254,209	355,094	2015%	102%	5%	1%
Drive w Pasg.	2,044	36,158	191,229	270,611	54,922	77,834	201,696	273,682	2587%	115%	5%	1%
Passenger	2,384	42,185	213,363	301,944	65,471	91,250	224,374	303,224	2646%	116%	5%	0%
All	7,225	124,845	689,931	996,869	179,809	260,209	717,619	996,869	2389%	108%	4%	0%

Regional Accessibility to Employment Opportunities

The impact of the 2025 Northgate 2X and 5X scenarios on regional accessibility to employment by auto is shown in Figure 4.23. Both 2X and 5X scenarios display spatial patterns very similar to that of the original 2025 Northgate scenario (see Figure 4.11), but the scale on each map reveals higher intensity in the 2X scenario and the highest intensity in the 5X scenario. If these maps were transformed into 3-D representations, the 5X map would show the highest peaks.

The outcome is much the same for accessibility to employment by walk and by transit, as shown in Figure 4.24. Here the contrasts are even sharper, with very large increases in walk mode accessibility concentrated within one mile of the Northgate TAZs, and transit accessibility following bus routes. As previously discussed, although accessibility improvements would appear to lead to increases in mode usage for walk and transit, these effects are very localized and only benefit persons living in those TAZs. Thus while the scale effects may seem impressive, regional outcomes leave the majority of TAZs with no improvement in regional accessibility by walk or transit modes.

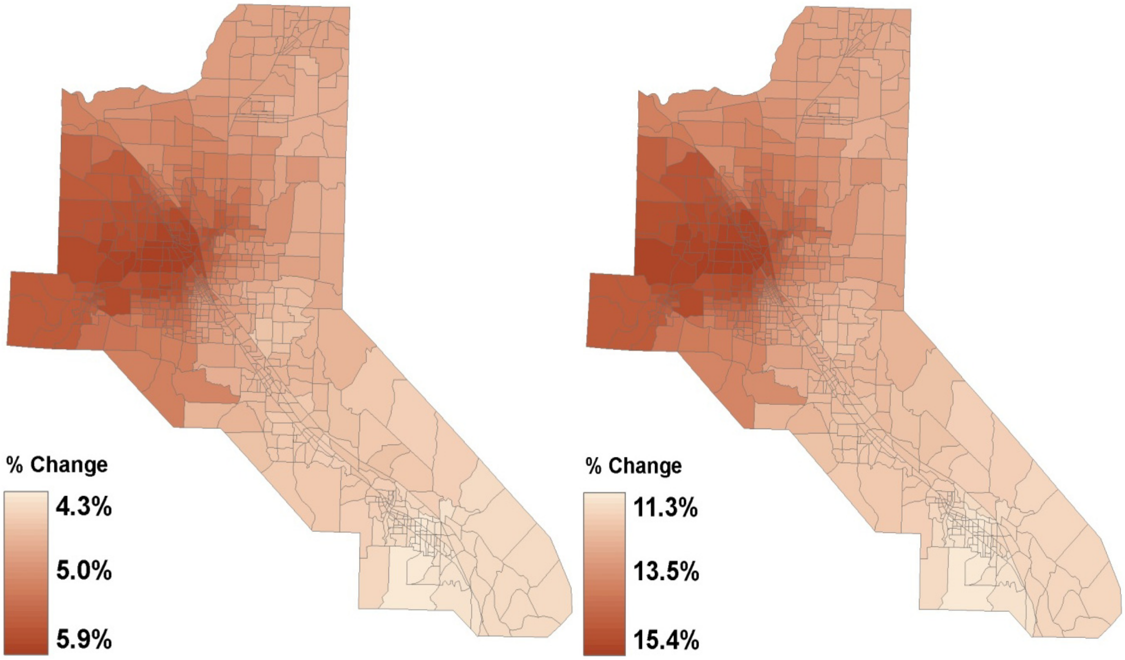

Figure 4.23: Changes in Regional Accessibility to Employment for the Northgate "2X" (left) and "5X" (right) Scenarios

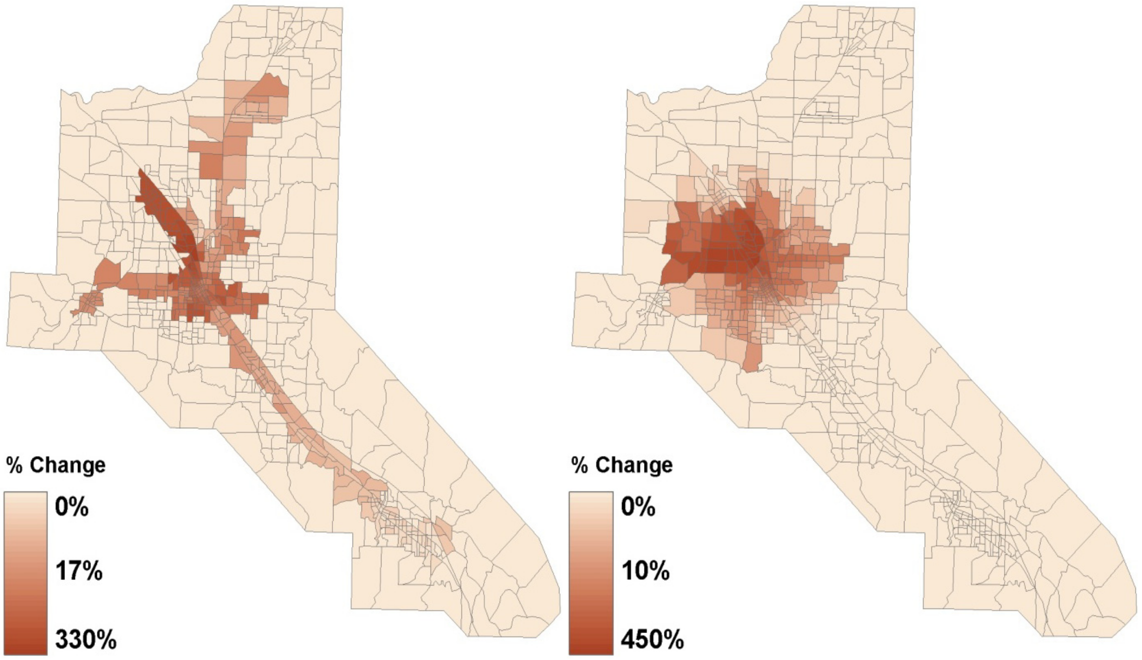

Figure 4.24: Changes in Regional Accessibility to Employment for the Northgate "5X" Scenario by Transit (left) and by Walking (right)

Local Accessibility (20-Minute Neighborhood)

The local accessibility metrics for the 2025 Northgate 2X and 5X scenarios reveal patterns that are similar to the regional accessibility metric. The percentage changes in the number of work and retail opportunities that can be reached within 20 minutes of travel time by each of the three primary modes are shown in Table 4.38. The increases are relatively flat across the four districts, because the entire region is accessible within a 20-minute car ride, yet there are marked differences between total employment (work) and retail employment, and between the 2X and 5X scenarios.

When considering transit and walk modes, this metric becomes more meaningful. As shown in the table, there are very large percentage increases in local transit accessibility for TAZs within Districts 1 and 2 for walk accessibility within District 1. The large increases in local transit and accessibility persist when aggregated to the level of Districts 3 and 4, but are clearly lower. Further, it is interesting that auto shows the largest percentage gain in local accessibility at the regional (District 4) level. This helps explain the larger mode share gains for auto relative to other modes at the regional level.

Table 4.38: Changes in Local Accessibility (20-Minute Neighborhood): Northgate "2X/5X" Scenarios

	Mode	Northgate 2X by District				Northgate 5X by District			
		1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Work	**Auto**	6%	6%	6%	6%	16%	16%	15%	14%
	Transit	39%	38%	3%	2%	106%	104%	7%	6%
	Walk	239%	47%	4%	3%	628%	122%	9%	7%
Retail	**Auto**	19%	20%	19%	18%	48%	49%	48%	46%
	Transit	74%	115%	15%	11%	186%	288%	37%	29%
	Walk	366%	80%	12%	9%	916%	200%	29%	23%

4.7.3 Conservation of Growth

The original Northgate scenario assumed that the project would add new employment to the region that would not otherwise be present in the Baseline scenario. As discussed in Section 4.3, the assumption of added growth is standard practice in TIAs and is generally held to be reasonable for new development proposals in general. In some cases, however, a land use change proposal may come before ODOT that would represent a "zero net growth" assumption. A "zero net growth" assumption might arise in a comprehensive planning exercise in which a city or region is interested in considering alternative growth management policies. Typically, such an exercise would have the goals of concentrating land use in designated commercial centers or near major transit centers. A scenario such as this would re-allocate activity to designated growth areas, while subtracting an equivalent amount from other areas in order to conserve the same level of region-wide growth.

4.7.3.1 Description of Test

In order to create a “Conservation of Growth” scenario, the 2025 Northgate scenario was modified as follows:

- Employment totals for the three Northgate TAZs were left unchanged from the original scenario.
- Equivalent amounts of employment by industry sector were subtracted from other TAZs in the region, such that total regional employment by industry sector remained the same as in the original Northgate scenario. Each TAZ’s employment was reduced in proportion to that TAZ’s share of regional employment in that particular industry sector for in the Baseline scenario. Thus, a TAZ with a large number of service sector jobs would have more jobs removed than one with fewer service sector jobs. A bucket-rounding method was used to ensure that jobs were removed in whole numbers rather than fractions and to ensure the target regional totals were conserved.

4.7.3.2 Analysis of Model Results

The results of the 2025 Conserve Growth scenario are compared to the 2025 Baseline scenario to evaluate how changes between the Conserve Growth scenario and the Baseline scenario might differ from the changes between the original Northgate scenario and the Baseline case. Since total employment is not increasing regionally and is being shifted from some TAZs to the Northgate site, the expectation is that accessibility will likewise be reduced in some parts of the region.

Network-wide V/C Changes

Changes to v/c ratios relative to the 2025 Baseline scenario are shown in Figure 4.25. This figure portrays results that are fairly similar to the original 2025 Northgate, but with several more links showing decreased v/c ratios in blue. Given the reduction in employment elsewhere in the region, one might expect more links to show smaller v/c values, but this is not the case, most likely because the reductions were spread throughout the region.

Total Network Travel Time and Distance

Metrics showing total network travel time and distance show how similar the Conserved Growth scenario results are relative to the original 2025 Northgate scenario outcomes. As shown in Table 4.39, the Conserved Growth scenario results in a 1 percent gain in VHT, but no appreciable change in VMT. It also results in small but noticeable decreases in transit trip miles and hours.

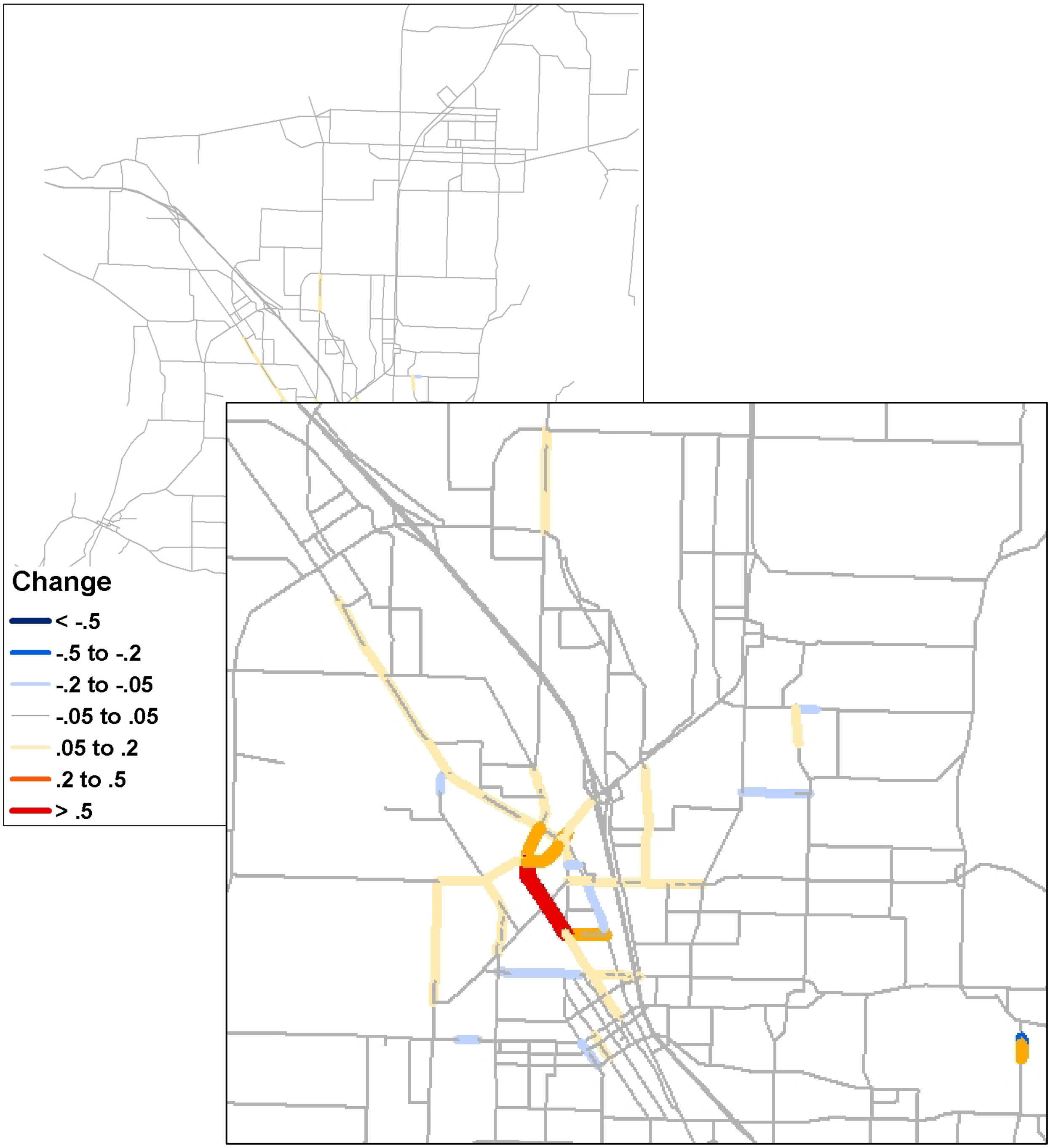

Figure 4.25: Absolute Changes in V/C between the 2025 Baseline and 2025 Conserved Growth Scenarios

Table 4.39: Change to Total Network Travel Distance and Time: 2025 Baseline vs. Conserved Growth Scenarios

2025	Baseline	Original Northgate	Conserved Growth	Original % Change	Conserved % Change
Auto/Truck Vehicle Miles (VMT)	2,109,860	2,118,955	2,119,977	0%	0%
Auto/Truck Vehicle Hours (VHT)	80,681	81,061	81,115	0%	1%
Transit Trip Miles	4,049	3,945	3,929	-3%	-3%
Transit Trip Hours	3,600	3,450	3,423	-4%	-5%

Total Person Hours of Travel Time

Similar to the original 2025 Northgate scenario, the Conserved Growth scenario shows large increases in PHT by all modes except park-and-ride within District 1 and still-noticeable increases within District 2. These results are shown below in Table 4.40. When aggregated to the District 3 level, reductions in PHT by all non-auto modes and commensurate increases in PHT by auto become evident. On balance, total PHT for the region increases by less than one percent.

Table 4.40: Total Person Hours of Travel Time: 2025 Baseline vs. Conserved Growth Scenarios

2025	Baseline by Study District				Conserved by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	50	1,272	7,329	11,134	415	1,498	7,142	10,823	729%	18%	-3%	-3%
Bike	5	120	742	1,067	44	149	744	1,064	726%	24%	0%	0%
Walk to Bus	11	269	1,615	2,433	92	317	1,571	2,365	750%	18%	-3%	-3%
PnR Bus	0	17	145	184	0	15	138	176	0%	-7%	-5%	-4%
Drive Alone	251	3,823	23,851	32,397	1,972	5,234	24,305	32,707	684%	37%	2%	1%
Drive w Pasg.	204	3,581	19,826	26,762	2,161	5,132	20,236	26,971	961%	43%	2%	1%
Passenger	225	3,999	21,136	28,682	2,468	5,729	21,488	28,762	995%	43%	2%	0%
All	747	13,081	74,645	102,660	7,151	18,074	75,624	102,868	858%	38%	1%	0%

Average Person Trip Travel Times

Table 4.41 shows average person trip travel times for the Conserved Growth scenario. Predictably, average travel times within District 1 are reduced relative to the Baseline scenario across all modes but park-and-ride. Within District 2, average trip travel times are still lower than the Baseline, especially for walk-to-bus, but are higher for the walk mode. As District 2 comprises an approximate one-mile buffer around the Northgate site, this appears to be evidence of persons being willing to walk farther to access what the site has to offer.

Table 4.41: Changes to Average Person Trip Travel Time (in minutes): 2025 Baseline vs. Conserved Growth Scenarios

2025	Baseline by Study District				Conserved by Study District				Percent Change			
Mode	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***	***1***	***2***	***3***	***4***
Walk	28.0	21.6	13.4	11.5	26.6	23.0	13.8	11.8	-5%	6%	3%	2%
Bike	11.1	10.6	9.7	8.6	9.0	10.2	9.7	8.6	-19%	-4%	0%	0%
Walk to Bus	16.5	25.8	22.4	20.7	16.0	22.4	22.2	20.6	-3%	-13%	-1%	0%
PnR Bus	0.0	21.1	21.0	22.5	41.3	21.3	21.0	22.6	0%	1%	0%	0%
Drive Alone	5.8	5.5	5.9	5.5	5.3	5.5	5.9	5.6	-8%	0%	0%	1%
Drive w Pasg.	6.0	5.9	6.2	5.9	5.6	5.9	6.2	6.0	-6%	-2%	0%	0%
Passenger	5.7	5.7	5.9	5.7	5.3	5.6	5.9	5.7	-6%	-2%	0%	0%
All	6.2	6.3	6.5	6.2	5.7	6.1	6.5	6.2	-8%	-3%	0%	0%

Trip Length Distributions

The effect of the Conserved Growth scenario on trip-length distributions is also very similar to that of the original 2025 Northgate scenario, as shown in Figure 4.26 and Table 4.42. Compared with the Baseline scenario, shorter trip lengths prevail across all modes with trip ends in Districts 1 and 2. Trip lengths are about equal to the Baseline at the District 3 level, and are slightly longer than the Baseline trip lengths at the District 4 level. (For the sake of brevity, only Districts 1 and 4 are shown in Figure 4.26.)

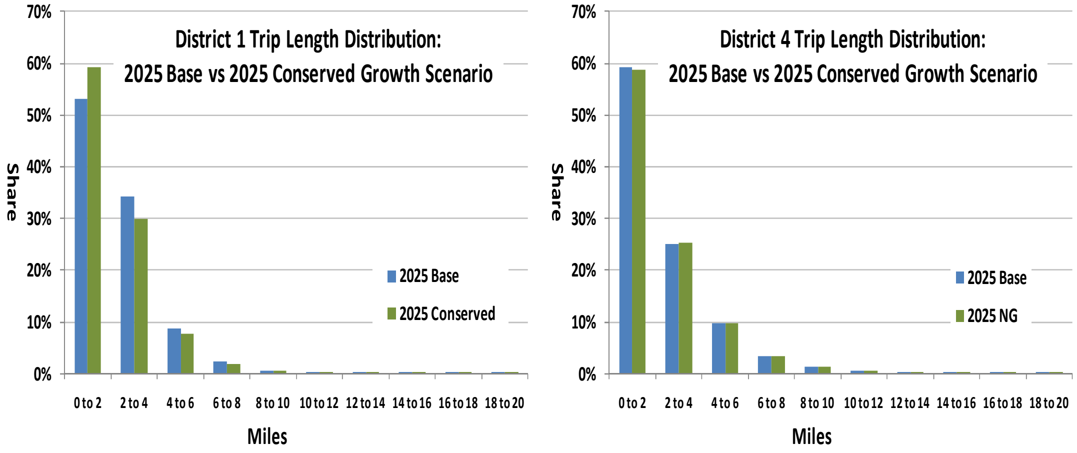

Figure 4.26: Trip Length Distributions (in miles) for the 2025 Baseline and Conserved Growth Scenarios for Districts 1 and 4

Table 4.42: Changes to Average Trip Distances (in miles): 2025 Baseline vs Conserved Growth Scenarios

2025	Baseline by Study District				Conserved by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	1.4	1.1	0.8	0.7	1.3	1.2	0.8	0.7	-4%	6%	3%	2%
Bike	1.8	1.8	1.6	1.4	1.5	1.7	1.6	1.4	-19%	-4%	0%	0%
Walk to Bus	1.3	1.5	1.5	1.5	1.3	1.5	1.6	1.5	0%	-5%	1%	1%
PnR Bus	0.0	2.4	2.6	2.6	2.7	2.4	2.6	2.7	0%	0%	0%	1%
Drive Alone	2.8	2.7	2.9	2.7	2.5	2.7	2.9	2.7	-11%	-1%	1%	1%
Drive w Pasg.	2.3	2.3	2.5	2.3	2.1	2.2	2.5	2.3	-10%	-3%	0%	1%
Passenger	2.1	2.1	2.3	2.1	1.9	2.1	2.3	2.1	-11%	-4%	0%	0%
All	2.4	2.3	2.5	2.3	2.1	2.3	2.5	2.3	-12%	-2%	0%	1%

Mode Shares

The impact of the Conserved Growth scenario on mode shares is shown in Table 4.43. The results are again similar to the original 2025 Northgate scenario. Despite increases in the number of trips by every mode to Districts 1 and 2, the share of those trips is dominated by multiple-occupancy auto trips. Zooming out to the full region, District 4 shows a net decrease in non-auto mode shares compared to the Baseline scenario.

Table 4.44 shows the changes in the actual number of trips by mode. Under the Conserved Growth scenario, District 1 would attract three percent more trips (74,989 vs. 72,633) than the original 2025 Northgate scenario. The reason for this is that the competition from other sites has been dampened by the reduction in employment elsewhere throughout the region.

Table 4.43: Changes to Mode Shares: 2025 Baseline and Conserved Growth Scenarios

2025	Baseline by Study District				Conserved by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	1%	3%	5%	6%	1%	2%	4%	6%	-16%	-22%	-7%	-5%
Bike	0%	1%	1%	1%	0%	0%	1%	1%	-2%	-9%	-1%	-1%
Walk to Bus	1%	1%	1%	1%	0%	0%	1%	1%	-16%	-4%	-3%	-2%
PnR Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	-35%	-6%	-5%
Drive Alone	36%	33%	35%	35%	30%	32%	35%	35%	-18%	-3%	0%	0%
Drive w Pasg.	28%	29%	28%	27%	31%	30%	28%	27%	9%	2%	1%	0%
Passenger	33%	34%	31%	30%	37%	35%	31%	30%	13%	3%	0%	0%
All	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%

Table 4.44: Changes to the Number of Trips by Mode: 2025 Baseline and Conserved Growth Scenarios

2025	Baseline by Study District				Conserved by Study District				Percent Change			
Mode	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Walk	107	3,526	32,773	58,103	936	3,903	30,979	55,219	772%	11%	-5%	-5%
Bike	29	676	4,599	7,455	292	872	4,597	7,398	914%	29%	0%	-1%
Walk to Bus	40	625	4,320	7,053	346	851	4,246	6,881	774%	36%	-2%	-2%
PnR Bus	0	47	416	491	0	44	394	468	0%	-8%	-5%	-5%
Drive Alone	2,622	41,628	243,231	351,213	22,383	57,235	246,975	352,651	754%	37%	2%	0%
Drive w Pasg.	2,044	36,158	191,229	270,611	23,109	52,618	195,219	271,884	1031%	46%	2%	0%
Passenger	2,384	42,185	213,363	301,944	27,923	61,838	217,478	302,368	1071%	47%	2%	0%
All	7,225	124,845	689,931	996,869	74,989	177,362	699,888	996,869	938%	42%	1%	0%

Regional Accessibility to Employment Opportunities

The most notable outcome of the analysis of the Conserved Growth scenario is its impact on accessibility measures. Figure 4.27 shows both positive (red) and negative (blue) changes in accessibility.

This is the only scenario analyzed in which accessibility is reduced in some TAZs, which is attributable to the assumption that the growth represented by Northgate would have occurred somewhere else. The places in the maps where TAZs of a positive value lie adjacent to a TAZ of a negative values appear to indicate thresholds at which the cost of travel outweighs attractiveness of employment opportunities for that particular mode.

The Conserved Growth scenario portrays a situation in which the Northgate project would improve accessibility by auto to the Northwest part of the region, particularly just west of I-5 in Medford, while reducing access to employment in other locations due to competitive losses in the central and southern portions of the region, as shown in the map in the upper right corner of Figure 4.27. These losses in accessibility should be evaluated in terms of the number of persons or households affected in each TAZ, as shown in the map in the upper left corner of Figure 4.27.

In terms of accessibility by transit, the map in the lower left corner indicates that only a small area immediately adjacent to the site and along transit lines to the northwest would benefit from the concentration of employment at Northgate, while accessibility along transit lines leading northeast, west and south of Northgate would be reduced. In terms of walk accessibility to employment, the map in the lower right corner of the figure shows positive changes within about one mile of the site and negative changes throughout much of the remainder of the region. Interestingly, there are a few walk access positive changes in spots along the I-5 corridor and at the northern edge of the region, possibly benefitting from employment losses in adjacent TAZs.

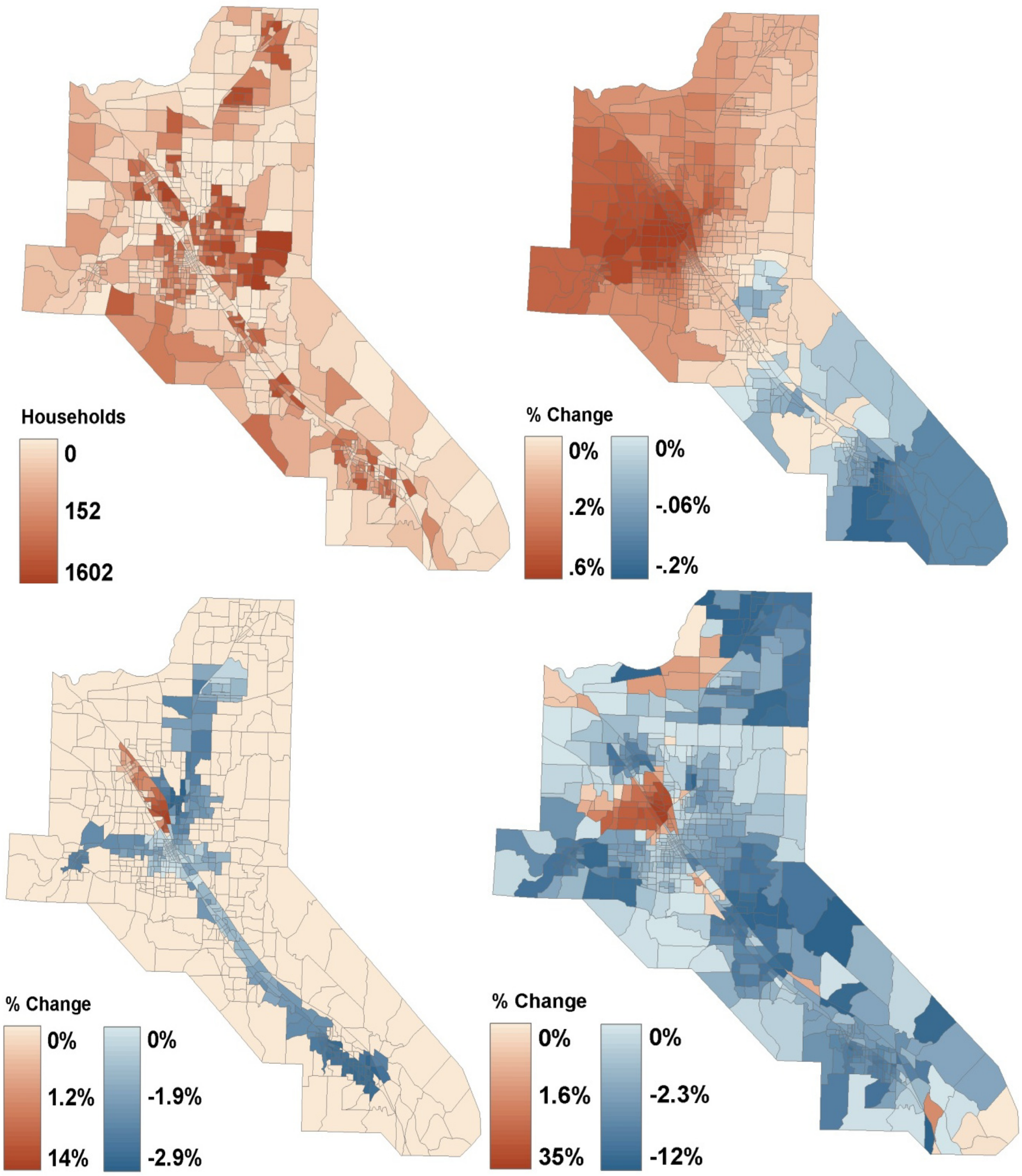

Figure 4.27: 2025 Households (upper left); Percent Change in Regional Accessibility to Total Employment by Auto (upper right); by Transit (lower left); and by Walk (lower right) Resulting From the Conserved Growth Scenario

Local Accessibility (20-Minute Neighborhood)

The local accessibility metric for the 2025 Conserved Growth scenario shows smaller percentage changes across all modes and study districts, compared with the other scenarios. As shown in Table 4.45, local access to total employment (work) and retail employment (shopping) by auto is fairly flat across the region. The ability to reach employment and shopping opportunities within 20 minutes by transit and walk modes improves within Districts 1 and 2, but declines for the region as a whole.

As with regional accessibility, this is the first scenario that indicated reduced accessibility at any level of spatial aggregation. Thus if a land use plan reflects a redistribution of employment rather than an actual gain, some areas will likely be negatively affected. The net impact will depend on the efficiency of this redistribution relative to where people live and, to a lesser extent, how well the transportation system serves these new destinations.

Table 4.45: Changes in Local Accessibility (20-Minute Neighborhood): Conserved Growth Scenario (relative to 2025 Baseline)

	Conserved Growth	Study District			
	Mode	*1*	*2*	*3*	*4*
Work	**Auto**	1%	1%	1%	0%
	Transit	12%	13%	-1%	-2%
	Walk	106%	19%	-1%	-1%
Retail	**Auto**	1%	1%	1%	1%
	Transit	29%	50%	-1%	-3%
	Walk	177%	32%	-3%	-4%

4.7.4 Summary of Sensitivity Tests

The sensitivity tests have provided additional insights into the nature of the performance metrics under consideration, as well as the behavior of the modeling tool itself. The various scenarios tested yielded travel behavior changes that were generally consistent with expectations, and the metrics themselves also generally performed well in representing the corresponding mobility consequences. General observations on the sensitivity tests can be summarized as follows:

- The ***Fringe Growth*** scenario demonstrated that locating a project in an area that is more removed from population will have a smaller impact on surrounding transportation facilities, provided they are adequately sized, compared with locating the same project in an urban center. While a fringe-located project is likely to attract almost exclusively auto trips, it will also attract substantially fewer patrons. The metrics that do well in portraying these consequences include the network-wide v/c, PHT by mode and study district, average person minutes by mode and study district, regional accessibility to employment, and number of trips by mode and study district.
- The ***Scaled Up Project*** scenarios demonstrated that as the intensity of a project increases, one can expect greater shifts in destinations throughout the region. The impacts on roadway system links included both positive and negative changes to v/c in response to shifts in travel demand patterns. At the local level, near the project site, the new activity opportunities result in increasing numbers of shorter trips by all modes, but especially by walk and transit. These are trips that might have otherwise traveled farther, likely by auto. At the full regional level, this scenario illustrated a countervailing force in which the greater the intensity of the project, the more likely it is to attract patrons from

throughout the region, bringing new trips to the project site, mostly by auto. The metrics that best capture these effects include network-wide v/c, PHT by mode and study district, average person minutes by mode and study district, regional accessibility to employment, and number of trips by mode and study district.

- The ***Conserved Growth*** scenario demonstrated that where there is a redistribution of the spatial arrangement of land uses, resulting in a zero net gain in employment, one can expect corresponding adjustments in the spatial distribution of trips. Further, even with no change in regional employment, the concentration of activity at a single location is likely to draw trips from much further away, particularly in a region with less competition among destinations. The metrics that best captured the dynamics of this scenario were regional accessibility to employment and local accessibility, both of which highlighted where gains and losses in accessibility would occur and for which modes. The network-wide v/c plots also did well in showing where individual facilities would be affected.
- This scenario was far from conclusive, though, partially due to the nature of the inputs. In an alternate (untested) case, for example, one could disperse the employment from the Northgate project across multiple, smaller nodes, thereby creating a number of smaller regional centers. This might actually result in improved accessibility in more locations and possible net reductions in trip lengths and net increases in walk and bicycle trips.

4.8 SYNTHESIS

In this section the strengths and weaknesses of each of the alternative mobility metrics are discussed in light of the findings of the scenario analyses. In particular, there is an interest in knowing which metrics tend to consistently reveal information that can be used to inform decision making and at what level of geographic resolution. Integral to this appraisal is the identification of contexts in which a particular metric might fail to provide useful information. A secondary objective is to assess how each measure co-varies with network-wide v/c changes.

4.8.1 Meta Lessons

As a first step, it is important to recognize modeled outcomes that tend to recur across scenarios and are reflected in multiple metrics. It is also important to recognize which modeled phenomena are artifacts of the method and which appear to be reflecting observable travel behavior. Given these considerations, the following generalizations can be drawn from the scenario analyses:

- ***The geographic distance at which one measures land use change impacts is all important.*** The study district analysis revealed clearly that the level of aggregation used to tabulate metrics may have profound impacts on the outcomes. These results would seem to be incontrovertible and not an artifact of the modeling methods. The most dramatic impacts will be experienced closest to the site of a land use change, with most metrics showing attenuated impacts further out. In this analysis, impacts attenuated at about four miles, but this may not be true for all regions. This has important implications for how mobility metrics are administered, the potential role of municipalities in establishing boundary conditions, and the role of ODOT or a regional government in coordinating cross-jurisdictional impacts analyses.

- ***At the regional level, all modeled scenarios led to slight increases in auto travel and slight net reductions in non-auto travel.*** This suggests that the nature of the development—with a large retail component—is one that is likely to attract more auto trips, regardless of location. To the extent that trips are attracted regionally, auto may dominate all other options, particularly if there is sufficient unused capacity. It may also suggest that in order for there to be a greater benefit to non-auto modes, additional transit service would need to be provided. An additional consideration is that the model estimates bus travel times as a function of congested travel times on the network and using straight multiplicative factors. This means that bus travel times become worse at an accelerated rate compared with auto travel times, which might not always be true.

- ***The concentration of a large amount of commercial development in a single location has non-linear increasing affects on trip attractions.*** This is borne out by the fact that in nearly every build scenario, there is a slight net increase in trip lengths, meaning people are willing to travel farther. It is possible that the model is overly sensitive to the attractiveness of the project; however, it is more likely that the model is appropriately sensitive and this case study reflects a context reality. In a relatively small urbanized region, a large development can make a "big splash," drawing demand from farther away than the same project would in a larger metropolitan area in which there is more competition. There is theoretical support for this possibility in the decisions of commercial businesses to co-locate, providing agglomeration benefits by providing more activity opportunities in a single location for patrons. This observation also has the negative implication that the notion that large regional shopping centers siphon away customers of smaller, neighborhood businesses. Had the employment from the Northgate project been dispersed to several smaller regional centers, this effect would no doubt have been smaller and, with enough intensity at each regional center, close to population, inter-city trip making may have actually been reduced.

- ***Because the model system is production constrained and because the build scenarios assume only increases in employment, without increases in households and workers, scenarios involving an increase, decrease or change in location of employment due to the Northgate project all produced the same number of total trips for the region.*** This is an artifact of the modeling system and the land use inputs, although not completely without merit. Evidence suggests that induced demand is more likely to result from persons traveling farther rather than making more trips. Nevertheless, the first step in making the model system more responsive would be to reformulate the trip distribution step, so that it is either doubly-constrained, or so that at least home-based work trips are attraction constrained, meaning that as the number of jobs increases, so to do the number of work trips. Implicitly, this would be tantamount to assuming that the project would promote higher labor force participation rates. These are not trivial changes that would require re-formulation of model components. Another, simpler option would be for the analyst preparing the land use plan to assume some in-migration to the region and add households with more workers to the land use inputs. More advanced modeling systems account for induced demand in other ways, such as including accessibility-related variables in trip generation equations.

4.8.2 Assessment of Mobility Metric Performance

The strengths and weaknesses of individual mobility metrics in their ability to provide consistent and meaningful insights into the impacts of a land use change proposal are easier to evaluate by looking across the various scenario outcomes. A summary assessment of each metric follows.

4.8.2.1 Network-wide V/C Changes

V/C remains the most direct way to evaluate operational impacts of a land use change on facility performance. As with the other metrics, the model used to project v/c changes showed the greatest impacts closest to the site. With increases in the intensity of development, v/c impacts spread outward in gradual, reasonable patterns, which appeared to be consistent with the study district treatment explored with the other metrics.

This study considered not only links for which v/c was projected to increase, but also links for which v/c was expected to decrease, meaning some capacity was freed up due to the change in area travel patterns. This offers the possibility of crediting a land use change proposal for freeing up capacity, which could be used to offset its negative impacts on other facilities.

From behavioral and policy standpoints, v/c's weakness is that it provides little insight into why traffic volume changes have occurred. Specifically, it does not indicate to what extent an increase/decrease in link volumes is due to shifts in trip frequencies, destinations, modes, or routes. Thus, it does not provide an indication of the net benefits to the traveling public.

4.8.2.2 Total Network Travel Time and Distance

Total network travel time (VHT) and distance (VMT) are frequently cited statistics in transportation planning documents and are appealing because they aim to capture the total amount of vehicular travel in a region, which has broader implications for greenhouse gas emissions and wear and tear on roadways. Although this particular study utilized a model that did not separate out truck VHT/VMT from that of auto, this would be possible with a model system that used multi-class network assignment methods.

Theoretical advantages notwithstanding, the analysis did not provide particularly convincing evidence that VHT and VMT were insightful measures of land use change impacts for several reasons. First, the necessity of system-wide calculations resulted in regional values of the metrics that showed very little change between baseline and build scenarios. This is partly due to the spatial diffusion and compensating effects in the network. Another reason for the lack of response is the fore-mentioned model structure, which constrains total trip production to household-level rates. While this might be seen as a limitation of the model system, it is also consistent with research on induced demand; that it is primarily due to persons traveling farther rather than more often. Thus, VHT/VMT would be expected to reveal larger changes in total travel times and distances for land use change proposals that included an increase in the number of households, but would remain relatively flat for proposals that only included a non-residential component. Moreover, VMT and VHT do not provide any indication of benefits to the traveling public and are less precise than v/c in terms of documenting operational performance.

This study also considered person-miles and hours of travel time on transit, an output of the travel model's transit assignment process. This did show more sensitivity to changes between scenarios, perhaps because it covers a much smaller travel market. Nevertheless, network-wide transit travel distance and time reductions could be the result of either fewer trips in general, shorter trips, or a shift in trips away from transit. At this aggregate level, these metrics provide little insight. In addition, this analysis does not pinpoint which transit routes would be affected most, limiting its value for operational analysis.

4.8.2.3 Total Person Hours of Travel Time

The analysis reported person hours of travel (PHT) by mode and by district. Across all scenarios, PHT provided a fairly consistent picture of the amount of travel, expressed as time, being allocated to each mode. In most of the scenarios, PHT showed consistent (sometimes dramatic) increases in District 1 (project site); additional but smaller increases in District 2; and yet smaller percentage changes in District 3. At the full-regional level, PHT's net outcomes were near zero in the aggregate, with some small but noticeable changes for the non-auto modes, which have a low starting value in the Baseline case. There was definitely variation between the scenarios, with much more dramatic increases in the Fringe Growth scenario due to the low values of its Baseline condition.

PHT is appealing because it captures both increases in trip lengths, expressed as time, as well as mode shifts. For this reason, it has policy relevance in attributing the benefits of a project to different segments of the population. Similar to VMT and VHT, it provides an estimate of the total amount of travel and differentiates it by mode. In this particular analysis, PHT was limited by the modeling system's lack of consideration of trips with external trip ends and consideration of truck trips. The wide variation of the magnitude of changes across different study districts also raises questions as to the appropriate level of geographic focus and whether it is stable enough across possible land use change scenarios to be used to support regulatory decisions.

4.8.2.4 Average Person Trip Travel Times

Average person trip travel times expressed in minutes (APM) was included in this study as an alternative to PHT. It does not represent the total amount of travel in the way that PHT does, but rather more narrowly focuses on the differences in travel time being experience by persons traveling by each mode. The advantage of APM over PHT is that it provides a more stable set of output values due to the normalization of travel time by number of trips.

The study broke down APM by district. Across all scenarios, APM consistently showed noticeable percentage decreases in travel times within District 1 for all modes, and within District 2 for all modes but walk and park-and-ride. By combining the knowledge that PHT for pedestrians increased while average travel times for pedestrians decreased, as measured by APM, it was apparent that the Northgate project was inducing persons to walk farther. In such cases, walking farther and incurring longer travel times is not necessarily a bad thing, particularly if it is being done to reach a more desirable destination. This is where strict interpretation of increased travel times as a negative benefit is problematic.

In some ways, APM is an indicator of changes in travel time and average traveler delay; however, it is not the same as facility delay and should not be interpreted as such. APM rolls changes in destinations as well as changes in route times into a single measure. While it appears to present a stable range of values, determining the appropriate level of geographic resolution remains an issue.

4.8.2.5 Trip Length Distributions

Trip length distributions (TLD) are standard output from travel demand models and have the advantage of providing a direct measure of changes in trip lengths resulting from a land use change. Average trip lengths also provide a normalized estimate of changes in trip distances. In this study, it was found that the spatial redistribution of trips between origins and destinations was the primary force behind changes to regional travel patterns, more so than changes in mode. TLDs and average trip lengths are a good indicator of that change.

While the graphic depiction of trip length distributions is a good way to illustrate changes, frequency distributions alone do not provide enough information. Average trip lengths by mode provide a better estimate of how far people have adjusted their travel patterns and produced consistent, predictable values across the range of scenarios in this study. Examined at the different study district levels, average trip lengths show how persons adjust their trips, by creating more short trips close to the project site, while lengthening their trips farther away from the project site. In this sense it provides about the same information value as average person minutes, but lacks the interpretation of average traveler delay.

4.8.2.6 Mode Shares

Mode shares are also standard output from a travel demand modeling system and provide the most direct way to evaluate whether a land use change would have an impact on mode usage. Mode shares are also discussed frequently in transportation planning documents. Expressed as percentages, with impacts expressed as percentage change in the percentages, changes in mode shares have the potential to be misleading. For this reason, the absolute number of trips by mode was also considered. Changes in both mode shares and in the number of trips by mode were tabulated by study district.

The number of trips by mode is not as useful a mobility metric as it is a check on the relevance of mode shares and, potentially, average trip travel times and distances. The table summaries indicate the magnitude of the trips, including where there are few or no trips by a particular mode in the baseline case. In addition, examination of the District 1 (project site) values show the number of trips that the project is likely to attract under each scenario, which has interesting implications. For example, this revealed that the Fringe Growth scenario was likely to attract 26 percent fewer trips than the original Northgate site.

Modeling results revealed consistent indications that all of the project scenarios were likely to result in increases to auto modes, particularly for multiple occupant. Transit, bike and walk mode shares were clearly projected to decline. At the local level, a shift to multiple occupancy auto travel was expected because the project had a large retail component, and shopping trips are more likely to involve multiple household members than, for example, commute trips. At the full regional level, the multiple occupancy effect washes out, but a clear reduction in non-auto trips remains. This, coupled with the observed increases in trip lengths, suggests that the spatial redistribution of trips is behind the changes in travel times, trip lengths, and mode shares.

4.8.2.7 Regional Accessibility to Jobs/Shopping Opportunities

Regional accessibility to jobs or shopping opportunities, using employment as a proxy, provided interesting graphical results that showed clear differences between the three primary travel models under examination. Across all scenarios, regional accessibility showed auto travel benefiting the most in terms of increased accessibility when measured across the region. In contrast, accessibility gains by transit were realized only along narrow transit route corridors. Similarly, accessibility gains by walk only occurred within about one mile of the project site.

The regional accessibility metric is particularly appealing because it gets at the motivation behind the shifts in travel patterns in response to land use change. In this sense, changes in trip lengths and mode shares may be viewed as responses to changes in accessibility. Accessibility also has broader appeal in an economic development context as a partial indicator of land values and attractiveness to new development.

As calculated in this study, regional accessibility is also somewhat independent of the amount of trip making predicted by the model. The only model outputs it uses are the inter-zonal travel times predicted for each mode, which are influenced by network congestion and level of service.

One caveat to the use of regional accessibility as a mobility metric is that it needs to be put in context. For this reason, we included a map of the locations of households in the study region. By comparing the location of households with the location of change in regional accessibility, one can determine how many persons benefit by accessibility changes and to what extent. Conceivably, regional accessibility percentage changes could be weighted by the number of persons in the TAZ to provide a composite measure;

however, it was decided that presenting the accessibility maps and household maps separately would more clearly illustrate how the metric works.

4.8.2.8 Local Accessibility (20-Minute Neighborhood)

The local accessibility, or “20-minute neighborhood” metric offers benefits similar to that of the regional accessibility measure. It is conceptually simpler than a continuous accessibility function, because it may be expressed as the “number of jobs (or other attractor of interest) that may be reached within 20 minutes of travel time. The analysis examined local accessibility by mode and by a TAZ’s location within a study district, and it consistently showed increases in accessibility closest to the project site, with diminishing accessibility further away for transit and walk modes. For auto modes, local accessibility showed no regional variation since nearly the entire region is accessible within 20 minutes.

One drawback of local accessibility is the selection of a travel time threshold, such as a 20-minute buffer, and whether that time is the appropriate value. A second drawback is that the metric treats all destinations within the buffer as being equally attractive. For example, a TAZ with 50 jobs that is two minutes away would be treated as equivalent to a TAZ with 50 jobs that is 19 minutes away.

5.0 CONCLUSIONS

The analysis provided in this report has demonstrated the potential for using various mobility metrics that might provide insight into the extent to which a large-scale land use change proposal meets the goals expressed in the OHP. In doing so, the information content of these various metrics, how they co-vary with changes in inputs and spatial scale, and their ability to "tell a story" about the impacts of a proposed land use change have been explored. The strengths and weaknesses of each metric are described in detail.

Three important general findings have emerged from this study. First, the modeling case study showed that v/c ratios are an extendable and robust evaluation metric. Second, sensitivity tests reveal that urban area context is important, particularly with respect to the location of the proposed land use change within an urbanized area and its prominence relative to competing activity centers. Finally, this research has extended the framework of geographic resolution currently practiced in IAMP activities, demonstrating the importance of spatial focus in interpreting the outcomes of land use change proposals more generally.

Based on this analysis, we have made recommendations for metrics for further consideration in the land use change evaluation process along with suggestions for their implementation. Taking into consideration the mobility metric selection criteria, the performance of each metric in the wide array of tests undertaken in this report, and the practical realities of implementation, we recommend two metrics for additional consideration: network-wide v/c and regional accessibility.

5.1 NETWORK-WIDE V/C

Consistent with provisions in the new TPR for balancing options, a network-wide v/c budget is being recommended as a potential replacement for current methods of applying v/c ratios. This study found that v/c calculations may be under-utilized in current practice since reductions in v/c have not been considered. The change would be to consider v/c ratios across a larger area of the region than is currently the practice, with distances subject to further investigation, and to consider reductions in v/c as possible credits to offset increased v/c. In this way, a municipality seeking approval for a land use plan change that would redistribute area travel patterns could get credit for freeing up capacity in parts of the roadway network and thereby prolonging the service life of those facilities. This would not preclude the need to address capacity deficiencies on other facilities where identified, nor would it preclude a more detailed site-level traffic impact study as required by ordinance. It would, however, be a useful mobility metric for negotiating the costs of mitigation and who bears that cost.

Implementation of a network-wide v/c calculation would be best done using a network-based travel demand model with feedback. The feedback element would be essential for establishing changes in travel patterns on a wide-area basis. In places comparing a future-year baseline scenario with an alternative future-year scenario, such as in a comprehensive plan amendment, this would seem to be the only viable options. Such a model was used in this study and would be available for all of the MPOs in Oregon.

In addition, this metric could be extended by attaching importance weights to facilities that reflect community planning objectives. For example, more weight could be attached to facilities of certain functional classifications, or based on criteria such as proportion of heavy trucks. The weighting scheme should reflect community priorities and could be developed through the TSP process.

One caveat is that research studies have shown that travel demand model network assignment models should be run to a very high level of convergence in order to reduce the chance that network v/c changes are not an artifact of an incomplete model process.

In areas where a network-based travel demand model is unavailable, roadway networks will tend to be sparser and non-auto mode options extremely limited. In these cases, alternative network paths are likely to be few, and it may be sufficient to apply a pivot-point trip distribution model, using a gravity-model type of formulation. This model could be implemented in a spreadsheet and used to predict new trip distribution patterns, by pivoting off of current travel patterns. The change in trip patterns could then be added or subtracted to existing roadway network links using a simplified single-pass route assignment method, which is probably only appropriate in rural and low-density urbanized areas. Based on the assignment, v/c ratios would be calculated and evaluated as described above.

5.2 REGIONAL ACCESSIBILITY

A regional accessibility measure of the kind describe above, using a continuous formulation, is recommended as a general approach for demonstrating the benefits to a region of a land use change proposal. In light of the TPR's consideration of multimodal mixed use developments, consideration of auto, transit and pedestrian modes separately, as done in this analysis, would seem to hold promise for an insightful portrayal of development impacts. Using appropriate econometric techniques, this measure could be recast in more formal economic terms, such as utility-equivalent travel time or cost.

As described above, regional accessibility changes are arguably the underlying cause of changes in area travel patterns due to large-scale land use changes. Thus, some of the other measures considered, such as changes to travel times, trip lengths, and mode shares, are actually the outcomes of accessibility changes. In addition, economic development goals are well-served by accessibility measures because they may be used to represent the value of the land in terms of access to markets of various kinds, including labor markets and consumer markets. Moreover, the continuous formulation used in this study avoids the need to establish arbitrary cutoff points, such as the study district bands or the 20-minute neighborhood.

It is recommended that regional accessibility be calculated as the percentage gain/loss in accessibility in each TAZ, weighted by the number of affected households or persons in that TAZ. A weighted value would provide a better indication of the actual benefit to area residents. The calculations should be stratified by the three primary modes explored in this study: walk, transit and auto, making it possible to attribute accessibility benefits to these different travel markets.

Ideally, a network-based travel demand model of the kind used in this study would be available for these travel time calculations, and this would typically be available for all of the MPOs in Oregon. The model would mainly be used to project travel time changes along the highway network. Transit travel times may be extracted from the model as well, but could also be derived from a simple analysis of transit schedules. Additionally, walk travel times could be based on an assumed rate of travel per unit distance along a street network, such as three miles per hour.

While this should be subject to further study, the spatial unit would not have to be a TAZ, but could be another convenient geographic unit, such as a Census block, block group or tract. This should make attractors relatively easy to tabulate using table-based methods. The formulation recommended here would be based on an attractor type, such as total employment, that is easy to tabulate and consistent with regional goals. Thus, it could be adopted into a regional TSP.

In addition, it would be possible to standardize the impedance function, using a negative exponential function with a coefficient equal to the reciprocal of average travel time in the region by mode. Average travel time could be computed from historical origin-destination data, the Census journey to work, or a household survey. Thus, it would not be strictly necessary to have an estimated access utility function like the one used in this study.

5.3 OTHER IMPORTANT METRICS

The set of metrics described above has the potential to represent many of the goals found in the OHP and in typical TSPs. Given that a regulatory review involves estimating impacts of proposed changes, forecasting the mobility-related outcomes of plan implementation seems to be a necessary step in the process. Therefore, the proposed metrics focus on travel outcomes that may be readily measured using conventional forecasting and analysis tools. These practical considerations not withstanding, there are additional metrics which the literature review and OHP policy goals suggest are important, but may not be adequately addressed by the modeled metrics.

Safety metrics are conspicuously absent. Crash frequency reduction (CFR) is a likely outcome of policies, plans and facility designs that would reduce vehicle volumes, slow travel speeds, and physically hinder movement conflicts between vehicles and between vehicles, pedestrians and bicyclists. The calculations involved in CFR, which are now available in the Highway Safety Manual (*AASHTO 2010*), are very specialized, require detailed design measurements that may be difficult to ascertain at the planning stage, and may not be available during a land use or comprehensive plan review process. Thus, CFR was not included in this analysis.

Reliability, or its inverse, volatility, is frequently cited as an important consideration in traveler decision-making. Analytical representation of reliability is an area of ongoing research. While variance in travel times and the frequency of non-recurring congestion are relatively straightforward to measure, there is currently no agreed-upon method for predicting variance or changes in travel time variance as a function of changes to input parameters. Not only is reliability difficult to predict, but it is also subject to a variety of measurement contexts, such as the appropriate time period over which to measure it and whether to measure it at the level of the intersection, segment, facility, corridor or some wider system level.Consequently, travel time variance can be analyzed at varying levels of resolution, which may lead to different conclusions, similar to the geographic focusing explored in the modeling exercises of this study.

5.4 EMERGING METHODS

The set of modeling tools used in this analysis represent the state-of-the-practice in travel demand modeling, and the limitations of these tools and the scenario inputs have been described where appropriate throughout the analysis. It is worth mentioning, however, that emerging methods in travel demand modeling and network operations modeling may offer possibilities for enhanced analysis.

5.4.1 Activity/Tour Based Models

Activity-based or tour-based travel demand modeling systems are now being used by a handful of metropolitan regions of the U.S., and others are under development for other regions, including Portland. These models represent travel in disaggregate form. Individual decision makers are modeled separately, enabling the analyst to more easily analyze impacts across a wider array of socio-economic groups. Importantly, activity/tour-based models address many of the deficiencies inherent in the state of the practice models that hampered this study *(Donnelly et al 2010*). Among the features of activity/tour-based modeling systems are the explicit modeling of travel in terms of daily patterns and organization of trips into tours, thereby reflecting the interdependence of trips made by the same individual and same household, as well as the interdependence of related decisions: timing, destination and mode. Such modeling systems have the ability to reflect changes in trip generation as a function of changes in accessibility. In addition, these modeling systems have been designed to better represent pedestrian and transit accessibility. Further, some regions, including Portland and Eugene, have recently developed bicycle route choice models that are more sensitive to attributes important to cyclists. The availability of activity/tour-based models in Oregon is likely a few years away. Their complexity and development costs are likely to limit their deployment to Portland and perhaps several of the larger MPOs in the state.

5.4.2 Dynamic Traffic Assignment

Dynamic traffic assignment (DTA) models have also been developed and tested in a number of regions, including Portland, but thus far have been mainly used in operational analyses for near-term impact analyses, usually in small areas or corridors. Use of DTA for long-range, system planning purposes remains in the research stage.

In essence, DTAs are regional micro-simulations of roadway traffic that could replace state-of-the-practice static network assignments for planning purposes (*Chiu et al. 2010*). DTAs provide a fine-grained representation of travel, minute-by-minute, rather than large peak and off-peak periods. DTA is worth mentioning here, because it is the one emerging tool that may be able to forecast variability in network level of service and thereby help to predict reliability.

DTAs enhanced temporal resolution, however, comes with large computational costs. In addition, DTAs utilize methods that do not use v/c ratios, but rather represent actual queuing behavior that would result when demand begins to fill up capacity. While queuing, rather than v/c, is a truer representation of reality, this does not support what has been standard practice in Oregon, which specified consideration of v/c. New policies now broaden options for considering measures other than v/c and emphasize potential safety and operation metrics such as queuing in some circumstances. From a practical perspective, DTA models are also notoriously difficult to use for horizon-year planning due to the need to provide adequate capacity to accommodate future-year demand, without which gridlock results and freezes the simulation.

5.5 APPROPRIATE USAGE

In practice, it is envisaged that there may be cases where models play a prominent role in evaluation of a land use change proposal and cases where utilization of models may not be warranted. In general, urbanized areas in which there exist a significant multi-modal alternatives and the realistic possibility of modal substitution represent complex analysis situations, which are best explored through a regional network-based model. These are cases which are most likely to benefit by the consideration of alternative mobility metrics. In fact, it is argued here that without the type of systematic analysis that a network-based travel model provides, it is difficult to accurately assess the direction and magnitude of land use change impacts in a multi-modal urban market. Fortunately, this will tend to be the larger urbanized regions in Oregon, all of which have some type of network-based model already in place.

Some smaller cities may not have models, but may still benefit by consideration of alternative mobility metrics, such as those considered in this study. Accordingly, the descriptions of metrics for further consideration include ideas for application that avoid the use of full-regional travel model by suggesting so-called sketch planning or pivot-point methods. Should quantitative evaluation of alternative mobility metrics become an adopted practice, pivot-point methods should be investigated and developed further.

In smaller urbanized regions, and in rural areas and IAMP regions in between urbanized areas, modal alternatives are likely to be few, if any, and travel networks relatively sparse. In these cases, alternative mobility metrics, such as those explored in this research are less likely to provide meaningful results, in which case network modeling may be unnecessary. In such areas, more familiar use of facility-specific v/c ratios may be most appropriate.

6.0 REFERENCES

American Association of State Highway and Transportation Officials (AASHTO). *Highway Safety Manual, First Edition.* Washington, D.C., 2010.

American Public Transit Association (APTA). *2009 Public Transportation Fact Book, 60th Edition.* Washington, D.C., 2009.

Balducci, P. and J. Stowers. State Highway Cost Allocation Studies. *NCHRP Synthesis,* No. 378. National Cooperative Highway Research Program, Transportation Research Board of the National Academies. Washington, D.C., 2008.

Bates, J., J. Polak, P. Jones, and A. Cook. The valuation of reliability for personal travel. *Transportation Research Part E,* No. 37, 2001, pp. 191-229.

Bertini, R. Congestion and Its Extent. Levinson, D. and K. Krizek, Eds. *Access to Destinations: Rethinking the Transportation Future of Our Region.* London, UK, 2005a.

Bertini, R. *You are the traffic jam: An examination of congestion measures*. Paper presented at the 85th Annual Meeting of the Transportation Research Board. Washington, D.C., 2005b. http://www.its.pdx.edu/pdf/congestion_trb.pdf Accessed August 10, 2010.

Bhat, C., S. Handy, K. Kockelman, H. Mahmassani, L. Weston, A. Gopal, and I. Srour. *Development of an Urban Accessibility Index: Summary Report*. Project Summary Report No. 4938-S. Center for Transportation Research, University of Texas, Austin, TX, 2002. http://www.ce.utexas.edu/prof/bhat/REPORTS/4938_S.pdf Accessed August 22, 2010.

Brown, M. *Keeping Score: Using the Right Metrics to Drive World Class Performance.* Quality Resources, New York, NY, 1996.

Cambridge Systematics. Multimodal Corridor and Capacity Analysis Manual. *NCHRP Report,* No. 399. National Cooperative Highway Research Program, Transportation Research Board of the National Academies. Washington, D.C., 1998.

Cambridge Systematics. A Guidebook for Performance-Based Transportation Planning. *NCHRP Report,* No. 446. National Cooperative Highway Research Program, Transportation Research Board of the National Academies. Washington, D.C., 2000.

Cambridge Systematics. Performance Measurement Framework for Highway Capacity Decision Making. *SHRP 2*, Report No. S2-CO2-RR. High Street Consulting Group, TransTec Management, Spy Pond Partners, and Ross and Associates, The Second Strategic Highway Research Program, Transportation Research Board of the National Academies. Washington, D.C., 2009. http://onlinepubs.trb.org/onlinepubs/shrp2/shrp2_S2-C02-RR.pdf Accessed August 10, 2010.

Cambridge Systematics. Guide to Effective Freeway Performance Measurement: Final Report and Guidebook. *NCHRP Web-Only Document,* No. 97. Texas Transportation Institute, University of Washington, and Dowling Associates, National Cooperative Highway Research Program, Transportation Research Board of the National Academies. Washington, D.C., 2006. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w97.pdf Accessed August 10, 2010.

Capital District Transportation Committee. *The Metropolitan Congestion Management Process*. 2007. http://www.cdtcmpo.org/rtp2030/materials/cm-doc.pdf Accessed November19,2010.

Carson, J., F. Mannering, B. Legg, J. Nee and D. Nam. Are incident management programs effective? Findings from Washington state. *Transportation Research Record,* No. 1683*, 1999,* pp. 8-13.

Cervero, R. *Accessible Cities and Regions: A Framework for Sustainable Transport and Urbanism in the 21st Century.* Center for Future Urban Transport, Institute of Transportation Studies, University of California. Berkeley, CA, 2005. http://repositories.cdlib.org/its/future_urban_transport/vwp-2005-3 Accessed August 10, 2010.

Cervero, R. Induced travel demand: Research design, empirical evidence, and normative policies. *Journal of Planning Literature,* No. 17, 2002, pp. 3-20.

Cervero, R. and G. Arrington. Vehicle trip reduction impacts of transit-oriented housing. *Journal of Public Transportation,* Vol. 11, No. 3, 2008, pp. 1-17.

Cervero, R. and J. Murakami. Effects of built environments on vehicles miles traveled: Evidence from 370 U.S. urbanized areas. *Environment and Planning A,* Vol. 42, 2010, pp. 400-418.

Chapman, J. and L. Frank. *Integrating Travel Behavior and Urban Form Data to Address Transportation and Air Quality Problems in Atlanta.* Final Report. Georgia Department of Transportation, Atlanta, GA, 2004.

Chin, S., O. Franzese, D. Greene, H. Hwang, and R. Gibson. *Temporary Losses of Highway Capacity and Impacts on Performance.* Report No. ORNL/TM-2002/3. Oak Ridge National Laboratory, Oak Ridge TN, 2002.

Chiu, Y-C, J. Bottom, M. Mahut, A. Paz, R. Balakrishna, T. Waller and J. Hicks. A primer for dynamic traffic assignment. ADB30 Transportation Network Modeling Committee, Transportation Research Board, 2010. http://www.fsutmsonline.net/images/uploads/mtf-files/dta_primer.pdf Accessed March 2012.

City of Portland. *Portland Pedestrian Master Plan*. Pedestrian Transportation Program, Office of Transportation, Portland, OR, 1998. http://www.portlandonline.com/shared/cfm/image.cfm?id=90244 Accessed August 10, 2010.

Cortright, B. TPR, Rezoning and Traffic Impact Analysis. Presentation at the Northwest Transportation Conference, Corvallis, OR, 2008.

Dailey, D. *The Use of Weather Data to Predict Non-recurring Traffic Congestion*. Washington State Transportation Center (TRAC), University of Washington, Seattle, WA, 2006. http://www.wsdot.wa.gov/research/reports/fullreports/655.1.pdf Accessed November 1, 2010.

Dickerson, A., J. Pierson, and R. Vickerman. *Road Accidents and Traffic Flows: An Econometric Investigation*. Department of Economics, Keynes College, University of Kent at Canterbury, Canterbury, UK, 1998. ftp://ftp.ukc.ac.uk/pub/ejr/RePEc/ukc/ukcedp/9809.pdf Accessed August 20, 2010.

Dill, J. Measuring network connectivity for bicycling and walking. Paper presented at the 83rd Annual Meeting of the Transportation Research Board. Washington, D.C., 2004.

Donnelly, R., G. Erhardt, R. Moeckel, and W. Davidson. Advanced Practices in Travel Forecasting. *NCHRP Synthesis,* No. 406. National Cooperative Highway Research Program Transportation Research Board of the National Academies, Washington, D.C., 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_406.pdf Accessed January 10, 2012.

Dueker, K., J. Strathman, and M. Bianco. Strategies to Attract Auto Users to Public Transportation *TCRP Report,* No. 40. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 1998.

Evans, J., and R. Pratt., Traveler Response to Transportation System Changes. Chapter 9 – Transit Scheduling and Frequency. Texas Transportation Institute, Parsons Brinckerhoff Quade & Douglas, Cambridge Systematics, J. Kuzmyak, SG Associates, Gallop Corporation, McCollom Management Consulting, H. Levinson, and K.T. Analytics. *TCRP Report,* No. 95. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 2004.

Ewing, R., and R. Cervero. Travel and the built environment: A meta-analysis. *Journal of the American Planning Association,* No. 76, 2010, pp. 265-294.

Federal Highway Administration (FHWA). Opportunities for linking transportation planning and climate change Chapter 2. *Highways and Climate Change*. U.S. Department of Transportation, Washington, D.C., 2008. http://www.fhwa.dot.gov/hep/climatechange/chapter_two.htm Accessed August 10, 2010.

Federal Highway Administration (FHWA). *How to Use Operations Objectives in the MTP*. U.S. Department of Transportation, Washington, D.C., 2007. http://ops.fhwa.dot.gov/publications/moguidebook/chap_4.htm Accessed August 10, 2010.

Federal Highway Administration (FHWA). *Guidebook on Method to Estimate Non-Motorized Travel: Supporting Documentation*. Publication No. FHWA-RD-98-166. U.S. Department of Transportation, Washington, D.C., 1999. http://www.tfhrc.gov/safety/pedbike/vol2/sec2.14.htm Accessed August 10, 2010.

Flanigan, E., and M. Howard. *An Interim Guidebook on the Congestion Management Process in Metropolitan Transportation Planning.* Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 2008. http://ops.fhwa.dot.gov/publications/cmpguidebook/ Accessed August 10, 2010.

Florida Department of Community Affairs (FDCA). *Transportation Concurrency: Best Practices Guide.* Tallahassee, FL, 2007. http://www.dca.state.fl.us/fdcp/dcp/publications/Files/TCBP.pdf Accessed August 10, 2010.

Florida Department of Transportation (FDOT). *2009 Quality/Level of Service Handbook.* Tallahassee, FL, 2009. http://www.dot.state.fl.us/planning/systems/sm/los/pdfs/2009FDOTQLOS_Handbook.pdf Accessed August 10, 2010.

Frank, L., and G. Pivo. Impacts of mixed use and density on utilization of three modes of travel: Single-occupant vehicle, transit, and walking. *Transportation Research Record,* No. 1466*,* 1994*,* pp. 63-70.

Furth, P., B. Hemily, T. Muller, and J. Strathman. Using Archived AVL-APC Data to Improve Transit Performance and Management*.* *TCRP Report,* No. 113. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 2006.

Garrett, M. *Oregon Highway Plan – Policy Intent Statements.* Memorandum of May 25. Oregon Department of Transportation, Salem, OR, 2011. http://www.oregon.gov/ODOT/TD/TP/docs/OHPrev/Intent.pdf?ga=t Accessed August 1, 2011.

Georgia Department of Transportation (GDOT). *Transportation Enhancement (TE) Program*. Atlanta, GA, undated. http://www.dca.state.ga.us/intra_nonpub/Toolkit/Guides/TEprgrms.pdf Accessed August 10, 2010.

Golob, T., W. Recker, and V. Alverez. Freeway safety as a function of traffic flow. *Accident Analysis and Prevention,* No. 36, 2004, pp. 933-946.

Gordon, P., A. Kumar, and H. Richardson. The influence of metropolitan spatial structure on commuting time. *Journal of Urban Economics,* Vol. 26, 1989, pp. 138-151.

Greene, D. Why CAFÉ worked. *Energy Policy,* Vol. 26, 1998, pp. 595-613.

Gregor, B. *Analysis of Congestion and Travel Trends Reported in the 2009 Urban Mobility Study Report.* Transportation Planning Analysis Unit, Oregon Department of Transportation, Salem, OR, 2009.

Gregor, B. *Statewide Congestion Overview for Oregon.* Transportation Planning Analysis Unit, Oregon Department of Transportation, Salem, OR, 2004. http://www.oregon.gov/ODOT/TD/TP/docs/tpauCM/overview0204.pdf?ga=t Accessed November 1, 2010.

Hallenbeck, M., J. Ishimaru, and J. Nee. *Measurement of Recurring versus Non-recurring Congestion*. Report prepared for Washington State Transportation Commission. Washington State Transportation Center (TRAC), University of Washington, Seattle, WA, 2003. Accessed at http://www.wsdot.wa.gov/research/reports/fullreports/568.2.pdf Accessed August 10, 2010.

Handy, S., M. Boarnet, R. Ewing, and R. Killingsworth. How the built environment affects physical activity: views from urban planning. *American Journal of Preventive Medicine*, Vol. 23(2S), 2002, pp. 64-73.

Hedel, R., and C. Vance. Impact of urban form on automobile travel: Disentangling causation from correlation. Paper presented at the 86 Annual Meeting of the Transportation Research Board, Washington, D.C., 2007.

Hess P., A. Moudon, and M. Logsdon. Measuring land use patterns. *Transportation Research Record,* No. 1780, 2001, pp. 17-24.

Institute of Transportation Engineers (ITE). *Trip Generation.* Washington, D.C., 2003.

Joint Subcommittee of the Oregon Land Conservation and Development Commission and the Oregon Transportation Commission (LCDC/OTC Joint Subcommittee). Recommendations on Amendments to Transportation Planning Rule 0060 and Oregon Highway Plan. Salem, OR, 2011. http://www.oregon.gov/LCD/docs/rulemaking/2009-11/TPR/Recommendation-Final.pdf Accessed August 1, 2011.

JRH Transportation Engineering. *Northgate Centre Revised Traffic Impact Analysis for Minor Comprehensive Plan Map Amendment and Zone Change.* Eugene, OR, 2006.

Kain, J. Impacts of congestion pricing on transit and carpool demand and supply. Curbing Gridlock – Peak Period Fees to Relieve Traffic Congestion. *Transportation Research Board,* Special Report 242, Vol. 2. Transportation Research Board of the National Academies, Washington D.C., 1994.

Kim, K. *Metro Travel Forecasting 2008 Trip-Based Demand Model Methodology Report.* Metro Planning Department Transportation Research and Modeling Services, Metropolitan Service District (Metro), Portland, OR, 2008.

Kittelson & Associates. *I-84 Chenoweth Interchange Area Management Plan: The Dalles, Oregon.* Prepared for the Oregon Department of Transportation. Region 4 Office, Oregon Department of Transportation, Bend, OR, 2009. http://www.oregon.gov/ODOT/HWY/REGION4/I84_Chenoweth_IAMP/I84_Chenoweth_IAMP.shtml Accessed July 15, 2011.

Klop, J. and E. Guderian. *Linking of Mobility Performance Measures to Resource Allocation: Survey of State DOTs and MPOs.* Report No. CDOT-2008-13. Research Branch, Colorado Department of Transportation Denver, CO, 2008. http://www.coloradodot.info/programs/research/pdfs/2008/resourceallocation.pdf Accessed August 10, 2010.

Kuzmyak, J., J. Evans, and R. Pratt. Traveler Response to Transportation System Changes. Chapter 19 – Employer and Institutional TDM Strategies. *TCRP Report,* No. 95. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 2010.

Kuzmyak, J., R. Weinberger, R. Pratt, and H. Levinson. Traveler Response to Transportation System Changes. Chapter 18 – Parking Management and Supply. *TCRP Report,* No. 95. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 2003.

Land Conservation and Development Commission (LCDC). *Draft Amendments to TPR 0060: Public Review Draft - October 25.* Salem, OR, 2011. http://www.oregon.gov/LCD/docs/rulemaking/2009-11/TPR/TPR0060-Public_Review_Draft-Oct25.pdf Accessed October 27, 2011.

MacDonald, D., C. Yew, R. Arnold, J. Baxter, R. Halvorson, H. Kassof, M. Meyer, K. Philmus, T. Price, D. Rose, C. Walton, and W. White. *Transportation Performance Measures in Australia, Canada, Japan, and New Zealand.* Report No. FHWA-PL-05-001. Federal Highway Administration, U.S. Department of Transportation, and American Association of State Highway and Transportation Officials, Washington, D.C., 2004. http://international.fhwa.dot.gov/performance/04transperfmeasure.pdf AccessedAugust 10, 2010.

Mannering, F. Poisson analysis of commuter flexibility in changing routes and departure times. *Transportation Research Part-B*, No. 23B, 1989, pp. 53-60.

McCourt, R. Oregon's transportation planning rule goes into the shop for repairs. *Transportation Research Record,* No. 1981*, 2006,* pp. 56-59.

McMullen, B., and C. Monsere. 2010. *Freight Performance Measures: Approach Analysis.* Report SPR 664; OTREC-RR-10-04. Research Section, Oregon Department of Transportation, Salem, OR, 2010. http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2010/Freight_Performance_Measures.pdf Accessed November 1, 2010.

National Cooperative Highway Research Program (NCHRP). Guide to Effective Freeway Performance Measurement. *Research Results Digest,* No. 312. Transportation Research Board of the National Academies, Washington, D.C., 2007.

National Transportation Operations Coalition (NTOC). *Performance Measures Initiative Final Report.* Washington, D.C., 2005. http://www.ntoctalks.com/ntoc/ntoc_final_report.pdf Accessed August 10, 2010.

Needle, J., and R. Cobb. Improving Transit Security. *Synthesis of Transit Practice,* No. 21. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 1997.

New Jersey Transportation Planning Authority (NJTPA). *North Jersey Strategy Evaluation.* Newark, NJ, undated. www.njtpa.org/planning/strat_eval/strat_eval.html Accessed August 10, 2010.

Noland, R., and K. Small. Travel time uncertainty, departure time, and the cost of morning commutes. *Transportation Research Record,* No. 1493*, 1995,* pp. 150-158.

Oak Ridge National Laboratory (ORNL). *Transportation Energy Data Book: Edition 29.* Center for Transportation Analysis, Energy and Transportation Science Division, Oak Ridge, TN, 2010.

Oregon Department of Transportation (ODOT). *Oregon Highway Plan Mobility Standards Discussion Paper.* Salem, OR, 2011a. http://www.oregon.gov/LCD/docs/rulemaking/2009-11/TPR/OHP_Background-Mobility_Standards.pdf?ga=t Accessed August 1, 2011.

Oregon Department of Transportation (ODOT). *OHP Policy 1F Revisions: Public Review Draft.* Salem, OR, 2011b. http://www.oregon.gov/ODOT/COMM/otc_main.shtml Accessed September 26, 2011.

Oregon Department of Transportation (ODOT). *Oregon Highway Plan Mobility Guidelines.* Salem, OR, 2009. http://www.oregon.gov/ODOT/TD/TP/docs/orhwyplan/Mobility.pdf Accessed August 10, 2010.

Oregon Department of Transportation (ODOT). *Development Review Guidelines*. Salem, OR, 2008. http://www.oregon.gov/ODOT/TD/TP/DRG.shtml Accessed August 20, 2010.

Oregon Department of Transportation (ODOT). *Interchange Area Management Plan Guidelines*. Planning and Implementation Unit, Transportation Planning Section, Salem, OR, 2006. http://www.oregon.gov/ODOT/TD/TP/docs/publications/iampGuidelines.pdf Accessed August 20, 2010.

Oregon Department of Transportation (ODOT). *Application of Oregon Highway Plan Mobility Standards*. Salem, OR, 2004. http://www.oregon.gov/ODOT/TD/TP/docs/TAPM/vcRatio.pdf Accessed August 10, 2010.

Oregon Department of Transportation (ODOT). *Oregon Highway Plan.* Salem, OR, 1999. http://www.oregon.gov/ODOT/TD/TP/orhwyplan.shtml Accessed August 10, 2010.

Oregon Department of Transportation (ODOT). *Report on 1998 Draft Highway Plan Level of Service Policy: Evaluation of Alternative Performance Measures and Recommendations for Policy Changes.* Transportation Planning Analysis Unit, Salem, OR, 1998.

Potts, J. Customer-Focused Transit. *TCRP Synthesis,* No. 45. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 2002.

Pucher, J., J. Dill, and S. Handy. Infrastructure programs, and policies to increase bicycling: An international review. *Preventive Medicine,* Vol. 50, 2010, pp. S106-S125.

Quade, E. *A History of Cost-Effectiveness.* Paper No. P-4557. Rand Corporation, Santa Monica, CA, 1971. http://www.rand.org/pubs/papers/2006/P4557.pdf Accessed August 10, 2010.

Reiff, B., and B. Gregor. *Transportation Planning Performance Measures.* Final Report SPR 357. Research Section, Oregon Department of Transportation, Salem, OR, 2005. http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/PlanningPerformanceMeasures.pdf Accessed November 1, 2010.

Research and Innovative Technology Administration (RITA). *Using Person Throughput Per Hour as a Performance Measure of Specific Portions of the Freeway System.* U.S. Department of Transportation, Washington, D.C., 2004. http://www.itsdeployment.its.dot.gov/Results.asp?ID=1019&rpt=A&filter=1&Year=2004 Accessed August 10, 2010.

Rogue Valley Metropolitan planning Organization. *2002 Travel Demand Model Development Documentation.* Prepared by the Transportation Planning Analysis Unit, Planning Section, Oregon Department of Transportation, 2008.

Sacramento Regional Transit. *FY 09- Key Performance Report*. Sacramento, CA, 2008. http://www.sacrt.com/documents/KPR908.pdf Accessed August 10, 2010.

Schrank, D., and T. Lomax. *2009 Urban Mobility Report*. Texas Transportation Institute, Texas A&M University, College Station, TX, 2009. http://tti.tamu.edu/documents/mobility_report_2009_wappx.pdf Accessed August 20, 2010.

Seaside Transportation System Plan. Prepared for the City of Seaside with support from Clatsop County, Oregon Department of Transportation, and Oregon Department of Land Conservation and Development. 2010. http://www.seasidetsp.org/TasksAndMaterials.aspx#revisedTSP Accessed July 10, 2011.

Small, K. The scheduling of consumer activities: Work trips. *American Economic Review*, No. 72, 1982, pp. 467-479.

Stecher, B., F. Camm, C. Damberg, L. Hamilton, K. Mullen, C. Nelson, P. Sorenson, M. Wachs, A. Yoh, G. Zellman, and K. Leuschner. *Toward a Culture of Consequences: Performance-Based Accountability Systems for Public Services.* Rand Corporation, Santa Monica, CA, 2010. http://www.rand.org/pubs/monographs/2010/RAND_MG1019.pdf Accessed August 22, 2010.

Strathman, J., and K. Dueker. Transit service, parking charges, and mode choice for the journey-to-work: An analysis of the 1990 NPTS. *Journal of Public Transportation,* No. 1, 1996, pp. 13-38.

Strathman, J., K. Dueker, T. Kimpel, R. Gerhart, K. Turner, and S. Callas. Automated bus dispatching, operations control, and service reliability: Baseline analysis. *Transportation Research Record,* No. 1666*,* 1999, pp. 28-36.

Strathman, J., and J. Hopper. Empirical analysis of bus transit on-time performance. *Transportation Research Part A,* No. 27A, 1993, pp. 93-100.

Strathman, J., T. Kimpel, J. Broach, P. Wachana, K. Coffel, S. Callas, B. Elliott, and R. Elmore-Yalch. Leveraging ITS Data for Transit Market Research: A Practitioner's Guidebook. *TCRP Report,* No. 126. Transit Cooperative Research Program, Transportation Research Board of the National Academies, Washington, D.C., 2008.

Strathman, J., T. Kimpel, P. Leistner, and K. Dueker, K. *Comprehensive Plan Amendment Impacts on Interchanges in Oregon.* Final Report SR 500-111. Research Section, Oregon Department of Transportation, Salem, OR, 2005. http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/Interchange.pdf Accessed September 15, 2011.

Strathman, J., and E. Simmons. *Financing Mechanisms for Capital Improvements: Interchanges.* Final Report SPR 687. Research Section, Oregon Department of Transportation, Salem, OR, 2010. http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2010/Financing_Mechanisms_for_Capital_Improvements.pdf Accessed October 15, 2011.

Transportation Research Board (TRB). The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience. *Transportation Research Board, Special Report ,* No. 264. Washington, D.C., 2002.

Transportation Research Board (TRB). *Highway Capacity Manual*. Transportation Research Board of the National Academies, Washington, D.C., 2000.

Turnbull, K., R. Pratt, J. Evans, and H. Levinson. Traveler Response to Transportation System Changes. Chapter 3 – Park and Ride/Pool. *TCRP Report,* No. 95. Transportation Research Board of the National Academies, Washington, D.C., 2004.

U.S. Department of Transportation (USDOT). *DOT Performance Plan – FY2003 and Performance Report – FY2001. Appendix 1: Data Details.* Washington, D.C., 2002. http://www.dot.gov/performance/pdf/complete.pdf Accessed August 10, 2010.

Virginia Department of Transportation (VDOT). *LOS Definitions Used in Traffic Impact Analysis*. Richmond, VA, undated. http://www.virginiadot.org/projects/resources/LOS-defined.pdf Accessed August 10, 2010.

Wang, C., M. Quddus, and S. Ison. Impact of traffic congestion on road accidents: A spatial analysis of the M25 motorway in England. *Accident Analysis and Prevention,* Vol. 41, 2009, pp. 798-808.

Washington State Auditor's Office (WSAO). 2007. *Washington State Department of Transportation: Managing and Reducing Congestion in Puget Sound.*Performance Audit Report No. 1000006. Olympia, WA, 2007. http://www.sao.wa.gov/auditreports/auditreportfiles/ar1000006.pdf Accessed August 10, 2010.

Willson, R. Employer Parking Subsidies, Mode Choice, and Public Policy. Unpublished Ph.D. dissertation. University of California, Los Angeles, CA, 1991.

Women's Transportation Seminar (WTS). Seaside TSP Wins Project of the Year. *WTS Newsletter, Portland Chapter,* Vol. 24:4, 2010, p.1.

Wray, J. *Policy for Applying LOS and V/C in the Transportation Development Process*. Ohio Department of Transportation, Columbus, OH, 1998. http://www.dot.state.oh.us/policy/PoliciesandSOPs/Policies/322-002%20%28P%29.pdf Accessed August 10, 2010.

Young, W., R. Thompson, and M. Taylor. A review of urban car parking models. *Transport Reviews*, Vol.11, 1991, pp. 63-84.