CITY OF SEATTLE

Comprehensive Street Classification, Performance and Design Standard System

FINAL WORKING PAPER

Nelson\Nygaard Consulting Associates
833 Market Street, Suite 900
San Francisco, CA 94103

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1. Introduction

By 2024, the City of Seattle expects to add 90,000 new jobs and 50,000 new households. To accommodate this growth with minimal negative impacts on the quality of life that has attracted all these new people, the city is focusing growth into its downtown and a number of compact, mixed-use "Urban Villages." More importantly, the city is currently working to connect these Urban Villages with a network of fast, frequent and efficient transit. This strategy results not only from sound 'Smart Growth' ideology, but also from the challenges posed by the city's highly constrained transportation geometry.

The right of way limitations on Highway 99 and I-5, along with the bridges over Lake Washington and the Ship Canal, represent a finite limitation on the overall vehicle capacity of Seattle's road network. There are few, if any, opportunities to increase the total number of vehicles that can move through the system. At best, the city can merely decide *where* the congestion goes, by shifting the bottlenecks to places where they have the least impact. As a result, the city has little choice but to invest in more efficient modes of transportation to accommodate its planned – and already entitled – growth.

This working paper is a companion document to another study that is developing the Urban Village Transit Network (UVTN). Its purpose is to define clear performance indicators to measure the success of the UVTN and, more importantly, give policymakers, planners and engineers tools to balance the requirements of the UVTN with those of other modes.

This paper is intentionally broad in scope. The transit system does not stand alone, but operates in a context where it competes with all modes of transportation – cars, bikes, pedestrians – as well as the particular economic development and quality of life goals of the property owners adjacent to a given transit line. When, for example, is it appropriate to increase delay for private vehicles in order to improve travel speed for buses? When is it appropriate to remove on-street parking in order to provide a dedicated bus lane? When should bicycle lanes be provided alongside high frequency transit routes? Are sidewalk narrowings or widenings appropriate?

In addition to addressing where transit sits within the context of other modes, this paper also considers the different land use contexts that transit operates in. Different solutions are appropriate in a neighborhood commercial street, in the downtown or in a low-density residential neighborhood.

1.1 Goals and Objectives

The primary goal of this working paper is to define clear, measurable Level of Service (LOS) standards to assess the performance of the UVTN. To accomplish this, however, the paper attempts to look more deeply at how transportation performance is judged, and strives to meet the following objectives:

- Explain the past development of transportation LOS standards, along with their advantages and their shortcomings
- Define how to measure transit performance from a variety of perspectives, including the operator, the customer, transportation systems managers and land use strategists
- Define how to measure transit performance where it must compete with other modes of transportation
- Define how transit performance measures should consider the land use context of its operating environment
- Define a process for balancing the needs of transit within any context
- Provide a flexible toolbox for the City of Seattle to manage its transportation system as its land use and economic development goals change over time.

It is important to note that this document is the first draft of a working paper, and it has not yet been reviewed with any City agency, King County Metro or other key stakeholders. Its largest purpose is to start discussion about how to coordinate the many transportation and land use projects currently being considered in Seattle. It is expected that both the overall framework and especially the individual performance targets will be adjusted significantly before these standards are adopted and put into use.

1.2 Background

To ensure that a city functions efficiently and reflects the needs and expectations of its population, it relies on significant investment in infrastructure and services.

Utilities such as water and power supply often have a relatively restricted interface with the community – few residents are aware of the power grid until there is a blackout. Services, such as police and fire protection, focus almost solely on community interface while having a limited physical infrastructure, such as police stations. Transportation and specifically transit, however, incorporate both significant infrastructure *and* community interface. Unlike the sewage system, residents have direct daily experience with the physical infrastructure of transportation – its roads, bridges, ferry docks and so on – as well as its service aspects, including signal timing, bus service and parking control officers.

To assess the effectiveness of investments in infrastructure and services, and to determine how best to meet future needs and expectations, it is crucial to monitor the performance of infrastructure and services.

Assessment of the performance of a transit network and services brings a range of challenges, including measuring the factors most important to users with divergent viewpoints. Among the points of view that must be taken into account include:

- Operators, who emphasize the efficient provision of service and cost effective use of limited resources
- Passengers, who emphasize quality, availability and convenience
- Overall transportation system managers, who emphasize systemwide vehicle and person capacity, as well as average speed and delays.
- Strategic planners, who emphasize the integration between transit land use and economic development
- Implementers and policymakers, who need to balance provision for the generally competing modes within a constrained context

Throughout this document, we attempt to take all of these points of view into account and distill measures that best accommodate them all.

1.3 Approach

This document is laid out so that it follows our overall analytical approach used to develop of a system of performance measures for the Seattle UVTN.

Chapter 2: Existing Policies and Performance Measures

To begin to bring balance to an over-reliance on Auto-LOS and other vehicular-oriented measures, we have examined Seattle's larger objectives as documented in its Comprehensive Plan, Strategic Transportation Plan and other key documents. In section 2.2 we summarize the city's transportation related objectives, then we translate them into specific, measurable outcomes, followed by performance indicators and performance targets that related back to the desired outcomes. The performance indicators have several aims in mind:

- Relate indicators to goals and objectives. The indicators should operationalize the city's Transportation Strategic Plan and Comprehensive Plan.
- Minimize data collection costs.
- Retain a high-level focus. While the indicators should encompass as many of the Transportation Strategic Plan and Comprehensive Plan goals and objectives as possible, the number should be kept low to retain a high-level focus.
- Ensure they are comprehensible to the public and policymakers.

Chapter 3: Street Classification: Function, Context and Form and Mode

Chapter 3 proposes to classify Seattle's streets according to two key criteria:

- The land use context for the street and its adjacent land uses

- The role and relative priority of the street in the city's transit, automobile, bicycle and pedestrian networks

Chapter 4: Quality of service measures for transit

In order to measure the success of the transit network, specific quality of service measures are proposed, along with targets, for each classification.

Chapter 5: Quality of service measures for other modes

This working paper does not yet consider quality of service measures for other modes, but different possible approaches are discussed in Chapter 5.

Chapter 6: Application of the performance measures

Finally, and perhaps most importantly, we propose a methodology for addressing the inevitable tensions that arise when a street is an important transit street as well as an important automobile, bicycle, pedestrian or freight street.

1.4 Limitations to this Approach

As we re-iterate throughout the text, this document is intended to be a working paper to begin discussion on measuring transportation performance. It focuses primarily on transit, specifically the Urban Village Transit Network, and it prioritizes measurements of importance to the customer, rather than the transit operator. We take this approach because significant mode shift toward transit is necessary for Seattle to achieve its expected growth without significant negative impacts upon its quality of life and future economy.

Among the important factors beyond the scope of this paper include:

Network Level Performance

This document focuses on transportation performance at the corridor or street segment level. While it does not specifically consider how to measure the performance of the entire transportation network, network performance goals form the basis of much of our thinking. At the network level, the City of Seattle is most interested in allowing its transportation system to accommodate planned growth in a sustainable manner. We recommend that the city adopt the following changes into its Comprehensive Plan and Transportation Strategic Plan, environmental compliance guidelines, congestion management program, and elsewhere as appropriate:

- Level of Service should reflect person delay rather than vehicle delay.
- Volume to Capacity ratios should examine person capacity rather than vehicle capacity.

This simple word swap would have far-reaching consequences and should not be done lightly. First, vehicular performance can be measured with simple automated hose counts. Measuring person-based performance may require hand counts of bikes, transit passengers and/or pedestrians, a more costly and complex undertaking. Secondly, on streets with high transit volumes, transit passenger counts may so dwarf auto passenger counts that tiny reductions in transit delay might justify huge increases in auto delay. The city may wish to set some network-wide or street-specific minimum accommodation for cars in order to ensure an appropriate balance among modes. The city may also want to maintain Auto LOS as a secondary measure, with person-based measures primary. Seattle has established the policy basis for these performance measures in both its Comprehensive Plan and Transportation Strategic Plan. For example, Strategy A3 of the Transportation Strategic Plan is to "Optimize the People-Moving Capacity of Existing Streets" (p. 70).

Some cities have adopted primary transportation performance measures that have more to do with quality of life than movement. Palo Alto's primary indicator is to ensure that total vehicles trips do not grow beyond 2000 levels. Trenton, NJ has indicators focused around economic development. London includes "public satisfaction," measured through regular polling, among its measures.

Some cities have also specified different performance measures for different types of streets, identifying primary auto streets where vehicular through traffic is given priority; neighborhood commercial streets, where on-street parking and pedestrian activity are given priority; and other designations. In Seattle, Transit Operating Speed will be a key performance measure that will apply in different ways depending upon street typology. Urban Village Transit Network streets will have a higher transit operating speed by policy than other streets.

Street Design

While our proposed street classification system is intended to incorporate street design guidance at a future date, it is not included in this paper.

Operator Performance

King County Metro will continue to need to maintain cost and service efficiency measures to judge its own performance, but these are not considered here.

1.5 Definition of Terms

In writing this document, we have chosen to adopt the definitions of transit performance measures provided in the Transit Capacity and Quality of Service Manual[1]:

[1] Transit Cooperative Research Program, *TCRP Report 100 Transit Capacity and Quality of Service Manual 2nd Edition.* Submitted by Kittleson Associates, 2003. Page 3-1.

- *Transit Performance Measure*. A quantitative or qualitative factor used to evaluate a particular aspect of transit service.
- *Quality of Service*. The overall measured or perceived performance of transit service from the *passenger's* point of view.
- *Transit Service Measure*. A quantitative performance measure that best describes a particular aspect of transit service *and* represents the passenger's point of view. It is also known elsewhere as a *measure of effectiveness*.

The TCRP document specifically urges caution when using the terms quality of service and level of service and suggests several primary differences between performance measures and service measures:

- Service measures must represent the passenger's point of view, while performance measures can reflect any number of points of view.
- In order to be useful to users, service measures should be relatively easy to measure and interpret. It is recognized, however, that system-wide measures will of necessity be more complex than bus stop or route segment measures.

Level of service (LOS) grades are developed only for service measures. However, transit operators are free to develop LOS grades for other performance measures, if those measures would be more appropriate for particular applications.

2. Existing Performance Measures

2.1 Shortcomings of Current Measures

Since the post-War era, most cities have adopted Automobile Level of Service (LOS) as their primary transportation system performance measures. Auto LOS is highly useful since it is easy to measure, and it can effectively estimate auto congestion, a factor of great concern to most cities and citizens. At intersections, Auto LOS estimates the average seconds of delay a motor vehicle will experience. Most cities use a letter scale from A (less than 10 seconds of delay) to F (more than 80 seconds of delay), but other cities add additional letters (G, H) to denote further delay.

Similar measures are available for street segments in between intersections, using both a letter scale as well as a numerical volume-to-capacity (v/c) ratio. V/C ratios take the total number of vehicles on a given stretch of roadway and divide by the capacity of that road to handle cars. A v/c ratio of 0.80 or lower represents free-flow conditions, while a ratio of 1.20 represents very congested conditions.

While useful for estimating the effects of congestion on motorists, Auto LOS and v/c ratios do not offer the full picture of a transportation network in a place as complex as Seattle. First, by focusing on spot locations, they say nothing about the ability of the overall transportation network to carry traffic. For example, they do not allow planners to estimate actual average travel time among various destinations. This constitutes a significant gap in the planning process, as travel time is the factor motorists care most about.

Secondly, and more importantly, these measures estimate delay only to vehicles, not people. A bus with 50 passengers on board is counted the same as an automobile with one passenger. In order to improve Auto LOS at a given intersection, for example, traffic engineers can remove bike lanes or transit priorities in order to give more accommodation for cars. The result may be that the intersection can handle more *vehicles* but fewer *people*. While this result may present short-term benefits for those who drive, it would contradict the city's goals for population and job growth. In the long-term, moreover, as the city grows, managing the transportation system with an exclusive focus on auto congestion paradoxically results in more auto congestion than an approach that considers all modes.

A street system that is optimized for cars is never optimized for transit. Due to their fundamental need to stop to board passengers, buses and streetcars travel a certain fraction slower than other vehicles under freeflow conditions in a given street. Synchronization of traffic lights, which may significantly speed up auto flow, may actually worsen transit speeds, as buses and streetcars fall behind "platoons" of cars and hit every light red.

As auto speeds improve and transit speeds worsen, two effects take hold: induced demand toward driving and mode shift away from transit. Since travel time is the primary factor by which individuals decide to make trips and choose their travel mode, projects that reduce congestion by expanding capacity are often filled to capacity the day they open – as a result of new travelers being "induced" into using the new capacity. Similarly, as auto travel time improves relative to transit travel time, many individuals give up on transit and shift to driving. If cities respond to these shifts by continuing to expand auto capacity while allowing transit to deteriorate, the result is a spiral of ever-increasing congestion and steady reductions in the ability of the overall system to move people.

This paper attempts to create a framework to break this inefficient cycle by looking to manage the transportation system as a whole, not just as a collection of unrelated modes.

2.2 Seattle's Existing Performance Measures

Before beginning to restructure the transportation performance system, it is important to examine Seattle's existing performance measures. The city and King County Metro have adopted several performance measures in the Seattle Comprehensive Plan and Six-Year Transit Development Plan respectively. In keeping with the rest of this document, these can be grouped into two broad categories: system-wide measures, which measure the performance of the entire transportation or transit system; and street-, corridor- or intersection-level measures, which have a narrower geographic focus.

System-Wide Measures

Commute mode choice is a main system-wide performance measure in both the Seattle Comprehensive Plan and King County Metro's Six-Year Transit Development Plan. The City's target, shown in Figure 2-1, is for single-occupant vehicle use to fall from 59% in 1990 to 35% in 2010, with commensurate increases in non-auto modes.[2] Although falling short of the interim target for 2000, significant progress towards this goal was made over the 1990-2000 period.

King County Metro's progress targets contain a similar (although not directly comparable) measure, focusing on high occupancy vehicle mode split to designated employment sites. Other selected targets are shown in Figure 2-2 (excluding those, such as cost per platform hour that are primarily focused on internal management, rather than performance from the user's perspective).

The Six-Year Plan also details a strategy to monitor customer satisfaction, through Metro's Annual Rider/Non-Rider Survey (Strategy M-2). However, no formal targets or measures are set for this in the Six-Year Plan.

[2] Comprehensive Plan Policy T-10.

Figure 2-1 Comprehensive Plan Mode Choice Targets for Seattle Residents

	Year			
Work Trips	**1990 Actual**	**2000 Goal**	**2000 Actual**	**2010 Goal**
Single-occupant car	59%	51%	57%	35%
Carpool	12%	12%	11%	13%
Public transportation	16%	20%	18%	27%
Bicycle and other	3%	5%	3%	9%
Walk	7%	8%	7%	10%
Work at home	3%	4%	5%	6%
Total	100%	100%	100%	100%
Non-Work Trips				
Transit	7%	9%	n/a	14%

Source: Seattle Comprehensive Plan; US Census 2000.

Figure 2-2 King County Metro Progress Targets

Measure	Evaluation Level	2001 Baseline	Target*
Annual boardings	County	96 million	105.5 million
Boardings per platform hour	Seattle/N King County	33	33
Annual Passenger Miles	County	470 million	520 million
% HOV mode split to designated employment sites	Seattle/N King County	52%	58%
% of households that use transit	Seattle/N King County	50%	52%
Boardings per capita	Seattle/N King County	112	115

* With 400,000 annual hours of new service added

Source: King County Metro Six-Year Transit Development Plan

Other Performance Measures

The Seattle Comprehensive Plan adopts vehicular level of service standards as the measure with which to judge the performance of the arterial and transit system. Arterial level of service, discussed in more detail in Chapter 5, is measured by volume-to-capacity ratio (*v/c*) at points on designated screenlines. Transit level of service is measured in the same way, at the screenline points which also correspond to transit routes. LOS (*v/c*) standards are either 1.00 or 1.20, depending on the screenline, as follows (exact screenline locations are detailed in the Comprehensive Plan):[3]

- 1.00 standard – Magnolia, South City Limit, NW 80th Street, Aurora Ave, Spokane Street, Jackson Street, and I-5 north of Lake Union

[3] Comprehensive Plan, Policies T22 and T23.

- 1.20 standard – North City Limit, Duwamish River, Ship Canal, South of Lake Union, and I-5 east of the CBD

King County Metro's Six-Year Transit Development Plan details four route-level performance indicators:[4]

- Riders per revenue hour
- Farebox recovery (ratio of operations revenue to operations cost)
- Passenger miles per revenue seat mile
- Passenger miles per revenue hour

A composite measure – Route Effectiveness – is defined as the sum of the number of standard deviations above or below the median of each subarea of each of the four measures. (Seattle/North King County constitutes one of the three subareas.) All these indicators are important efficiency measures from the operator's perspective, but they do not take into account factors that transit passengers most care about: frequency, reliability, travel time, etc.

Later sections of this document detail a proposed new performance indicator – Transit Quality and Level of Service – that we propose to supercede or complement these transit performance indicators. The City's current transit indicator in particular, while simple to measure if Vehicle Level of Service data are already available, only measures one extremely limited aspect of transit service, namely if buses are caught in congestion. As discussed at the beginning of this chapter, however, measures to reduce vehicular congestion do not always benefit transit.

Relation of Measures to Goals

As outlined in our approach, one of the core values of performance measures is in helping to operationalize wider goals and objectives. While these goals and objectives set the overall policy direction, it can be difficult to assess the extent to which they are being achieved. System-wide performance measures address this need by providing a concrete indication of the level of success on a citywide basis. Corridor-based and other lower-level performance measures provide this feedback at a different scale, and can also be useful as triggers regarding policy decisions such as the allocation of right-of-way (see Chapter 6).

As shown in Figure 2-3, the existing system-wide mode split indicator captures the vast majority of the relevant goals and objectives in the Seattle Comprehensive Plan, Seattle Transportation Strategic Plan, and King County Metro Six-Year Transit Development Plan. It measures the success of those goals and objectives that call for land use patterns that support the use of non-automobile modes, and those that directly address improvements in transit, pedestrian and bicycle facilities.

[4] Six-Year Transit Development Plan, Strategy M-3.

Figure 2-3 also shows that some goals and objectives are best operationalized at a lower geographic scale, such as an individual corridor. Some of these are already adopted, while some are either considered in the remainder of this document or accompanying work:

- Arterial (Vehicle) Level of Service (adopted)
- Transit Quality and Level of Service (discussed in Chapter 4)
- Pedestrian Level of Service (discussed in Chapter 5)
- Bicycle Level of Service (discussed in Chapter 5)
- Freight Level of Service (discussed in Chapter 5)

The goals and objectives that are not operationalized with this set of performance measures relate to commute trip length (Comp. Plan Goal LG22), environmental pollution from vehicles (Comp. Plan Goal TG2), and protection of neighborhood streets from through traffic (Comp. Plan Goal TG12). Since this document focuses on performance indicators necessary for Seattle to accommodate its growth plans and make its transit system work, its does not yet consider other goals such as environmental quality or freight movement; these may be addressed later and incorporated into a more comprehensive set of indicators.

Note that Figure 2-3 focuses on broader goals and objectives, rather than specific strategies and actions which are primarily measured by whether they are implemented or not. However, these performance measures will help to implement several specific strategies in the Transportation Strategic Plan, particularly:

- Establish and Implement Transit Service Priorities (T4)
- Evaluate Transit Service Investments Against Clear Performance Standards for Ridership and Cost-Effectiveness (T4.2)
- Update and Integrate Transit Street Classifications to Establish a System that Guides Transit Investments (T4.4)
- Simplify System for Designating Key Pedestrian Streets (W4.2) (as part of related work for this project)

Each of these objectives is taken into account as we begin to create a more comprehensive performance framework in Chapter 3.

Figure 2-3 Relationship Between Goals, Objectives and Performance Measures

Ref.	Goal/Objective	Corresponding Measure
Comprehensive Plan		
LG4	Promote densities and mixes of uses, especially within urban villages, that support walking and use of public transportation	Mode split
LG22	Accommodate concentrations of housing and employment at strategic locations in the transportation system conveniently accessible to the City's residential population, thereby reducing work trip commutes	Not directly addressed
LG24	Accommodate concentrations of employment and housing at densities that support pedestrian and transit use and increase opportunities within the City for people to live close to where they work	Mode split
LG64	(High Density Multifamily Areas) Accommodate the greatest concentration of housing in desirable, pedestrian-oriented urban neighborhoods having convenient access to regional transit stations, where the mix of activity provides convenient access to a full range of residential service and amenities, and opportunities for people to live within walking distance of employment	Mode split
LG68	(Pedestrian Oriented Commercial Zones) Promote commercial areas with a development pattern, mix of uses and intensity of activity generally oriented to pedestrian and transit use by maintaining areas that already possess these characteristics and encouraging the transition necessary in other areas to achieve these conditions...[including] an active, attractive, accessible pedestrian environment	Mode split
TG2	Reduce and/or mitigate air, water and noise pollution from motor vehicles	Not directly addressed
TG3	Promote energy-efficient transportation	Mode split
TG4	Meet the current and future mobility needs of residents, businesses and visitors with a balanced transportation system	Mode split
TG5	Provide a range of viable transportation alternatives, including transit, bicycling and walking	Mode split
TG6, TG15	Reduce the use of the car over time, particularly for commute trips	Mode split
TG8	Make the best use of the City's limited street capacity, identify key functions of streets, and seek to balance competing uses	Transit, Pedestrian, Bicycle, Vehicle and Freight LOS
TG9	Ensure adequate capacity on the street system for transit and other important uses	Transit Quality and Level of Service
TG10	Support a shift towards transit, carpools and vanpools, bicycling and walking	Mode split
TG11	Support efficient freight and goods movement	Freight LOS
TG12	Protect neighborhood streets from through traffic	Not directly addressed

Ref.	Goal/Objective	Corresponding Measure
TG13	Use level-of-service standards, as required by the Growth Management Act, as a gauge to judge the performance of the arterial and transit system	Vehicle LOS Transit Quality and Level of Service
TG16	Make the best use of the City's limited street space, seek balance among competing uses, and protect neighborhoods from overflow parking	Transit, Pedestrian, Bicycle, Vehicle and Freight LOS
TG17	Provide mobility and access by public transportation for the greatest number of people to the greatest number of services, jobs, educational opportunities and other destinations	Transit Quality and Level of Service
TG18	Increase transit ridership, and thereby reduce use of single-occupant vehicles to reduce environmental degradation and the societal costs associated with their use	Mode split
TG19	Increase walking and bicycling	Mode split
TG20	Create desirable, safe convenient environments that are conducive to walking and bicycling	Mode split Pedestrian and Bicycle LOS
TG21	Preserve and improve commercial transportation mobility and access	Freight LOS
Transportation Strategic Plan		
C-1	Optimize General Traffic Flows on Arterial Streets	Vehicle LOS
W1	Make Street Crossings Safer and Easier	Pedestrian LOS
W2	Improve the Sidewalk System	Pedestrian LOS
W4	Use Design Standards That Make Walking Safer and More Attractive	Pedestrian LOS
B2	Make Improvements to Reduce Barriers and Resolve Bicycle Safety Problems	Bicycle LOS
B3	Ensure that Bicycles Can Cross Bridges Safely and Conveniently	Bicycle LOS
B4	Provide Street Space for Bicyclists	Bicycle LOS
T2	Improve Transit Speed and Reliability	Transit Quality and Level of Service
FM1	Improve Major Truck Streets to Support Safe, Efficient Truck Movements	Freight LOS
Metro Six-Year Plan		
6	Make improvements to the transit operating environment in locations and along corridors where actual or potential for high ridership exists and where local jurisdictions provide the necessary supporting plans, policies, permits and/or funding to do so.	Transit Quality and Level of Service
7	Improve access for pedestrians (including persons with disabilities) and bicyclists as well as the waiting environment at transit facilities with the highest use	Pedestrian LOS

3. Proposed Street Classification System

This chapter proposes modest revisions to Seattle's current street classification system to make it clearer and to relate it directly to the proposed performance measure system in Chapters 4 to 6.

3.1 Current System

Seattle has long had one of the best street classification systems in the country, avoiding the problems of the "arterial, collector, local" system so common in late 20th century suburban cities. In the suburbs, where almost all trips are by car and where different land uses are separated from one another, it is possible to classify streets solely by their intended auto volume (arterial versus local) or the use they serve ("Residential" street).

In Seattle's 19th century street grid, however, every street must serve a complex variety of functions. As a result, Seattle's current street classification system combines a variety of factors, including:

- **Modal function.** Seattle acknowledges that some streets are very important to automobile circulation, and it grades them according to a scale of importance, including Principal Arterial, Minor Arterial, and Collector Arterial. More importantly, Seattle adds transit importance to the mix, including Principal Transit Route, Major Transit Route and Minor Transit Route. Additional classifications are provided for bicycle routes, emergency service routes and key pedestrian streets.
- **Physical form.** In some cases, as in bicycle facilities, classifications are based upon physical form rather than network priority.
- **Jurisdiction.** Facilities controlled by the County, State or other jurisdictions are also noted.

In addition to its street classification system, Seattle also has a sophisticated land use classification system. This system divides the city in three key ways:

- **By scale of intensity**, from the Downtown at the most intense, to its mixed-use neighborhood centers to low density single family home neighborhoods.
- **By noting single-use districts**, such as the University of Washington campus and exclusively industrial areas, and
- **By areas where various amounts of growth will be focused,** specifically the Urban Villages.

While these systems offer a sound approach to land use and transportation planning, they also present a few limitations:

- The transportation classifications mix form and function in somewhat inconsistent ways
- The transportation and land use classifications are not linked to one another
- While some performance measures have been attached to the transportation classifications, these are not applied consistently across all classification types.
- Tools are not provided to help balance modes that compete against one another, or transportation goals that compete with land use goals.
- Tools are not provided to inform key design or street management decisions in a given corridor.

This paper attempts to big upon Seattle's existing efforts in order address these gaps.

3.2 Proposed System

The proposed system of street typologies includes three key elements:

- **Function,** the relative importance of the street for each mode of transportation. Seattle has already defined most of its functional priorities and has included these in its Geographic Information System database. Function is the starting point for system-wide transportation performance measures and is the focus of this report.

- **Context**, the adjacent land uses. This is particularly important for neighborhood commercial streets, which have special needs regarding traffic speed, pedestrian accommodation and on-street parking. Context informs system-wide transportation performance measures and is addressed in this report. It is also a key factor in street design standards.

- **Form**, the physical shape of the right of way. Form is the starting point for street design standards, which are not thoroughly considered here. Designations such as "Alley," "Boulevard," or "Woonerf" are primarily related to form.

These elements are combined in different ways to inform decisions about street design and management. Specifically:

- When measuring the performance of a given corridor as part of the overall network, the functional role of the corridor is paramount, followed by its adjacent land use context. The physical form of the street is less important.

- When considering the design standards for a corridor, the physical form is paramount. Context informs critical elements such as the provision of on-street parking, and function determines important details such as bicycle lanes, bus bulbouts and intersection design.

The focus of this paper is on performance measures, so function and context are considered here. Form can be addressed later in order to link this document to the city's design standards approach.

This chapter attempts to take Seattle's existing transportation and land use classification framework and modify it for greater consistency and usefulness. It begins by more clearly defining the functional context of streets and follows with the physical context. The following chapter then begins to apply these new classifications to the measurement of transportation systems.

3.3 Transportation Function: Classification by Mode

Seattle has already completed a basic framework of functional classification, noting the relative importance of each street to each mode of transportation. We suggest some modifications to this system as follows:

Figure 3-1 Proposed New Functional Classifications

Classification	Existing Sub-Categories	Proposed Performance Classifications
Transit		
	Regional Transit Way Principal Transit Street Major Transit Street Minor Transit Street Temporary Transit Street Transit Restricted Street	UVTN Secondary Transit Route Tertiary Transit Route
Automobiles		
Principal arterials	Regional freeway/expressway Regional arterial Principal arterial-general Principal arterial-residential	These classifications will need to be addressed in more detail in later working papers. For the purpose of this paper and for comparing transit performance against auto performance in Chapter 6, we have simplified the automobile system into three key categories: • Primary Auto Arterial • Secondary Auto Arterial • Tertiary Auto Street
Minor arterials	Minor arterial-general Minor arterial-residential	
Collector arterials	Collector arterial	
Access streets	Commercial access street Residential access street Woonerf Alley	
Bicycle		
	Bicycle Path Bicycle Lane Bicycle Route Key Bicycle Street Shared Roadway Bicycle Prohibited	As with autos, the bicycle system will need further development in later working papers. For comparison against transit performance in Chapter 6, we have simplified bicycle classifications into two categories: • Primary Bicycle Street • Secondary Bicycle Street
Pedestrian		
	Key Pedestrian Street	Key Pedestrian Street
Truck		
	Truck Route Truck Street Commercial Access Street Truck Restricted Street	Trucks will also need further development in later working papers. For the time being, we have included two key categories: • Primary Truck Route • Secondary Truck Route
Other		
Boulevard	Class I Boulevard—Natural Landscaping Class II Boulevard—Formal Landscaping	These classifications are really a matter of "Form" and will be addressed separately.

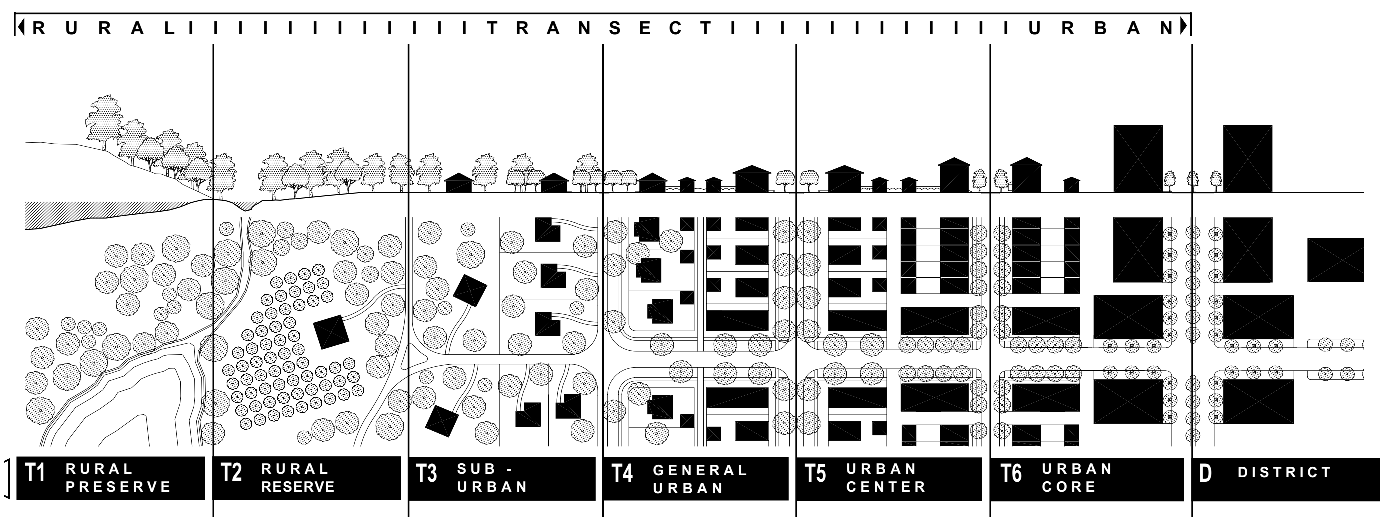
3.4 Transportation Context: Classification by Adjacent Land Use

Over the last decade, architects, urban designers and traffic engineers have increasingly come to agree upon a basic principle: that *context* determines all of the design details that shape our cities, including their roads, buildings and landscape. The so-called "New Urbanists" describe context using a framework called the "Transect," borrowed from early 20th century urban design techniques and a tool of biologists. The concept is simple. In all great places around the world, one can draw an imaginary line from edge to center, from the wilderness to the urban downtown. This line passes through a series of places of increasing urbanity, each with its own set of characteristics.

In rural areas, for example, buildings are small and spaced far apart. Streets have no curb, no sidewalk and little if any lighting. Plantings are informal. In neighborhood commercial centers, shopfronts line the street, formal plantings and street lighting are in place, and sidewalks, curbs and on-street parking define the street. Putting "main street" light fixtures in a rural area is a violation of the Transect rules, just like letting blackberries grow rampant along a main street.

While simplistic, the Transect is a very useful tool for crafting design standards, parking management tools and other details about streets in a city like Seattle.

Figure 3-2 The Duany Plater-Zyberk "Transect"



Many cities, including Seattle, use some form of the Transect in their zoning rules. Rather than using zoning to separate uses, such as stores from houses, mixed use zoning separates areas according to an urbanity gradient. In Figure 3-3 below we examine how Seattle's existing zoning categories incorporate the ideas of the Transect, defining the city from its most dense urban core to its single-family residential areas. We also begin to explore how key design and management characteristics of streets relate to their urban context.

Note that we have rearranged Seattle's context zones slightly. The main commercial streets in each of the various Urban Villages have different characteristics than the secondary or primarily residential streets in those areas. As a result, we have grouped the Downtown Urban Core streets together with the main commercial streets in the Urban Center Villages, and we have created a special category for the commercial main streets of the Hub Urban Villages and the Residential Urban Villages. These categorizations may need refinement, but it allows us to group streets with common characteristics into five clear categories.

While the physical form of the adjacent uses sets the primary design guidelines for a road, the actual uses inside the adjacent buildings have bearing on several key details, including:

- Parking management
- Sidewalk design
- Speed limit
- Other design details, including signage and lighting

Each of these design and operational details are addressed below.

Parking Management

In general, on-street parking is favored in all of Seattle's urban centers, as it is critical to the health of neighborhood commercial districts and offers a valuable buffer between sidewalks and traffic. The provision of on-street parking, however, is often in tension with a desire to expand the travel capacity of a given street, and draft goals and policies from the revised Comprehensive Plan show how on-street parking is a temporary condition, and secondary to the purpose of moving people in the public right of way. Parking management is discussed in more detail in Chapter 6.

Sidewalk and Landscape Criteria

In the most urban areas, where pedestrians dominate, pedestrian comfort outweighs motorists' desire for speed. Both speed limits and design speeds should not exceed 25 mph, regardless of the functional classification of the roadway. These criteria are not dealt with in detail here, but are provided in a cursory fashion to demonstrate how the city's design guidelines can relate directly to the same criteria that define performance measures.

Signage and Lighting Standards

Similarly, signage and lighting standards relate strongly to context. These will be addressed in other documents.

Figure 3-3 Seattle Context Zones and Their Influence on Streets

Seattle Context Zone	New Urbanist Equivalent	Definition	Potential Parking Management Criteria (to be refined in separate document)	Potential Sidewalk and Landscape Criteria	Suggested Speed Limit and Design Speed
Urban Center	T6: Urban Core	Seattle's more urban places, including the Downtown Core and the commercial streets in Seattle's Urban Center Villages, such as the U-District.	All on-street parking paid and short term On-street parking may be restricted or removed to accommodate increased person capacity of street, according to City guidelines	Attached Landscape buffer: none Tree spacing: 20'- 40' Minimum, preferred and maximum usable sidewalk widths or clear zones to be established.	25 mph maximum Typical speed should be 20 mph, regardless of functional classification.
Urban Village Center	T5: Urban Center	The commercial streets in the Residential and Hub Urban Villages, plus the remaining streets in the Urban Center Villages.	All on-street parking short-term, and metered/paid where appropriate. On-street parking generally required and may only be removed under special circumstances, as per City guidelines.	Attached Landscape buffer: none Tree spacing: 20'- 40' Minimum, preferred and maximum usable sidewalk widths or clear zones to be established.	30 mph maximum Typical speed should be 25 mph, regardless of functional classification.
Urban Village	T4: General Urban	The non-commercial streets in Seattle's Residential Urban Villages and Hub Urban Villages.	On-street parking generally required and may only be removed under special circumstances, as per City guidelines. Residential parking permit zones considered as appropriate.	Unattached Landscape buffer: minimum 5' Tree spacing: Min 40' Minimum, preferred and maximum usable sidewalk widths or clear zones to be established.	Speed limit may vary depending upon functional classification, but typically speed limit will be 30 mph or under, with typical speeds at 25 mph.
Single-Family Residential Neighborhood	T3: Sub-Urban	Low density residential areas throughout Seattle.	Network functionality is primary consideration, and on-street parking may be removed to accommodate additional person movement.	Unattached Landscape buffer: minimum 5' Tree spacing: Min 40' Minimum, preferred and maximum usable sidewalk widths or clear zones to be established.	Speed limit dependent upon functional classification and design speed.
Manufacturing/ Industrial Centers	D: District	Single-use manufacturing districts.	Truck loading is primary consideration and may preclude other on-street parking. Remaining parking generally metered. Short term where needed for customer access; long term where used primarily by employees	Where truck bays present, none required No landscape buffer or tree requirement Where no truck bays, minimum sidewalk width required.	Speed limit dependent upon functional classification and design speed.

3.5 Transportation Form

Finally, in addition to function and context, the physical form of the street right of way influences many decisions about street design and management. Form has little influence on performance measures, so it is not addressed in detail in this report.

Seattle already has a rich variety of street types that are based primarily upon form. These include form typologies such as:

- Green Streets
- Two types of Boulevards
- Various types of bicycle facilities
- Alleys and Woonerfs
- Parks Streets
- Stairs
- Dock Street, including "underwater streets"

These form typologies are all valid and may be defined in more detail in a design manual.

3.6 Pulling it Together: Classification Mapping

Figure 3-4 below begins to show how all the proposed classifications, including their most complex combinations, can be shown simultaneously on a single map. Using the city's existing GIS database, we have produced a "Classification Map" as shown in Figure 3-4.

Figure 3-4 Proposed Functional and Land Use Classifications

FUNCTIONAL CLASSIFICATIONS			
Mode	**Source Mapping**	**Line**	**Comments**
TRANSIT		Widest, bottom	
UVTN (Primary Transit)	To be defined. "Principal Transit Routes" are shown as placeholder	Dark Red	The UVTN is not yet mapped. Instead, we use "The Principal Transit Route" layer.
Secondary Transit	To be defined. "Major Transit Routes" are shown as placeholder	Mid-red	See above
Tertiary Transit	Remainder of transit not included above	Pink	For clarity, this layer is not mapped, but is available in the GIS. Tertiary transit does not feature prominently in the proposed performance measure system.
AUTO		Medium, in middle	
Primary Auto	"Principal Arterials"	Dark Blue	
Secondary Auto	"Minor Arterials" plus "Collector Arterials"	Light blue	
Tertiary Auto	Other streets		For clarity, these are not mapped.
BICYCLE		Narrow	
Primary Bicycle	'Routes commonly used by cyclists' and 'Lanes/trails' from City of Seattle. These equate to Comprehensive Plan classifications ("Bicycle Street" and "Urban Trails")	Dark green	
Secondary Bicycle	Not yet defined	Light Green	Not mapped
PEDESTRIAN		Narrowest, top	
Primary Pedestrian	Not clearly defined	Orange	These categories have not been mapped. They will be more clearly defined in a future work task.
Secondary Pedestrian	Not defined	Yellow	
TRUCK			
Primary Truck	Transport fig T-27 from Comp Plan	Gray	For clarity, these have not been mapped.

LAND USE CONTEXT CLASSIFICATIONS			
Context Zone	**Source Mapping**	**Map Color**	**Comments**
Urban Core and Urban Center main streets	Land Use Plan	Pale orange	We have mapped only the Urban Core. The main streets of the Urban Center Villages still must be defined.
Commercial streets in Hub and Residential Urban villages	Land Use Plan	Not colored	These have not yet been defined and so have not been mapped.
Hub urban villages and residential urban villages	Land Use Plan	Pale Orange	These are mapped.
Single family residential areas	Land Use Plan	Pale Yellow	
Manufacturing/ Industrial Centers	Land Use Plan	Not mapped	This document does not focus on these areas, so they have been omitted for the time being.

In addition to being displayed graphically, our proposed classification system can also use a shorthand notation that notes Context Zone plus priority for each mode. The abbreviations are outlined in Figure 3-5.

For example, a street such as Broadway in Capitol Hill would be defined as:

$$C_{UC}T_2A_2P_1$$

That is, Context Zone "Urban Center," Secondary Transit route, Secondary auto route and primary Pedestrian.

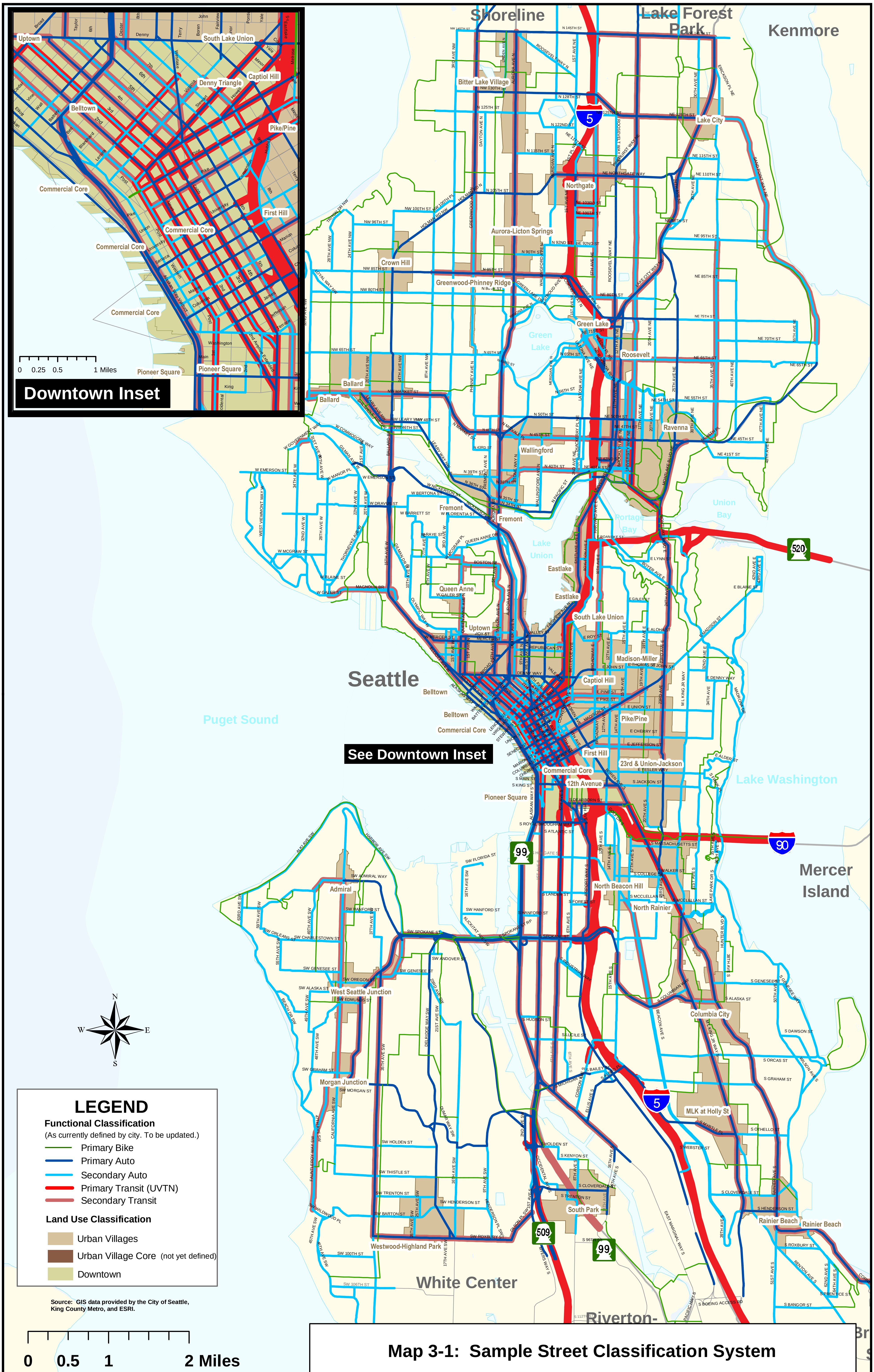
Similarly, Aurora in Fremont would be:

$$C_{UV}T_2A_1$$

That is, Context Zone "Urban Village," Secondary transit route, Primary auto route.

Figure 3-5 Shorthand for Proposed Functional Classifications

Route description	Shorthand
CONTEXT	
Urban Core and Urban Center main streets	C_{UC}
Commercial streets in Hub and Residential Urban villages	C_{CS}
Hub urban villages and residential urban villages	C_{UV}
Single family residential areas	C_{SF}
Manufacturing/ Industrial Centers	C_{MI}
TRANSIT ROLE	
UVTN (Primary Transit)	T_1
Secondary Transit	T_2
Tertiary Transit	T_3
AUTO	
Primary Auto	A_1
Secondary Auto	A_2
Tertiary Auto	A_3
BICYCLE	
Primary Bicycle	B_1
Secondary Bicycle	B_2
PEDESTRIAN	
Primary Pedestrian	P_1
Secondary Pedestrian	P_2
TRUCK	
Primary Truck ('Heavy Vehicle')	H_1



Map 3-1: Sample Street Classification System

4. Quality of Service Measures for Transit

4.1 Introduction to Quality of Service

This chapter uses the classification system outlined in the previous chapters to define performance measures for transit (being the focus of this working paper). Compatible performance measures for other modes of transportation are considered briefly in Chapter 5. Tools for balancing the performance of modes against one another are considered in Chapter 6.

As described earlier in this document, we are focused specifically on *Quality of Service* (QOS), the overall measured or perceived performance of transit service from the passenger's point of view. King County Metro will need to maintain its own efficiency measures from the operator's point of view.

Defining Transit Quality of Service

It is not realistic to attempt to measure every aspect of a transit network's quality of service. However, it *is* necessary to select a range of indicators that suitably represent and reflect the quality of service of the transit network and how attractive it will be to passengers.

From a practical perspective the approach we have adopted requires that:

- the necessary range of indicators is identified
- the measures of these indicators are aggregated in such a way that will provide a single indicator that can be used to compare transit QOS with measures of other modes. This comparison can then be used to help balance the needs of transit with the needs of other modes and the urban context in which they operate.

This section:

- identifies the uses for the Transit Service Measures
- broadly outlines the range of potential quality of service measures
- describes a framework with which these measures can be applied
- describes in more detail the measures proposed as part of this process.

Unit to be assessed - *Transit Route Segment*

The process developed in this study aims to avoid the intersection-by-intersection or block-by-block focus of the Highway Capacity Manual approach. In addition to this, it aims to consider the transportation network from the perspective of transit rather than traffic. For this reason, we have proposed transit service measures that incorporate aspects of network and route performance (such as frequency and reliability) as well as more localized indicators such as travel speed.

We have chosen the term *Transit Route Segment* to refer to the portion of a route or road corridor to be assessed. The transit route segment for assessment will be defined based on the needs of the planning process. For example, if a commercial main street is being re-configured, the planners' focus will be one or two blocks. If a monorail is being designed, the planners' focus could be several miles. Regardless of the length of the site in question, however, a minimum *Transit Route Segment* length of three miles should be used in the assessment process. This creates flexibility in how standards are addressed in a given area, while still assuring the aggregate results that the UVTN requires.

To the extent possible, route segments should begin and end at timepoint interchanges. This will provide consistency with King County Metro, allowing the use of available data.

4.2 The Uses of the Transit Service Measures

Different groupings of the transit service measures outlined in the following sub-section will be used for different purposes, as described below.

System Assessment

For the purpose of assessing the performance and/or service quality of a route segment (or larger element) of the UVTN, an aggregate of *all* the key Transit Service Measures outlined below will be used (as described in Section 4.4).

Design

For the purpose of undertaking design work on a street or particular element of the transportation network (which could be smaller than the defined route segment), an aggregate of *two* key Transit Service Measures (speed and reliability) will be used (as described in Section 4.6).

4.3 Potential Quality of Service Factors

We researched a broad variety of approaches to measuring Transit Quality of Service to identify a methodology that would meet certain key criteria including:

- Measures factors of most importance to allow transit to achieve Seattle's economic development, quality of life and land use goals
- Requires modest investment in data collection, using the city's existing resources
- Understandable to engineers, planner and policymakers

The most suitable methodology we found is described in great detail in the Transportation Cooperative Research Program's *Transit Capacity and Quality of Service Manual*, prepared by Kittleson & Associates. While that document is now in its second edition, the first edition (TCRP, 1999) outlined a range of factors affecting quality of service that include:

- **Service Coverage** – Whether or not transit service is provided near one's origin and destination is a key factor in the choice to use transit.
- **Pedestrian Environment** – Even if a transit stop is located within a reasonable walking distance of a person's origin and destination, the walking environment will influence their choice to use transit.
- **Frequency** – How often transit service is provided and when it is provided are important factors in one's decision to use transit.
- **Amenities** – The facilities that are provided at transit stops and stations help make transit more comfortable and convenient to customers.
- **Transit Information and System Legibility** – Potential riders need to know where and when transit service is available before they can begin using it. Regular riders need to be informed about service changes that will affect them.
- **Transfers** – Requiring transfers between routes adds to a passenger's total trip time by transit. To deliver an integrated system, such transfers should be limited to a finite set of nodes and timed to minimize waiting times or the risk of missed connections.
- **Total Trip Time** – Total trip time includes the travel time from one's origin to a transit stop, waiting time for a transit vehicle, travel time on-board a vehicle, travel time from transit to one's destination, and any time required for transfers between routes during the trip. The importance of each of these factors varies from person to person.
- **Cost** – Potential passengers weigh the cost and value of using transit versus the out-of-pocket costs and value of using other modes.
- **Safety and Security** – Riders' perceptions of the safety and security of transit, as well as actual conditions, enter into the mode choice decision.
- **Passenger Loads** – Transit is less attractive when passengers must stand for long periods of time, especially when transit vehicles are highly crowded. Crowded vehicles also slow down transit operation, as it takes more time for passengers to get on and off.
- **Appearance and Comfort** – Having clean, graffiti-free transit stops, stations, and vehicles improves transit's image, even among non-riders. Passengers are also

interested in ride comfort, which includes both seat comfort and the severity and amount of acceleration and deceleration (both lateral and longitudinal).

- **Reliability** – Reliability affects the amount of time passengers must wait at a transit stop for a transit vehicle to arrive, as well as the consistency of a passenger's arrival time at a destination from day to day. Reliability encompasses both on-time performance, as well as the regularity of headways between successive transit vehicles.

The full excerpt from the TCRP report is provided in Appendix A.

4.4 Selected Measures for Assessing Quality of Service

In developing appropriate measures of Quality of Service for Seattle's UVTN, Nelson\Nygaard drew on the measures recommended in the TCRP report. We then adapted them to meet the needs of City of Seattle and their planning and implementation process. We also selected five key measures that, in aggregate, best define the service characteristics most important to Seattle. These include:

- Frequency
- Span of Service
- Reliability
- Loading
- Travel Speed

These selected measures are described in the following sub-sections. The descriptions are structured as follows:

- Justification of the measure's selection
- System of measurement, along with specific targets and Quality of Service scoring
- Issues for consideration when applying the measure

The proposed "System of Measurement" charts are especially important. For each key measure, specific targets are set that correspond to numerical Quality of Service "scores." These scores are equivalent to the A-F letter scale in traditional Level of Service measures, but they have two key advantages:

- The letter ranking cannot be confused with elementary school grades, where 'F' stands for "Fail." Rather, it lets us define what "fail" means and adjust it given the context.

- More importantly, they allow us to combine different factors into an aggregate scale, weighting some factors more strongly than others.

In this chapter, we focus exclusively on the desired performance of the UVTN. Specific thresholds are set for good performance and poor performance. In each case, we also set a "failure" threshold for each factor. *A score in this category would automatically mean that remedial action is necessary, even if a UVTN segment scores very well in all other measures.*

The thresholds within each factor will require additional scrutiny and review from a variety of agencies and will likely be adjusted.

The performance measures have been designed to maximize the use of existing data. However, a significant amount of new data collection and processing will be required, and King County Metro and the City of Seattle will need to develop an agreement on how to share the costs of these efforts. Note that King County Metro is currently purchasing new on-board systems that will provide more accurate data, and the introduction of this system of performance measures could usefully be timed to coincide with the introduction of this technology.

In the final section of this chapter, we provide tools for weighting the individual measures against one another for an aggregate Quality of Service score. This aggregate score is then used in Chapter 6 to balance transit performance against the performance of other modes.

Each of the five key transit measures is addressed below.

Frequency

Justification of the measure's selection

The UVTN has been defined as a system of high frequency transit services running at least every 15 minutes or better. The 15-minute headway represents the point at which the passenger no longer needs to consult a schedule to use the service. It also permits transfers to be made rapidly even without timing of connections. It is recognized that the threshold frequency of 15 minutes is a point at which the benefits of transit tend to grow exponentially.

From the user's perspective, frequency determines the number of times an hour a user has access to the transit mode, assuming that transit service is provided within acceptable walking distance (measured by service coverage) and at the times the user wishes to travel (measured by hours of service). Service frequency also measures the convenience of transit service to choice riders and is one component of overall transit trip time (helping to determine how long one waits for a transit vehicle).

System of measurement

Although the measure of *frequency* strictly refers to the number of services per hour, the measure of *headway* is often more useful and easier to use. The unit of headway also measures frequency, but measures it in terms of minutes between services.

The conditions for assessing the UVTN in terms of frequency are as follows:

- Select segment to be measured. Refer to requirements of Transit Route Segments outlined earlier in Section 4.1.
- Service frequency LOS is determined by destination from a given transit stop, as several routes may serve a given stop, but not all may serve a particular destination. Some judgment must be applied to bus stops located near timed transfer centers. There is a considerable difference in service from a passenger's perspective between a bus arriving every 10 minutes and three buses arriving in a row from a nearby transfer center every 30 minutes, even though both scenarios result in six buses per hour serving the stop. In general, buses on separate routes serving the same destination that arrive at a stop within 3 minutes of each other should be counted as one bus for the purposes of determining service frequency LOS.
- The assessment of frequency should be based on the longest headways on the daily schedule, excluding Owl service.
- In general, segments will be selected so that frequencies are consistent along the whole segment. Where this is not the case, an average should be used, based on the relative lengths of the partial segments with a particular frequency.

Proposed UVTN Transit Frequency Measurement

	QOS	Headway (minutes)	Comments
Pass	+3	< 7	Passengers don't need schedules, headway based
	+2	7 – 10	Passengers don't need schedules, headway based
	+1	11 - 15	Frequent service, passengers start consulting schedules
Fail	-3	16 - 20	Undesirable time to wait if bus/train missed
	-6	21 – 30	Service unattractive to choice riders
	-9	> 31	Service unattractive to all riders

For consideration when applying the measure

It should be emphasized that although headways are given as continuous ranges for the purposes of determining LOS, passengers find it easier to understand schedules when clock headways are used (headways that are evenly divisible into 60). When clock headways are used, transit vehicles arrive at the same times each hour. This is particularly important when headways approach the higher end of the acceptable range.

For late night *owl* services, headways should be 30 minutes or less.

It should be noted that this measure would introduce a system of headway management, in contrast to Metro's current policy of schedule adherence. This has broad implications for the agency, since the reliability measure will need to be consistent with the method that Metro uses to control service. In any case, Metro will need to continue to control schedule adherence for routes with headways of more than 15 minutes.

Span of Service

Justification of the measure's selection

While it is often feasible to run high frequency transit services during a limited peak period, a truly useful and attractive transit system needs to maintain this level of service throughout the day. This is important for a number of reasons, including:

- As mixed land uses cluster in urban villages / along transit lines, the purpose and timing of trips will become more diverse and the transit network will need to respond to this demand.
- Analysis of travel data shows that non-commuter travel demand is growing significantly faster than commuter trips. To achieve the City's environmental and travel demand management aims, it is important that this high-growth travel can be captured by transit.
- Unit costs of peak-only services are usually higher than for all-day services, because of the inefficiency of partial shifts.

System of measurement

Span of service (also known as hours of service) is relatively easy to measure. It is the number of hours in the day that a service runs at UVTN frequencies.

The conditions for assessing the UVTN in terms of *span of service* are as follows:

- Select segment to be measured. Transit Route Segments outlined earlier in Section 4.1.
- Span of service LOS is determined by assessing the hours of service for the whole route. This is important, as the UVTN will be made up of services running at high frequencies throughout the required hours of service. If one element of the network shuts down early, the network is essentially flawed, and its usefulness severely compromised.

- In general, segments will be selected so that service spans are consistent along the whole segment. Where this is not the case, an average should be used, based on the relative lengths of the partial segments with a particular span.

Proposed UVTN Span of Service Measurement

	QOS	Service Span (hours)	Comments
Pass	+3	20 – 24	Night service provided (e.g. 4:30 am – 12:30 am or better)
	+2	18 – 20	Late evening service provided (e.g. 5:00 am – 1 am)
	+1	16 – 18	Late evening service provided (e.g. 6:00 am – 10:00 pm)
Fail	-3	14 – 16	Early evening service provided (e.g. 6:00 am – 8:00 pm)
	-6	12 – 14	Minimal span not useful to many riders. (e.g. 6:00 am – 6:00 pm)
	-9	< 12	Service useful only for regular riders making rigidly scheduled commutes. (e.g. peak-only service)

For consideration when applying the measure

If a route has sufficient ridership to justify UVTN-level frequencies levels for over 16 hours a day, it will generally have sufficient ridership to justify (or require) a night (or *owl*) service running at reduced frequencies.

Reliability

Justification of the measure's selection

A high-frequency 'headway-scheduled' system such as the UVTN reduces some of the challenges involved with a lower-frequency 'timetable-scheduled' system. Nevertheless, passenger confidence in the system, and its ability to capture patronage is still is heavily dependent on the reliability of the UVTN services.

This dependence goes much deeper than pure waiting time, as every interface, whether between two UVTN services or between the UVTN and a local service, will be affected by service reliability (or lack thereof).

System of measurement

Care was taken to adopt a system of measurement that encourages addressing problems associated with delays, for example adding extra services during poor weather or diverting services during delay events. It was also deemed necessary to focus on achieving scheduled headways *or better*. Note that headway adherence is used to measure reliability, so schedule adherence (including early arrivals) is only considered to the extent that it affects headways.

Method #1 – TCRP Headway Adherence Approach

The *headway adherence* approach outlined in the TCRP report (TCRP, 2003) assesses reliability based on both late-running and early-running services. Since the UVTN will be running to a headway schedule, we modified this approach in such a way that it was based on the assumption that when transit is running to a headway schedule rather than a timetable, it is acceptable for services to run early, so long as that does not cause an increase in the waiting time for the following service(s).

We therefore propose the concept of measuring the *gap* between buses to determine the percentage of transit vehicle arrivals where the actual headway *exceeded* the scheduled headway by more than a certain time.

The easiest way to illustrate this approach is through an example. The table below describes 10 services along a route where the scheduled headway is 5 minutes:

A	B	C	D = C - A	E
Service No.	Scheduled headway	Actual headway	Actual – Scheduled ('gap')	Only count delays ('gaps' > headway)
1	5	5	0	0
2	5	8	3	3
3	5	2	-3	0
4	5	3	-2	0
5	5	2	-3	0
6	5	10	5	5
7	5	5	0	0
8	5	5	0	0
9	5	2	-3	0
10	5	3	-2	0
Standard Deviation		2.72	2.72	1.75
Coefficient of variation		0.54	0.54	0.35

Notes:
Coefficient of Variation = Std Deviation of Headway / Scheduled headway
Column E can be calculated using the Excel IF function: IF (Logical test, value if true, value if false).

The conditions for assessing the UVTN in terms of reliability are as follows:

- Select segment to be measured. Transit Route Segments outlined earlier in Section 4.1.
- Service reliability LOS is determined by destination from a given transit stop, as several routes may serve a given stop, but not all may serve a particular destination.
- Set up a table such as included in the example above and time services in order to fill in Column C.

- If headway adherence is measured at multiple points, an average of the coefficient of variation should be taken.

Proposed UVTN Reliability Measurement				
	QOS	Coefficient of Variation	Probability of delay of > 0.5 headway	Comments
Pass	+2	0.00 - 0.21	≤1%	Service is provided like clockwork, with very regular headways.
Pass	+1	0.22 - 0.30	≤10%	Most vehicles are off the scheduled headway by a few minutes, but the likelihood of being off-headway by more than one-half the scheduled headway amount is low (e.g., 5 minutes off a 10 minute scheduled headway).
Fail	-3	0.31 - 0.39	≤20%	Vehicles are often off-headway, with a few headways much longer or shorter than scheduled.
Fail	-6	0.40 - 0.52	≤33%	Headways are quite irregular, with up to one in three vehicles one-half a headway or more off-headway.
Fail	-9	0.53 - 0.74	≤50%	Bunching occurs frequently.
Fail	-9	> 0.50	>50%	Most vehicles are bunched.

Note: these coefficients of variation were taken directly from the TCRP report (TCRP, 2003) and have not been independently verified for the purpose of this study. It appears that these coefficients were based on gaps that were both shorter and longer than the scheduled headway. These figures will therefore need to be re-visited should this overall approach be adopted. For the purposes of this report, however, the pass-fail ratings have been slightly modified to take account of the TCRP outputs.

The measure of *coefficient of variation* is a coefficient of standard deviation, thus in itself means very little from a perceptual perspective. The column titled *Probability of delay of > 0.5 headway* provides a more understandable measure of reliability, corresponding to the probability that a given transit vehicle's headway will be off-headway by more than one half of the scheduled headway. From the explanation given in the TCRP report (TCRP, 2003), it is understood that this probability was only measured for services arriving after a wait (*gap*) *greater than* the scheduled headway.

If this system of measurement is adopted, the values in the columns titled *Coefficient of variation* and *Probability of delay of > 0.5 headway* will need to be verified and refined to meet the needs of Seattle.

Method #2 – Empirical Approach

As an alternative to the relatively theoretical approach outlined in Method #1, it could be advantageous to develop a measure that is more easily understood by stakeholders. An example of such a measure could be one that assigns QOS ratings based on the probability of different degrees of headway variation (*gaps*) occurring.

An example of such a system is outlined below.

Potential Alternative UVTN Reliability Measurement

	QOS	Measure of degree of Variation	Comments
Pass	+3	> 90% services running < 1 min late > 95 % services running < 3 mins late < 1% of services running > 5 mins late	Service running like clockwork
	+2	> 75% services running < 1 min late > 95 % services running < 3 mins late < 2% of services running > 5 mins late	Some vehicles a minute or two late
	+1	> 60% services running < 1 min late > 90 % services running < 3 mins late < 3% of services running > 5 mins late	Many vehicles off scheduled headway by several minutes
Fail	-3	> 3% of services running > 5 mins late	Headways irregular but bunching does not yet occur
	-6	> 5% of services running > 5 mins late	Occasional bunching
	-9	> 10% of services running > 5 mins late	Regular bunching

Weighting of measures

Regardless of the method adopted to measure reliability, it is clear that a full bus running late will delay more passengers than a bus carrying very few passengers. There is some merit, therefore, in weighting measures of delay to reflect the number of people being affected by it (i.e. measuring person delay rather than vehicle delay). The precise process by which this will be done will depend on the method of measurement adopted.

Pass-ups

Based on an understanding of the effects of different degrees of delay and the number of passengers affected, the operators would likely develop protocols by which pass-ups are used to re-gain the required headway gaps.

This is important because on particularly busy routes, even a slight delay produces a "snowball effect", because the number of passengers waiting for a bus is related to the length of the gap in front of the bus. This will happen even if a scheduled 5-minute service opens up a seemingly small 7-minute gap.

If pass-ups are used, they will need to be incorporated into the system of measurement, to ensure that there recurrence (and negative impacts on transit users) is limited.

Loading

Justification of the measure's selection

Loading constitutes a potent measure as it provides a useful indication of a range of issues affecting transit. This was articulated well in the TCRP (2003) report[5]:

> *From the passenger's perspective, passenger loads reflect the comfort level of the on-board vehicle portion of a transit trip—both in terms of being able to find a seat and in overall crowding levels within the vehicle.*
>
> *From a transit operator's perspective, a poor LOS may indicate the need to increase service frequency or vehicle size in order to reduce crowding and to provide a more comfortable ride for passengers.*
>
> *A poor passenger load LOS indicates that dwell times will be longer for a given passenger boarding and alighting demand at a transit stop and, as a result, travel times and service reliability will be negatively affected.*

System of measurement

Care was taken to adopt a system of measurement that encourages tailoring vehicle specification to the passenger and system needs. The level of service measures proposed by TCRP note that to achieve a LOS of A, there should be more than two seats for each carried passenger. This risks inadvertently promoting inefficiency, with transit services running at under half their capacity.

In addition, the TCRP approach assesses passenger load using the measures of square meter per passenger or passengers per seat. These measures could risk confusion if, for example, low floor buses with a metro-style side-bench seating replaced coach-style buses. The metro-style configuration could feasibly transport higher number of passengers over crowded, short-haul sections more comfortably and efficiently than coach-style configurations.

For this reason, we have chosen the measure of *percentage of vehicle capacity* (% Capacity). This measure will provide a more 'level' means of comparison between different vehicles serving different needs. It will also encourage the use of vehicles better-suited to different roles in the transit network.

Other possible measurements of loading should be discussed with King County Metro, since all measures are, at best, an inexact science. Eventually, a better way to measure load may be "Number of standees / square foot," already common in many high-capacity transit operations. Here, the square foot is a measurement of floor area not obstructed by seats. This area is higher for a perimeter seating arrangement.

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[5] Transit Cooperative Research Program, *TCRP Report 100 Transit Capacity and Quality of Service Manual 2nd Edition.* Submitted by Kittleson Associates, 2003. Page 3-43.

If measurements are taken at multiple points along a segment, an average should be used.

Loading			
	QOS	% Capacity	Comments
Pass	+3	55 – 70%	For low capacity vehicle configurations (i.e. high proportion of seats), most or all passengers would have seats. For high capacity vehicle configurations (i.e. low proportion of seats), limited availability of seating (depending on the precise configuration of the vehicle).
	+2	71 – 85% or < 50%	Generally standing room only, but free passage for boarding and alighting.
	+1	86 – 100%	Approaching maximum capacity, density of passengers risks slowing boarding and alighting. Generally still comfortable for passengers, albeit standing.
Fail	-3	101 – 110%	Some level of overcrowding. Density of passengers causes some delays in boarding and alighting, potentially uncomfortable for passengers.
	-6	110 – 120%	Overcrowded, density of passengers causing some delays in boarding and alighting. Uncomfortable for passengers,
	-9	> 120%	Severe overcrowding. Approaching crush capacity, density of passengers causing significant delays in boarding and alighting. Uncomfortable for passengers, starting to bring safety risks.

For consideration when applying the measure

The capacity of a transit vehicle is generally determined by the manufacturers. It describes the number of passengers (seated and standing) that can safely and comfortably travel on the vehicle. It generally also reflects the operational needs of the vehicle such as passenger circulation (within the vehicle and boarding and alighting). However, stated capacities can often differ from passengers' perceptions. For this reason the City of Seattle and King County Metro should agree on the capacity of each vehicle type for the purposes of this analysis, using the manufacturer's stated capacity as a starting point. This will also allow the tailoring of standards to different vehicle types.

In periods of peak demand, vehicles are sometimes loaded to levels above their capacity. Once a vehicle is loaded to a point where it becomes unrealistic for any more passengers to board it is said to be at crush capacity. As loadings increase from capacity to crush capacity, the passenger circulation (within the vehicle and boarding and alighting) becomes less efficient, increasing the required dwell times at stops.

Note that the measure here refers to average loads, whereas variations in loading can be the key issue from the passenger's perspective (for example, a crush load followed by an empty vehicle). These variations, however, tend to be caused by poor headway adherence, and for this reason this measure needs to be considered alongside the reliability measure. High *average* loads indicate a need for more capacity on a route, whereas high *variations* in loads tend to indicate that reliability problems need to be addressed.

Travel Speed

Justification of the measure's selection

Travel speed of services provided by most urban transit agencies are gradually slowing, typically at rates of 1-3% per year. This is just gradual enough that it rarely becomes a political issue, and yet it represents a profound decay over just a few years. Overall transit travel speed, including stops, may be one of the most powerful transit performance measures, for the simple reason that speed affects the transit operation in two independent ways:

- Falling speeds mean rising operating cost (slower service → longer running times → more buses needed to maintain a given headway → more cost). This comes at the expense of additional needed service to which this money could be devoted.
- Falling speeds discourage ridership, because the service is less attractive relative to the automobile.

The TCRP document recommends the use of Transit/Auto Travel Time difference as the preferred measure of travel speed. This recommendation has at least one serious problem. In the face of increasing levels of auto congestion, it would seem counter-productive to assess transit speeds relative to auto speeds. If this measure were used, there would be a risk that as auto travel time increased, so would transit travel time, meaning that over time, the speed and efficiency of the transport network would gradually reduce.

Based on the recognition of these issues, Nelson\Nygaard developed an alternative measure of *Percentage of Posted Speed Limit*.

This was selected on the basis that it constitutes a readily available and simple term of reference. Importantly, posted speed limit is a reasonably consistent term of reference because it is less prone to "creep" than measures such as auto or network speeds. By using it as an assessment measure, it is therefore possible to promote improved transit travel speeds and avoid the risk of declining speeds on the overall network.

System of measurement

Although *travel speed* would generally be measured in MPH, the system of measurement to be used in this case is travel speed as a proportion of the posted speed limit. The unit will therefore be *Percentage of Posted Speed Limit* (%SL).

The conditions for assessing the UVTN in terms of transit travel speed are as follows:

- Select segment to be measured. Transit Route Segments outlined earlier in Section 4.1.
- The measurement of transit travel speed needs to incorporate all aspects of the trip, including dwell time at stops and traffic signals, delays caused by traffic congestion and mechanical faults.

- Travel time along a segment would then be divided by the speed limit

Proposed UVTN Loading Measurements

	QOS	% Posted Speed Limit	Comments
Pass	+3	> 20% of services running > 0.7SL > 90% of services running > 0.5SL (or 10 MPH, whichever is greater) 100% of services running > 0.3SL (or 10 MPH, whichever is greater)	A very high proportion of transit services running at speeds that would make it attractive compared to driving.
	+2	> 10% of services running > 0.7SL > 80% of services running > 0.5SL (or 10 MPH, whichever is greater) 100% of services running > 0.3SL (or 10 MPH, whichever is greater)	A high proportion of transit services running at speeds that would make it attractive compared to driving.
	+1	> 5% of services running > 0.7SL > 70% of services running > 0.5SL (or 8 MPH, whichever is greater) 100% of services running > 0.3SL (or 8 MPH, whichever is greater)	An acceptable proportion of transit services running at speeds that would make it attractive compared to driving.
Fail	-3	< 70% of services running > 0.5SL > 5% of services running < 0.3SL (or 8 MPH, whichever is greater)	An unacceptable proportion of transit services running at speeds that would make it attractive compared to driving.
	-6	< 50% of services running > 0.5SL > 10% of services running < 0.3SL (or 8 MPH, whichever is greater)	An unacceptable proportion of transit services running at speeds that would make it attractive compared to driving.
	-9	< 30% of services running > 0.5SL > 20% of services running < 0.3SL (or 8 MPH, whichever is greater)	An unacceptable proportion of transit services running at speeds that would make it attractive compared to driving.

For consideration when applying the measure

As mentioned earlier, posted speed limit has the potential to serve as a reasonably consistent term of reference (unlike auto or network speeds which tend to be prone to "creep"). One of the main reasons that the posted speed limit was selected is that it is very uncommon that it changes without significant effort and process. This said, care needs to be taken to ensure that posted speed limits are not reduced as a means of improving the measured travel speed LOS.

4.5 Framework for Assessing Transit Quality of Service

This subsection describes the process by which the individual QOS measures can be brought together to provide an overall assessment of the QOS of a particular transit route or network segment. While the individual performance criteria help determine the actions necessary to optimize the transit system itself, aggregation of the criteria helps to provide a more complete picture of the quality of service that different elements of the transit network offer. It also assists in determining how to balance the needs of transit with those of other modes. These weighted scores are used in the "balancing process" described in Chapter 6.

Process

The process for measuring Transit Quality of Service is summarized as follows:

- Select segment to be measured. Transit Route Segments outlined earlier in Section 4.1.
- Undertake the measurements of individual QOS indicators (Frequency, Hours of Service, Reliability, Loading and Travel Time) as outlined in Section 4.4.
- Incorporate into the Transit Service Measures Report Card (as described in the following subsection).

Transit Service Measures Report Card

As outlined earlier, the use of *Transit Service Measures* is an effective and appropriate way of assessing the quality of service offered by a transit network. We see an advantage to maintaining the transparency of the measurement process and consider that the production of a "Report Card" for each transit route segment assessed. This will ensure that the relative performance of the route segment in all of the component service measures is taken into account in the planning process.

A sample report card is provided in the figure below. Sample scores are inserted in gray.

The features of the report card are summarized below.

Service Measure

The service measure is shown in the left hand column. Details of these service measures, and how they are calculated or applied are provided in Section 4.4.

Weighting

Some service measures are considered more important than others. In this case, we assumed that frequency and travel time are the most important factors that determine transit mode split, the key concern of the city. To accommodate these differences, therefore, a simple weighting has been applied. For the frequency and travel time measures, each point is multiplied by two.

QOS scores ("Fail / Pass" columns)

This portion of the "Report Card" brings together the scores from the individual QOS assessment processes.

For an overall assessment to be considered a "pass", all measures must be +1 or greater; that is, if any individual measure appears in the red-shaded portion of the table, it causes an instant 'fail' in the overall assessment.

The scores for the individual assessments are entered in the body of the table.

QOS scores ("Total" column)

The individual scores are then multiplied by the weighting of their row to calculate the number in the "Total" column. The numbers in this column are then summed to calculate the Total Aggregated Quality of Service. This final sum can be divided to get an average weighted score. In the sample below, the total score of 11 points produces a weighted average of 1.6, Acceptable to Good overall.

QOS descriptions

The meaning of the different QOS scores will vary depending on the individual measure. This said, the global meaning of the different scores are provided at the bottom of the report card.

Location: ______________________									Date of assessment:
Service Measure	Weighting	FAIL			PASS			Total	Comment
		-9	-6	-3	+1	+2	+3		
Frequency	2					2		4	
Hours of Service	1						3	3	
Reliability	1				1			1	
Loading	1				1			1	
Travel Speed	2				1			2	
Total	7							11	Aggregated Quality of Service
					1.6				Average Score

QOS Descriptions		Fail – Very Poor	Fail - Poor	Fail	Acceptable	Good	Excellent		

Limitations associated with the aggregation of individual transit service measures

The aggregation of a range of individual transit service measures into a single measure is a necessary part of the overall process we have developed to balancing the needs of different modes of transport while improving transit quality of service. This said, the process of aggregation should be considered with caution for a number of reasons, as outlined below.

- Particularly poor performance on one segment or in one measurement may produce an overall poor score for a route that otherwise performs well.
- Route segments scoring higher on such measures as Frequency could benefit the most from high performance in other service measures. For example, if travel speeds are improved on high frequency routes, there will be greater saving in operating costs and travel time.

There are a number of methods that could be applied to address these potential issues, including:

- Reduce the effect of aggregation by classifying the route segment by the poorest performing transit service measure.
- Select critical transit service measure(s) (eg: frequency) and require better performance overall performance for route segments that score well in the critical measure(s).

4.6 Transit Quality of Service Measures for Design Work

The overall Transit QOS measure (as explained and developed in Section 4.5) can be readily used in the 'balancing' process outlined in Section 6.

It is recognized, however, that for design processes associated with short sections of transit segments (e.g. a few blocks), it is not necessary to undertake all the assessments associated with the Transit QOS measure. Rather, it is considered appropriate to use an aggregate of *two* key Transit Service Measures (speed and reliability).

These transit measures would be calculated as described in Section 4.4 and a simplified process of aggregation, as outlined below.

The resulting QOS can then be used in the 'Balancing Process' (as outlined in Section 6).

Location: ____________________								**Date of assessment:**
Service Measure	**FAIL**			**PASS**			**Total**	**Comment**
	-9	-6	-3	+1	+2	+3		
Reliability				1			1	
Travel Speed				1			2	
Total							3	Aggregated Quality of Service
				1.5				Average Score

QOS Descriptions	Fail – Very Poor	Fail - Poor	Fail	Acceptable	Good	Excellent		

5. Quality of Service Measures for Non-Transit Modes

To be useful to traffic engineers, planners and road designers, the transit Quality of Service measures outlined in Chapter 4 must be paired with comparable measures for other modes. Planners must know the extent to which one mode can be inconvenienced in order to benefit another mode. They must understand how the competing needs of each mode are best balanced against the others.

This chapter begins to explore how Quality of Service measures may be developed for automobiles, bicycles, pedestrians, freight and parking. The measures are designed to be directly compatible with those proposed for transit, so that straightforward balancing tools can be developed, as shown in Chapter 6.

This section is intentionally cursory, and provides 'placeholders' rather than final recommended performance measures. Before implementing, more detail will need to be developed for each of these modes below.

5.1 Automobile

Existing LOS Standards

As discussed in Chapter 2, volume to capacity (v/c) ratio is the currently adopted Arterial Level of Service measure in the Seattle Comprehensive Plan. Adoption of such a level of service standard in the Comprehensive Plan is a State requirement, although the Washington State Growth Management Act grants a significant amount of flexibility in the choice of a measure and its application. Once a jurisdiction sets a standard, it is used to assess concurrency, i.e. if the impacts of new development can be met through existing capacity, and/or to determine the required mitigations.

V/c ratios take the total number of vehicles on a given stretch of roadway and divide by the capacity of that road to handle cars. A v/c ratio of 0.80 or lower represents free-flow conditions, while a ratio of 1.20 represents severely congested conditions. The Seattle Comprehensive Plan uses a screenline method to measure v/c, taking a measurement point that crosses a series of parallel roads. The method measures travel time along a corridor rather than a single facility, and is intended to reflect the ability a driver has to use alternative routes. Arterial Level of Service standards are set at either 1.0 or 1.2, depending on the screenline (those that are placed at bodies of water, such as the Ship Canal, are higher, due to the lack of alternative routes).

The Arterial Level of Service standards defined in the Comprehensive Plan have a limited, legal focus – to assess concurrency requirements for new development. While these are useful in this regard, they are perhaps not best suited to the role of balancing the needs of different modes on a specific street segment, due to the following reasons:

- By focusing on spot locations (albeit on a screenline, rather than a single arterial), they say nothing about overall travel time between destinations – the factor that motorists care most about.
- Standards are defined for only a limited number of screenlines.
- Standards are set as a simple pass/fail test, rather than a graduated scale (such as the −3 to +3 scale for transit proposed in this document, or an A-F letter scale.)

Possible Performance Measures

There is a range of different methods of measuring performance for automobiles. These include:

- Volume/capacity ratio
- Intersection delay
- Graded A-F level of service (which can be based on v/c ratio or intersection delay, accounting for roadway type and free-flow speed)
- Average travel times between destinations

Each method has a range of advantages and disadvantages, which are beyond the scope of this working paper to explore. In addition, it would be helpful for any new methodology to be consistent with updated concurrency standards in the Comprehensive Plan, and other applications. For these reasons, the existing v/c methodology is used as a placeholder in this working paper, prior to the possible development of new performance standards for automobiles.

5.2 Bicycle

Recent research has resulted in two emerging national standards for bicycle level of service:

- Bicycle Compatibility Index, developed for the Federal Highway Administration[6]
- Bicycle Level of Service, developed for the Florida Department of Transportation[7]

Both are similar, in that they employ a formula to take into account various roadway design features and traffic characteristics, and express results on a scale of A through F. Grade "A" represents the best conditions for bicycles. The Bicycle Compatibility Index (BCI) is the best established of the two measures, and is recommended as the interim measure for the City of Seattle. The BCI requires the following inputs:

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[6] The Bicycle Compatibility Index: A Level of Service Concept. Implementation Manual. FHWA-RD-98-095. Available at: www.hsrc.unc.edu/research/pedbike/98095/index.html

[7] Landis, Bruce, *et. al.* (1997), "Real Time Human Perceptions: Toward a Bicycle Level of Service," *Transportation Research Record 1578*. Available at: www11.myflorida.com/planning/systems/sm/los/pdfs/BLOS%20TRB%20Scanned.pdf

- Geometric and roadside data:
  - Number of through lanes
  - Curb lane width
  - Bicycle lane or paved shoulder presence and width
  - Area character (residential or non-residential)
- Traffic operations data
  - Posted speed limit
  - 85th percentile speed of motor vehicles
  - Average Annual Daily Traffic volume
  - Percentage of traffic constituted by trucks
  - Percentage of vehicles turning right into driveways or minor intersections
- Parking data
  - Presence of on-street parking
  - On-street parking occupancy
  - Parking time limit

Note that both of these methodologies apply to mid-block segments only. Intersection level of service methodologies for bicycles are currently under development by the Florida Department of Transportation.[8] They also apply only to on-street facilities.

5.3 Pedestrian

Establishing a performance indicator for pedestrians is fraught with several problems. Not only is there a lack of a nationally recognized standard measure, but – as with bicycles – there are also numerous, interwoven factors affecting the quality of the pedestrian environment. The Pedestrian Level of Service measure described in the *Highway Capacity Manual* primarily focuses on the capacity of sidewalks and other facilities; in other words, an empty, hostile suburban sidewalk can score better than a busy, vital, urban commercial street. While this may be appropriate in limited instances in Seattle where capacity is a real concern (for example at station entrances and around busy bus stops), a more generally applicable measure of the quality of the pedestrian environment is necessary.

A number of cities, such as Fort Collins, CO, have developed their own measures for pedestrian quality. The Fort Collins methodology takes into account five criteria: directness of routes; continuity of routes; street crossings; visual interest; and amenity and security. Another promising standard results from Florida Department of Transportation research.[9]

[8] Landis, Bruce *et. al.* (2003), “Intersection Level Of Service For The Bicycle Through Movement,” *Transportation Research Record No. 1828.* Available at: www11.myflorida.com/planning/systems/sm/los/pdfs/TM%20IntBLOS4.pdf
[9] Landis, Bruce *et. al.* (2001), “Modeling the Roadside Walking Environment: Pedestrian Level of Service,” *Transportation Research Record No. 1773.*

Similar to the Bicycle Compatibility Index, the Pedestrian Level of Service methodology uses a formula to take into account various relevant characteristics, and expresses results on a scale of A through F. It requires the following inputs:

- Sidewalks
  - Presence and width of sidewalk
- Lateral separation of pedestrians and motor vehicles
  - Widths of outside lane and any shoulder or bike lane
  - Presence of on-street parking
  - Presence and width of buffers between sidewalk and travel lane (e.g. trees)
- Motor vehicle volume and speed
  - Motor vehicle traffic volume
  - Number of through traffic lanes
  - Average motor vehicle speed

Pedestrian Level of Service is to be considered in detail by Nelson\Nygaard and DKS Associates in a separate Technical Memorandum or working paper. Ideally, the indicator will consider ease of pedestrian crossings, as well as travel along the street.

5.4 Freight

There is no nationally accepted or locally adopted performance standard for freight. Given the importance of freight traffic to the regional economy, however, it is essential that one be developed, in order to balance the needs of trucks with other modes.

The primary concern of freight traffic is congestion and travel speed. For this reason, we recommend that the key performance indicator for freight be the same as that for automobile traffic. This is currently volume/capacity ratio, but could be amended if an alternative automobile level of service indicator is developed. The standards for freight traffic should be higher than those for general vehicle traffic, in view of the higher economic cost of delays.

In addition, Primary Truck streets would need to meet certain minimum design standards, including:

- Clearances at bridges and other structures
- Turning radii
- Lane widths
- Absence of weight limits or other restrictions

Available at: www11.myflorida.com/planning/systems/sm/los/pdfs/pedlos.pdf.
Software available at: www.dot.state.fl.us/planning/systems/sm/los/los_sw2.htm.

5.5 Parking

While it is not technically a travel mode, on-street parking is important to consider in the same framework as the needs of transit, automobiles, bicycles, pedestrians and freight. This is largely because it represents a competing demand for right-of-way, which has to be balanced against the demands of other modes. The less reliant the adjacent land use on curb parking, the greater the scope to introduce bus bulbs, turn lanes, peak-period only lanes and turn lanes, or to remove parking altogether. Chapter 6 therefore indicates a preliminary scope to remove on-street parking, based on the land use context and the competing demands on the limited right-of-way.

The City has already developed detailed policies on where to install parking meters, or similar payment technologies for on-street parking such as pay stations. It is also in the process of completing a more comprehensive policy on parking management, placement and removal that will replace the draft parking section in this report.

6. Application of the performance measures

A key aim of this project is to show how Transit Service Measures can be used to inform the planning and implementation processes relating to the UVTN.

We recognize that no transportation planning process for any mode takes place in isolation. This process has significant influence on and from the context of the route segment in question and the other modes sharing (and competing for) space in the route segment.

Based on this recognition, we have developed a process that focuses on bringing the different modes together in consideration of the context in which the route segment is located. By considering the modes together with the context it provides the opportunity to:

- *balance* the often competing needs of the different modes within different contexts
- *inform* a process of compromise whereby the net gain for the community can be maximized while the net impact on different modes and context can be minimized.

How the 'Balancing Process' works

The following summarizes the different actions that make up the 'balancing process'.

1. Locate the route segment in question. This can be as short as a single block or as long as a citywide corridor. It can also apply to an entire network.
2. Determine the context for the route segment in question according to the "Classification Map" in Chapter 3.
3. Determine the different transport roles that the route segment in question is serving, as shown on the "Classification Map" in Chapter 3. This will determine which modes / rows on the selected 'Balance Table' should be considered in the Balancing process.
4. Determine the necessary service measures. For transit service measures see Chapter 4. For 'placeholder' service measures for other modes, see Chapter 5.
5. Assess site constraints to determine the level of competition of competing modes within the physical dimensions of the route segment. This will determine which QOS / column on the selected 'Balance Table' should be considered in the Balancing process.
6. Adjustments to the physical roadway or its management may then be made to bring each mode into balance with the others. That is, to raise Bicycle LOS from "Minimum" to "Desired," Auto LOS may be reduced from "Preferred" to "Desired."

Because on-street parking can be used as an important tool both for increasing traffic capacity (by removing it) as well as promoting the health of commercial streets (by retaining it), we have also included parking in the table. Throughout, we have added more detailed notes that planners and engineers should consider while proposing adjustments to street design and management. Other design guidelines, such as standards for sidewalks, landscaping, lighting and signage, could also be considered as part of this overall balancing table, but they are beyond the scope of this working paper.

Figure 6-1 Balancing Quality of Service for Competing Modes

MODE / FUNCTION	CONTEXT ZONE	Minimum Quality of Service (Very high competition within corridor)	Desirable Quality of Service (High competition within corridor)	Preferred Quality of Service (Low competition within corridor)	BALANCING TOOLS
ROADWAY OPERATIONS STANDARDS					
Transit		Transit QOS	Transit QOS	Transit QOS	
UVTN	All	≥ +1	≥ +1.5	≥ +2	Minimum UVTN standards must be met regardless of context or competition from other modes. Where conflict or substandard QOS results from *delay*, person delay rather than vehicle delay will determine remedial action.
Secondary transit	Urban Center Village	≥ -1	≥ -0.5	≥ +1	For secondary transit routes, person delay or person capacity will be considered when there is a conflict that results from delay or capacity concerns. Automobile, Bicycle and Pedestrian QOS may all be adjusted so they come into balance.
	Urban Village Commercial Streets	≥ -1	≥ -0.5	≥ +1	
	Hub/Residential Urban Villages	≥ +0.5	≥ +1	≥ +1	
	Single family residential areas	≥ +0.5	≥ +1	≥ +1	
Other transit	All	-	≥ -1	≥ -0.5	Person capacity and person delay may be considered, but are not crucial.
Auto		Vehicular V:C	Vehicular V:C	Vehicular V:C	
Primary Auto	Urban Center Village	< 1.2	< 0.8	> 0.6	Person delay and person capacity must also be considered when reducing other modes' QOS level to raise auto QOS to the same level.
	Urban Village Commercial Streets	< 1.2	< 1.0	> 0.6	
	Hub/Residential Urban Villages	< 1.0	< 0.8	> 0.6	
	Single family residential areas	< 1.0	< 0.6	< 0.4	
Secondary Auto	Urban Center Village	< 1.2	< 0.8	> 0.6	
	Urban Village Commercial Streets	< 1.2	< 1.0	> 0.6	
	Hub/Residential Urban Villages	< 1.2	< 0.8	> 0.6	
	Single family residential areas	< 1.2	< 0.6	< 0.4	
Tertiary Auto	All	-	< 0.9	< 0.8	
Bicycle		Bicycle QOS	Bicycle QOS	Bicycle QOS	
Primary Bicycle	Urban Center Village	D	B	A	In neighborhood commercial districts, transit and pedestrian QOS should generally take precedence over the provision of dedicated bicycle facilities. Where possible, primary bike routes should also avoid the UVTN. Where grades and other obstructions prevent relocating a key bicycle network street to a parallel street, secondary transit (not UVTN), primary auto and primary pedestrian QOS may be degraded to provide balance with Bicycle QOS.
	Urban Village Commercial Streets	D	C	A	
	Hub/Residential Urban Villages	C	B	A	
	Single family residential areas	B	A	A	
Secondary Bicycle	Urban Center Village	D	B	A	Same as above.
	Urban Village Commercial Streets	D	D	A	
	Hub/Residential Urban Villages	D	B	A	
	Single family residential areas	D	B	A	
Pedestrian		Pedestrian QOS	Pedestrian QOS	Pedestrian QOS	
Primary Pedestrian	Urban Center Village	B	A	A	The success of all modes relies upon an excellent and complete pedestrian network. In general, degradation of pedestrian QOS should be avoided at all costs.
	Urban Village Commercial Streets	B	A	A	
	Hub/Residential Urban Villages	C	A	A	
	Single family residential areas	D	B	A	
Secondary Pedestrian	Urban Center Village	C	B	A	
	Urban Village Commercial Streets	C	B	A	
	Hub/Residential Urban Villages	C	B	A	
	Single family residential areas	D	B	A	

MODE / FUNCTION	CONTEXT ZONE	Minimum Quality of Service (Very high competition within corridor)	Desirable Quality of Service (High competition within corridor)	Preferred Quality of Service (Low competition within corridor)	BALANCING TOOLS
Truck		Vehicular V:C	Vehicular V:C	Vehicular V:C	
Primary Truck	Urban Center Village Urban Village Commercial Streets Hub/Residential Urban Villages Single family residential areas	< 0.8 < 1.0 < 0.8 < 0.6	> 0.6 > 0.6 > 0.6 < 0.4	< 0.4 < 0.4 < 0.4 < 0.4	Freight movements have a much greater economic value to the city than the movement of other vehicles. Where vehicular v:c cannot be improved due to competition with other modes, special truck bypasses or other tools should be considered.
ROADWAY DESIGN and MANAGEMENT STANDARDS					
Parking	Urban Center Village	Compete removal of parking is acceptable in order to achieve "Desirable" QOS for all other modes	Compete removal of parking is acceptable in order to achieve "Desirable" QOS for other modes	Maintain on-street parking, at least during off-peak. In general, parking will be paid/metered.	Parking management and remediation plan required for any parking removal.
	Urban Village Commercial Streets	Significant on-street parking reduction is acceptable in order to achieve "Desirable" QOS for transit and pedestrians.	Limited parking removal at spot locations acceptable in order to achieve "Desirable" QOS for transit and pedestrians.	Maintain all on-street parking. In general, parking will be paid/metered.	Parking management and remediation plan required for any parking removal.
	Hub/Residential Urban Village	Compete removal of parking is acceptable in order to achieve "Minimum" QOS for other modes	Limited parking removal at spot locations to achieve "Desirable" QOS for all modes.	Maintain all on-street parking. All parking must be managed.	Parking management and remediation plan required for any parking removal.
	Single family residential areas	Compete removal of parking is acceptable in order to achieve "Minimum" QOS for other modes	Limited parking removal at spot locations to achieve "Desirable" QOS for all modes.	Maintain all on-street parking.	Parking management and remediation plan required for any parking removal.
Sidewalk Design					These design elements may also be included in this table format, but they are not within the scope of this paper.
Landscape Requirements					
Lighting Requirements					

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Appendix A

Transit Capacity and Quality of Service Manual Excerpt

Service Coverage

Whether or not transit service is provided near one's origin and destination is a key factor in the choice to use transit. Ideally, transit service is provided within a reasonable walking distance of one's origin and destination, or demand-responsive service is available to one's doorstep. The specifics of "reasonable walk" varies from source to source and depends on the situation: for example, people will walk farther to rail stations than to bus routes and the elderly do not walk as far as "average" adults. Potential barriers, such as wide or busy streets, hills, or an absence of pedestrian facilities, also play an important role. In general, 0.4 km (0.25 mi) or 5 minutes walk time is the limit of a bus route's typical "service area"; for a rail transit station, these figures can be doubled.[R12]

If transit service is not provided near one's origin, other possible options include driving to a park-and-ride lot or riding a bicycle to transit. Both of these options require that the transit operator provide additional facilities (parking lots, bicycle storage facilities, and/or bicycle racks).

If transit service is not provided near one's destination, the choices are even more limited. The car one drove to a park-and-ride lot will not be available at the destination, nor will a bicycle left behind in a storage facility be available. A bicycle carried in a bicycle rack on a bus will be available at the destination, but a customer will need some degree of confidence that space will be available in the bike rack when the bus arrives. A small number of transit systems allow bicycles on-board transit vehicles (typically rail vehicles), but often not during peak commute hours or in the peak commute direction. A bicycle storage facility will also be required at one's destination and, probably (depending on the climate and the length of the ride), showers, lockers, and changing facilities.

Pedestrian Environment

Even if a transit stop is located within a reasonable walking distance of one's origin and destination, the walking environment may not be supportive of transit. Lack of sidewalks, poorly maintained sidewalks, lack of street lighting, and hills all discourage pedestrian travel. Wide or busy streets without signalized crosswalks at regular intervals, or without pedestrian refuges in the median, also discourage pedestrian travel. This latter factor in particular poses difficulties for transit operators providing service on arterial streets: the arterial street generally provides better transit vehicle speeds, but potential passengers using stops along the street must cross the street at some point during their round trip, either when they depart or when they return.

Passengers with disabilities must have sidewalk facilities, curb cuts, and bus stop loading areas between both their origin and a transit stop and between their destination and a transit stop in order to have the ability to access fixed-route transit service. In the U.S., new or improved facilities must meet Americans with Disabilities Act (ADA) standards. Without these facilities, passengers with disabilities must rely on paratransit service, which generally provides customers with fewer choices in travel times, and usually costs substantially more for transit operators to provide service.

Scheduling

How often transit service is provided and when it is provided are important factors in one's decision to use transit. The more frequent the service, the shorter the wait time when a bus or train is missed or when the exact schedule is not known, and the greater the flexibility customers have in selecting travel times. The number of hours during the day when service is provided is also highly important: it does not matter whether a transit stop is located within walking distance if service is not provided at the times one desires to travel—transit will not be an option for that trip. passengers at a stop.

Amenities

The facilities that are provided at transit stops and stations help make transit more comfortable and convenient to customers. Typical amenities, some of which were illustrated in Exhibit 4-3, include the following:[(R8)]

- *Benches,* to allow passengers to sit while waiting for a transit vehicle.
- *Shelters,* to provide protection from wind, rain, and snow in northern climates and from the sun in southern climates. In cold climates, some operators provide pushbutton-operated overhead heaters at shelters located at major transit centers.
- *Informational signing,* identifying the routes using the stop, their destinations (both intermediate and ultimate), and/or scheduled arrival times.
- *Trash receptacles,* to reduce the amount of litter around the transit stop.
- *Telephones,* to allow passengers to make personal calls while waiting for a transit vehicle, as well as providing for the ability to make emergency calls.
- *Vending facilities,* ranging from newspaper racks at commuter bus stops to manned newsstands, flower stands, food carts, transit ticket and pass sales, and similar facilities at rail stations and bus transfer centers.
- *Air conditioning* on-board transit vehicles, to provide a comfortable ride on hot and humid days.

Transit operators usually link the kinds of amenities at a stop to the number of daily boarding riders at that stop. TCRP Report 19(R8) provides guidelines for installing various kinds of transit amenities.

Transit Information

Potential riders need to know where and when transit service is available before they can begin using it. Regular riders need to be informed about service changes that will affect them. This information can be provided by a variety of means:

- *Printed maps, schedules, and brochures* that passengers can take with them, available on-board transit vehicles, at transit facilities, and at local businesses.
- *Posted information* on-board vehicles and at transit facilities. As transit systems adopt automatic vehicle location (AVL) systems, it is becoming feasible to display real-time schedule information on-board buses, at bus stops, and at bus terminals
- *On-board announcements* of major transit stops assist not only the visually impaired, but passengers unfamiliar with a route or area.
- *Telephone information* available at times that are convenient to potential passengers (including weekends and evenings).

- *Personal computers* can be used to access transit information via the Internet, and to subscribe to e-mail lists that automatically send service change and other announcements to persons on the list.

Transfers

Requiring transfers between routes adds to a passenger's total trip time by transit, although this can be minimized by implementing timed transfers. It also raises the possibility that a missed connection will occur, which would further increase the length of the transit trip. Transfers increase the complexity of a transit trip to a first-time passenger, as well. Requiring a surcharge for transfers can inhibit ridership.

Total Trip Time

Total trip time includes the travel time from one's origin to a transit stop, waiting time for a transit vehicle, travel time on-board a vehicle, travel time from transit to one's destination, and any time required for transfers between routes during the trip. The importance of each of these factors varies from person to person. Some persons will view the trip as an opportunity for exercise during the walk to transit and for catching up on reading or work while on transit. Other persons will compare the overall door-to-door travel time of a trip by transit to the time for the same trip by private automobile. Waiting time at a transit stop may seem longer than the equivalent amount of time spent walking or on-board a vehicle. In general, both the absolute travel time and the travel time in relation to competing modes will be factors in a potential passenger's choice to use transit.

Total trip time is influenced by a number of factors, including the route spacing (affecting the distance required to walk to transit), the service frequency (affecting wait time), and the frequency of stops, traffic congestion, signal timing, and the fare-collection system used (affecting travel time on-board a transit vehicle).

Cost

Potential passengers weigh the cost and value of using transit versus the out-of-pocket costs and value of using other modes. Out-of-pocket transit costs consist of the cost of the fare for each trip, or the cost of a monthly pass, while out-of-pocket automobile costs include road and bridge tolls and parking charges. Other automobile costs, such as fuel, maintenance, insurance, taxes, and the cost of buying an automobile generally do not occur for individual trips and thus generally do not enter into a person's consideration for a particular trip. Thus, if a person does not pay a toll to drive someplace and free parking is provided at the destination, transit will be at a disadvantage because there will be no immediate out-of-pocket cost for driving, while there will be for transit. Some *Transportation Demand Management* (TDM) techniques seek to overcome this obstacle by encouraging employers who provide free parking (in effect subsidizing the true cost of providing parking) to also provide subsidized transit passes or other means of encouraging transit use as an alternative to the private automobile.

Safety and Security

Riders' perceptions of the safety and security of transit, as well as actual conditions, enter into the mode choice decision. Not only is personal safety considered, relating to potential transit crime and vehicular crashes, but personal irritants are considered as well, such as encountering unruly passengers on a regular basis or having to listen to someone else's radio. Security at transit stops can be improved by placing stops in well-lit areas and by having public telephones available for emergency calls. Transit systems use a variety of methods to enhance security on-board transit vehicles, including having uniformed and plainclothes police officers ride transit, establishing community volunteer programs, providing two-way radios and silent alarms for emergency communication, and using video cameras.

Passenger Loads

Transit is less attractive when passengers must stand for long periods of time, especially when transit vehicles are highly crowded. When passengers must stand, it becomes difficult for them to use their travel time productively, which eliminates a potential advantage of transit over the private automobile. Crowded vehicles also slow down transit operation, as it takes more time for passengers to get on and off. Most transit agencies assess the degree of passenger crowding on a transit vehicle based on the occupancy of the vehicle relative to the number of seats, expressed as a load factor. A factor of 1.0 means that all of the seats are occupied. The importance of vehicle loading varies by the type of service. In general, transit provides load factors at or below 1.0 for long-distance commute trips and high-speed mixed-traffic operations. Inner-city service may approach 2.0 or even more, while other services will be in between. Because the number of seats provided varies greatly between otherwise identical rail vehicles operated by different transit systems, *passengers per unit vehicle length* is being applied more often for rail capacity calculations than load factors.

Appearance and Comfort

Having clean, graffiti-free transit stops, stations, and vehicles improves transit's image, even among non-riders. Some transit systems (for example, Bay Area Rapid Transit in the San Francisco Bay Area, Housatonic Area Regional Transit in Danbury, CT, and the Tidewater Transportation Commission in Norfolk) have established standards for transit facility appearance and cleanliness and have also established inspection programs.[R5,R19] Passengers are also interested in ride comfort, which includes both seat comfort and the severity and amount of acceleration and deceleration (both lateral and longitudinal).

Reliability

Reliability affects the amount of time passengers must wait at a transit stop for a transit vehicle to arrive, as well as the consistency of a passenger's arrival time at a destination from day to day. Reliability encompasses both on-time performance, as well as the regularity of headways between successive transit vehicles. Uneven headways result in uneven passenger loadings, with a late transit vehicle picking up not only its regular passengers but those passengers that have arrived early for the following vehicle, with the result that the vehicle falls farther and farther behind schedule and more passengers must stand. In contrast, the vehicles following will have lighter-than-normal passenger loads and will tend to run ahead of schedule. With buses, this "bunching" phenomenon is irritating both to passengers of the bunched buses, as well as to passengers waiting for other buses, who see several buses for another route pass by while they wait for their own bus. With signaled rail operations, bunched trains often have to wait at track signals until the train ahead of them moves a safe distance forward. The resulting unscheduled waits are not popular with passengers, particularly when no on-board announcements are given explaining the delay.

Reliability is influenced by traffic conditions (for on-street, mixed-traffic operations), vehicle maintenance and staff availability (reflecting whether a vehicle can leave the garage or is likely to break down on the road), and by how well vehicle operators adhere to schedules.