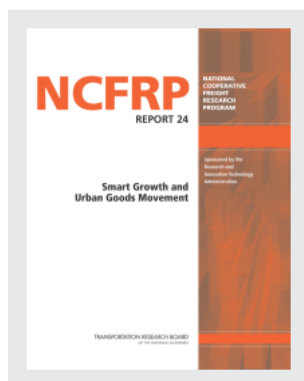


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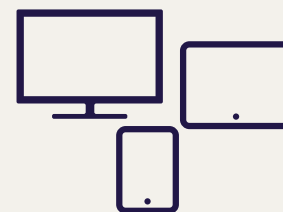
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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

NCFRP REPORT 24

**Smart Growth and
Urban Goods Movement**

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TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2013
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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

America's freight transportation system makes critical contributions to the nation's economy, security, and quality of life. The freight transportation system in the United States is a complex, decentralized, and dynamic network of private and public entities, involving all modes of transportation—trucking, rail, waterways, air, and pipelines. In recent years, the demand for freight transportation service has been increasing fueled by growth in international trade; however, bottlenecks or congestion points in the system are exposing the inadequacies of current infrastructure and operations to meet the growing demand for freight. Strategic operational and investment decisions by governments at all levels will be necessary to maintain freight system performance, and will in turn require sound technical guidance based on research.

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FOREWORD

By William C. Rogers

Staff Officer

Transportation Research Board

NCFRP Report 24: Smart Growth and Urban Goods Movement identifies the interrelationships between goods movement and smart growth applications, in particular, the relationship between the transportation of goods in the urban environment and land-use patterns. The results of the research can be used by decisionmakers to more accurately understand urban goods movement demand, relevant performance metrics, and the limitations of current modeling frameworks for addressing smart growth and urban goods movement.

Smart growth and its compact, transit-oriented, and walkable land use has been proposed as an alternative to urban sprawl. There has been substantial research on the application of smart growth to passenger transport, but little has been done to examine its impact on goods movement. Transportation planning organizations are looking to influence future land-use patterns to create livable, sustainable communities by reducing such factors as vehicle miles traveled (VMT) and congestion, and therefore reducing greenhouse gas emissions. However, along certain road segments, smart growth policies could increase congestion and greenhouse gas emissions. An increase in the share of travel completed in a congested environment would decrease average speed, increase the frequency of hard vehicle accelerations, decrease vehicle fuel economy, and increase air pollutant emissions. Improved modeling that fully accounts for impacts of future land use on personal and goods transportation, in terms of VMT and potentially other metrics, could be used to help design smart growth strategies that result in the greatest emissions benefit. In addition, land-use activities (zoning, urban growth limits, etc.) are often disconnected from decisions regarding investments in the goods movement system. Understanding how land-use decisions can impact goods movement demand will become increasingly important.

Under NCFRP Project 32, the Puget Sound Regional Council and the University of Washington were asked to (1) describe current smart growth principles and practices, both domestic and international, and identify overarching themes to develop a definition of smart growth; (2) identify metrics and performance measures, especially for goods movement (if available), that have been proposed and/or applied; (3) identify a wide variety of stakeholders that would be affected by smart growth plans, policies, and regulations; (4) interview the stakeholders to identify and define the attributes of smart growth that might impact goods movement; (5) develop smart-growth scenarios that impact goods movement; (6) input the scenarios into a demand-forecasting model and compare the smart-growth scenarios with different baseline and transportation network alternatives; and (7) describe the implications of the smart-growth and goods movement interaction on transportation modeling and freight planning.

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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

CHAPTER 1

Introduction

In the quest to design cities that support a good quality of life, a lively discussion has developed regarding the role of transportation in urban environments and the approach that might create vibrant, livable spaces. Much of this discussion has focused on passenger travel, land use, and the importance of non-motorized transport. However, the role of goods movement has often been ignored.

In developed economies, every business and person relies on the trade of goods and services. Moving the people and products required for this trade is essential to a thriving economy and can have important consequences for a community. Urban goods movement refers to the movement of products throughout the urban area (including waste removal and package delivery). In most urban regions, space is a scarce resource, with heavy competition for roadway space and parking. Many urban regions were established before motorized transport, and their infrastructures are not well designed for the large vehicles associated with goods movement. These areas are typically densely populated with pedestrian and residential activity. In addition, many metropolitan regions today are challenged to address concerns about air quality, noise, and the competition among various interests for roadway space. Unfortunately, the state of knowledge about urban-goods-movement activities and effective methods for managing these movements is lacking.

Freight planning has developed significantly over the past decade, beginning with the freight-planning requirements in the federal Safe, Accountable, Flexible, Efficient Transportation Equity Act-A Legacy for Users (SAFETEA-LU), which are still relevant within the context of the current Moving Ahead for Progress in the 21st Century Act (MAP-21) legislation. State and regional planning organizations have begun to invest in the personnel, data, and analysis necessary to develop transportation plans that consider freight activities and their economic, social, and environmental impacts (BRMPO 2007; NCHRP 2007; Waldo 2010). Unfortunately, most truck models currently in use are limited because of their short time in development (compared with advanced passenger models) and the lack of sufficient data and knowledge, particularly in the urban context.

Early transportation models were concerned with high-capacity freeway networks and were focused on automobile use and monocentric city design, which minimized the predictive power of these models to incorporate transit use, measure vehicle emissions, and consider freight mobility and polycentric development form (Garrett and Wachs 1996). Spurred by the federal Clean Air Act Amendments and the Intermodal Surface Transportation Efficiency Act, models have become increasingly more complex, with greater capabilities to consider emissions and traveler behavior. Twenty years after the passage of these acts, the need to better understand energy use and emissions in relation to transportation has garnered additional support for these models. Unfortunately, impressive advancements in activity-based models for passenger vehicles have yet to translate into practical models for freight—and specifically for truck—movements.

2 Smart Growth and Urban Goods Movement

At the same time, the urban planning and transportation literature has targeted smart growth, growth management, and urban center concepts as potentially beneficial urban strategies (see, for example, Braun and Scott 2008; Cervero 1996; Ewing and Cervero 2001; Frank 2000; Hess et al. 2001; Giuliano and Small 1999; Redfearn 2007; and Song 2005). However, incorporating the impacts of these strategies on goods movement has not been a priority. Instead of land use as an analysis consideration, analysis of goods movement has explored reducing the number of vehicles required to move goods (van Rooijen et al., 2008), cost reduction (in terms of monetary, environmental, or time costs) (Quak and de Koster 2007), and the organizational structure of goods-movement systems. For example, Holguín-Veras et al. (2006) considered the motivations of key stakeholders in choosing delivery times, and Vleugel and Janic (2004) considered vehicle choice, trip planning, route planning, and the choices of other actors as key decisions in the urban-goods-movement system.

The general knowledge gap regarding the land use and freight connection is further exacerbated by this lack of appropriate modeling tools. Comprehensive regional modeling tools that can capture land-use and transportation interactions for passenger travel are still in their infancy and do not adequately capture freight activity, even though addressing goods movements along with passenger movement is necessary to have truly effective smart growth.

This report summarizes the literature relevant to the impacts of smart growth on goods movement and identifies areas in which research is needed. It begins by defining smart growth and then identifies the relationships between smart growth and goods movement. The state of the literature in these fields is summarized, and emerging research agendas are established to provide better understanding of the interactions between smart-growth development patterns and urban goods movement. The report then describes a series of targeted interviews conducted in Philadelphia, Pennsylvania, and Seattle, Washington, with truck drivers, logistics managers, planners, architects, and developers, to gain insight from those most directly involved with goods movement. These findings are used to identify and define the attributes of smart growth that might impact freight. This information, in turn, is developed into smart-growth scenarios that are input into a demand-forecasting model for the Puget Sound region. By comparing smart-growth scenarios with different baseline and transportation network alternatives, the relationship between freight and smart growth is analyzed, and the ability of the model to capture this relationship is evaluated. The report concludes by describing the implications of the smart-growth and goods-movement interaction on transportation modeling and freight planning.

CHAPTER 2

Defining Smart Growth

Smart growth is a more current manifestation of the 1970s' growth-management movement and has been promoted for various reasons. Smart-growth design generally includes compact development (moderate to modestly high density), a mixture of land uses in that development, and a range of feasible transportation options that promote and facilitate the use of modes of travel other than the automobile (e.g., transit, bicycles, and walking) (Smart Growth Network 2011; Carlson and Mathur 2004). Most research on smart growth has focused on personal travel and not on goods movement.

Considerable research shows that smart-growth communities frequently demonstrate lower automobile-based trip making, with a commensurate increase in shorter, non-motorized trips and increased transit use (Cervero 1989, 1996; Cervero and Landis 1997). These attributes are attractive to communities and regions looking for ways to reduce peak-period automobile trip making and thus reduce demand for increased roadway capacity, while also providing a wide variety of other public benefits such as reduced greenhouse-gas emissions and healthier lifestyles due to increased physical activity levels.

Table 1 identifies the principles of smart growth as defined by the Smart Growth Network. While central to achieving smart-growth outcomes, some of the principles have no direct effect on, and are not affected by, goods movement. Greater attention is given in this report to those principles that most closely relate to goods movement—the ones associated with the transportation system.

Smart-growth practices are intended to foster communities with a unique sense of place; preserve natural and cultural resources; equitably distribute the costs and benefits of development; expand employment, transportation, and housing choices; and support long-range, regional sustainability (Porter et al. 2005; EPA 2010). These broad principles lead to physical environments that, on a regional scale, are dichotomized into compact urban centers or villages and rural countryside. Urban areas are centers of population and employment. They are characterized by high residential and employment density; a mix of land uses and housing types; affordable housing options; and a range of transportation options including passenger cars, transit, and non-motorized options. With population and employment focused in dense, affordable, and accessible urban areas, development pressure is relieved from the countryside on the urban fringe. Rural resource lands are left to provide essential agriculture and ecological functions, as well as nearby access to open space and recreation for urban populations. Demand for truck trips is increased in urban areas (Klastorin et al. 1995), but the cost and environmental impact per delivery order is less in denser areas (Wygonik and Goodchild 2011).

The overarching theme of smart growth is efficiency. Compact urban jurisdictions can provide infrastructure and services at a lower per-capita expense (Porter et al. 2005), and because a variety of housing, jobs, goods, and services are available within close proximity, trip lengths in smart-growth areas are shortened (Cervero 1989, 1996; Cervero and Landis 1997). Often,

Table 1. Principles of smart growth (from Smart Growth Network 2011).

Create a range of housing opportunities and choices.	Providing quality housing for people of all income levels is an integral component in any smart-growth strategy.
Create walkable neighborhoods.	Walkable communities are desirable places to live, work, learn, worship, and play, and therefore they are a key component of smart growth.
Encourage community and stakeholder collaboration.	Growth can create great places to live, work, and play, as long as it responds to a community's own sense of how and where it wants to grow.
Foster distinctive, attractive communities with a strong sense of place.	Smart growth encourages communities to craft a vision and set standards for development and construction that respond to community values of architectural beauty and distinctiveness, as well as expanded choices in housing and transportation.
Make development decisions predictable, fair, and cost effective.	For a community to be successful in implementing smart growth, it must be embraced by the private sector.
Mix land uses.	Smart growth supports the integration of mixed land uses into communities as a critical component of achieving better places to live.
Preserve open space, farmland, natural beauty, and critical environmental areas.	Open space preservation supports smart-growth goals by bolstering local economies, preserving critical environmental areas, improving communities' quality of life, and guiding new growth into existing communities.
Provide a variety of transportation choices.	Providing people with more choices in housing, shopping, communities, and transportation is a key aim of smart growth.
Strengthen and direct development toward existing communities.	Smart growth directs development toward existing communities already served by infrastructure in order to utilize the resources that existing neighborhoods offer and to conserve open space and irreplaceable natural resources on the urban fringe.
Take advantage of compact building design.	Smart growth provides a means for communities to incorporate more compact building design as an alternative to conventional, land-consumptive development.

distances between trip origins and destinations are short enough to support non-motorized transportation options such as walking or bicycling. Transit is also more effective at serving dense, mixed-use nodes or corridors. For these reasons, urban smart growth has been associated with decreased vehicle miles traveled (VMT) and increased walking and transit use (Frank et al. 2007; Frank et al. 2006; Ewing et al. 2002; Ewing and Cervero 2001; Handy et al. 2005; Porter et al. 2005). Reduced VMT may translate into reduced greenhouse-gas emissions, decreased fuel and energy consumption, reduced traffic congestion, and increased physical activity for those travelers who choose to use transit or non-motorized forms of transportation (TRB 2009).

Although the benefits of smart-growth development are most apparent in urban settings, they also provide benefits in rural communities. The same principles of mixed uses and center or village clustering may reduce the number and shorten the distances of local trips. For example, even in a rural setting, the proximity of the grocery store to the post office will shorten trip length or eliminate secondary trips. Because of lengthy commutes, among other things, rural smart-growth development may have minimal impact on regional vehicle miles of travel. Nonetheless, the benefits of smart-growth development will promote non-motorized modes for local trips and as such may improve health (through physical activity) and reduce localized air-quality issues.

While smart growth is sensitive to community context, strategies to implement smart growth are often the result of state or regional growth-management regimes. Growth management varies drastically across the states that implement it. The strongest growth-management regimes require the designation of urban growth areas and sufficient infrastructure to absorb the preponderance of future new development, thereby protecting natural and resource lands (Born and Bassok 2010).

To achieve these goals, local jurisdictions (e.g., cities and counties) are required to develop a comprehensive plan that describes how anticipated population and employment growth and associated infrastructure needs will be met. Local jurisdictions use a myriad of tools to implement smart-growth goals.

With regard to goods movement, the aspects of smart growth concerned with transportation and transportation efficiency are most pertinent. Several smart-growth principles will have significant effects on urban goods movement, the location of trip generators, and the land use surrounding these facilities. These components affect one or more of the following: safety (including crash rates and severity), number of vehicle trips, length of vehicle trips, environmental impacts, and roadway capacity. These aspects will be further addressed through modeling, which is discussed in Chapter 8.

Aspects of smart growth that deal with land use and can affect changes in urban form have benefits for the transportation system, the environment, and the well-being of people (in terms of physical and mental health), but they also impact goods movement. In particular, increased densities and the mix of land uses are effective at achieving smart-growth principles, while at the same time increasing the demand for goods in certain areas and increasing the potential for conflicts between modes. In other words, while many issues that jurisdictions and regions are concerned with improve with the implementation of smart-growth principles, issues surrounding goods movement may be exacerbated unless properly considered.

A reference manual developed for the Washington State Department of Transportation catalogued 50 different regulatory tools used by jurisdictions across the nation to implement smart-growth strategies that would result in land uses that help minimize travel time and cost while increasing travel options (Moudon et al. 2003). These tools demonstrate the breadth of potential strategies, and they are classified in six categories: compact development, mixed land uses, connectivity of motorized and non-motorized facilities, pedestrian environment and safety, parking, and affordable housing.

Not all smart-growth developments and communities exhibit all the characteristics contained in the smart-growth principles. In other words, places that may be perceived as having smart growth may in fact only reflect some of the important qualities of smart growth necessary to achieve the various intended benefits. The trip-making behavior associated with smart-growth developments and neighborhoods is a function of many factors, including, but not limited to the following:

- The actual mix of land uses in the smart-growth area
- The total size of the smart-growth area
- The quality and completeness of the non-motorized transportation network to, from, and within that area
- The quality of the transit service to, from, and within the smart-growth community, as well as how effectively the transit service and non-motorized transportation network connect the smart-growth community to other destinations

Other factors such as weather, the availability and cost of parking, and public attitudes toward walking, biking, and transit can play significant roles in the actual travel behavior of residents and employees who live and work in smart-growth communities.

2.1 Benefits of Smart Growth

The concepts of smart growth and growth management are utilized throughout the United States as planners around the country attempt to combat sprawl to control its theorized effects. Many scholars argue that sprawl is a cause of obesity and that denser urban forms can reduce the

scale of this disease (Ewing et al. 2002; McLellan and Borak 2005). Those interested in congestion claim that denser designs will reduce or shorten the number of household trips (Litman 2005; Downs 2004). Along similar lines, research focusing on air quality suggests that denser designs would also reduce overall emissions (Frank 2005).

These assumptions are not without their critics. In terms of air quality, some researchers are beginning to suggest that only considering the ambient environment does not suffice and that the micro-scale should also be considered (Dannenberg 2003). Others argue that the built environment's role in people's desire to walk or bicycle is actually much smaller than the effects that weather or terrain have on those choices (Cervero 2003). The following discussion highlights the most salient impacts of smart-growth principles.

2.1.1 Trip-Length Reduction

Many studies document a reduction in commuting trip lengths in areas where the jobs-housing ratio (a planning tool in which a jurisdiction achieves a roughly equal number of jobs and housing units) is considered to be relatively balanced. The jobs-housing balance is central to smart growth in several ways. Allowing for areas that include both employment and housing takes advantage of compact design, which in turn leads to more walkable communities. In addition, a mix and balance of jobs and housing provides for a mix of land uses, which makes an area more attractive for, and raises demand for, walking, and increases the overall densities that support the ability to provide transit services. Taken as a whole, communities with a jobs-housing balance attract activities to them, directing further development to existing communities and away from areas targeted for open space preservation or agricultural activities. Although a balance of jobs and housing may not mean that all the people who live in a community also work there, it (1) creates the opportunity for them to do so and (2) helps achieve multiple smart-growth objectives.

Cervero (1989, 1996) suggests that having people live closer to where they work will cause a noticeable decrease in VMT, which implies a reduction in air pollution as a result of reduced tailpipe emissions and also a reduction in traffic congestion. A study of the 23 largest cities in the San Francisco Bay area found that residents in balanced communities had shorter commutes and were more likely to use modes other than the automobile for commute trip purposes (Cervero and Landis 1997).

Cao et al. (2007) demonstrate that travel behavior is influenced by neighborhood characteristics, even when controlling for self-selection, that is, while some people choose to live in dense neighborhoods with ample transit service because of those traits, others still use transit more if it is available to them even if they have not explicitly chosen to locate near those transit facilities. Levine et al. (2005) found that Boston commute times were shorter than those in Atlanta because of the amenities provided and the types of pedestrian-oriented development that exist within the city. This study goes on to suggest that Atlanta residents might choose higher-density dwelling areas that required less reliance on the automobile. Boarnet and Crane (2001) found that in Los Angeles and San Diego people residing in compact, access-friendly neighborhoods drove less, and they suggested that this difference may be attributed to the relatively higher cost of owning a car in more densely populated areas due to parking problems and traffic congestion.

In a study using census tracts in the greater Seattle area, Frank and Pivo (1994) found that the choice of whether to drive is dependent on the mix of land uses and, further, that work-related trips were 30% shorter in census tracts shown to be more balanced in terms of jobs and housing. In a later study of the same region, Frank (2000) found that travel times were 24% longer for unbalanced census tracts. While the latter result is somewhat smaller than that of the previous

study, it still suggests that people living in areas with a better jobs-housing balance have shorter commute trips—a consequence of incorporating many of the smart-growth principles.

2.1.2 Consequences of Reduced Trip Length

The most marked positive consequence of a reduction in trip length relates to the improvement in air quality. In an attempt to model the effects of various land decisions on air quality, 1,000 Friends of Oregon (1996) analyzed the impact of three different land-use alternatives on VMT: (1) a “no-build” alternative in which there would be no changes to Portland’s land-use patterns, (2) a “highway-only” option—including the proposed Western Bypass that would have circumvented the city, and (3) the “Land Use Transportation Air Quality Connection” (LUTRAQ) option. LUTRAQ involved adding higher densities, various transit-oriented development (TOD) features, rail lines, higher parking costs, and subsidized transit passes, that is, a smart-growth option. The results showed that LUTRAQ greatly reduced the number of trips and VMT, doubled the number of commuting trips using transit, and therefore reduced overall emissions and air pollution.

The success of LUTRAQ is partly due to land-use policies and partly to transportation-demand-management (TDM) strategies (e.g., transit, rideshare) aimed at trip reduction that have been shown to be among the most cost-effective tools for improving air quality (*Special Report 264* 2002). Zattero et al. (1998) found that TDM measures in the Chicago area increased transportation facility efficiency and reduced air pollution, thus combating a rise in suburbanization-induced highway congestion. Seika et al. (1998) modeled the air-quality emissions in London based on engine improvements for the vehicle fleet and several trip-reduction scenarios. While improved engine performance had a much greater effect in lowering pollution, modeled trip reduction that cut movements into the city core by 10% still showed a significant reduction of overall particulate matter (2%), carbon monoxide (2.5%), and nitrogen oxide (2%) in background urban concentrations.

In addition to improved air quality, trip reduction has several other benefits. An overall reduction in trips from the highway network would relieve congestion, which would increase productivity and reduce costs to travelers and firms. The 2011 annual urban mobility report conducted by the Texas Transportation Institute (2012) states that the costs of traffic congestion in terms of wasted time and fuel were \$100 billion in 2011, which included 1.9 billion gallons of wasted fuel and an annual average cost of \$750 per traveler (Schrank, Lomax, and Eisele 2011). Of course, trip reduction may not be able to completely solve this problem. Downs (2004) suggested that as some drivers leave the roadway through TDM, telecommuting, or for other reasons, induced demand for the roadway would return conditions to what they were previously.

Research on telecommuting and teleworking suggests that the reduction in trips creates the ability of workers to spend more time on leisure activities (Golob and Regan 2001). However, similar to the idea of induced demand, people with more free time would then be able to make trips elsewhere, though this might happen at different times of day and thus reduce congestion during the peak periods. Regardless, the smart-growth environment fosters situations in which reductions in trips are feasible, and the trips that are made may be shorter and more localized.

2.1.3 Trip-Frequency Reduction

Similar to studies of trip-length reduction, Nowlan and Stewart (1991), examining the jobs-housing balance in Toronto, showed that for each additional 100 dwelling units added near the commercial core there were 120 fewer trips during the morning commute, and that for every 100 people who moved into the area there were 70 fewer commute trips. Buliung and Kanaroglou (2006) found that residents of Portland’s central business district (CBD) had far

fewer vehicle trips than their suburban counterparts. Further, residing within the CBD lowered the likelihood of auto ownership, with non-auto owners residing in the CBD traveling within a 7-square-kilometer radius, compared with a 25-kilometer radius for one-car households and a 100-kilometer radius for suburban households owning four vehicles. However, after a comprehensive review of the literature on this topic, Badoe and Miller (2000) concluded that a jobs-housing balance will reduce regional driving trips in aggregate terms but that individuals make as many trips as they would have otherwise, albeit with those trips being shorter than they would have been and using more non-driving options. As such, with a mixing of land uses and consideration of affordable housing, thorough implementation of smart-growth principles can reduce regional trip making, improve air quality, reduce overall trip lengths, and promote mode shifts away from single-occupancy vehicles to transit and non-motorized modes of travel.

2.1.4 Residence and Firm Location-Decision Factors

Certainly, not all roadway transportation congestion problems are due to a lack of jobs-housing balance, and transportation congestion would continue even if the imbalance did not exist. In other words, even if all communities in a region adopted smart-growth principles, some level of roadway congestion would continue. At present, when average job tenure is relatively short, residential choices are increasingly being made based on criteria unassociated with employment location—for example, housing affordability and school quality—and therefore lengthy commutes can be created even when no jobs-housing imbalance exists. Cervero (1989) found that executives switched employers, on average, every 3 years, and more recent national studies by the U.S. Bureau of Labor Statistics (2006) have found overall job tenure to be 4 years. At the same time, Americans move roughly every 8 years—12.5% of the population moved between 2009 and 2010 (U.S. Census Bureau 2011).

These frequencies suggest that factors other than the home-to-work commute length are more important for household and firm location decisions. Furthermore, in 1995 only 17% of all trips made were for work purposes, a fact which signifies that achieving a jobs-housing balance would only marginally alleviate roadway congestion (Federal Highway Administration [FHWA] 1997). More recent trip-purpose data show that this number has not changed much and that, in 2001, it even fell slightly to 16% (National Household Transportation Survey [NHTS] 2007). Nonetheless, fostering smart-growth communities may have enormous benefits, especially when considering the large percentage of non-work trips.

2.1.4.1 Residential Location Choice

If work trips and housing costs are not the only considerations in location decision making, what are the factors related to housing choice? And can smart-growth communities address those considerations?

Traditional models for residential choices only considered three factors: the length of the work trip, housing costs, and a final component that included everything else. Giuliano (1989) describes the three main critiques of these models: (1) they are too simple, relying principally on monocentric assumptions; (2) they are not able to deal with two-worker households in which separate commute trip lengths need to be minimized; and (3) they rely on assumptions that conditions are static, that is, they cannot deal with dynamic changes.

Giuliano (1989) further suggests that to fully understand the location considerations for housing, a temporal element must be added because workers will tend to minimize the travel cost to all potential jobs from their housing choice over the time they live in that location. In addition, a financial sensitivity element should be added to the transportation cost because at low perceived out-of-pocket costs people will drive more, and vice versa. Finally, proximity to activities (e.g., access to good schools) and neighborhood characteristics now play a much larger role in the

decision-making process. In other words, all else being equal, a smart-growth environment with many activities within walking distance of a residence would be preferable to a residence that offers poorer access and walkability. For more recent reviews of the residential-location-choice literature, see Bhat and Guo (2004) and Prashker et al. (2008).

Handy et al. (2005) analyzed travel behavior in Northern California using myriad neighborhood characteristics such as accessibility, physical activity options, safety, socializing opportunities, outdoor spaciousness, and attractiveness, as shown in Table 2. These characteristics are notably similar to the smart-growth principles previously discussed, in that access, provision of non-motorized facilities, and safety all affect travel behavior in the same manner in which they affect smart growth. Their study concludes that proximity to, and an appropriate mix of, amenities reduces overall driving.

2.1.4.2 Firm Location Choice

All else being equal, firms would want to minimize their total costs in choosing an operating location, which implies that in their location decision they should consider shorter commute times for employees along with site availability, access for customers, and cost. Further, because employers have to consider access to the labor force, and given that workers, especially those in high-technology industries, are geographically mobile (Herzog et al. 1986; Bagchi-Sen 2003), employers must also consider the amenities available to workers and local conditions, including taxes, school quality, and proximity to recreational activities. Access to amenities and proximity to those amenities, through a diverse mix of land uses, are more prevalent in smart-growth communities.

Table 2. Neighborhood characteristics (from Handy et al. 2005).

Factor	Statement
Accessibility	Easy access to regional shopping mall
	Easy access to downtown
	Other amenities such as a community center nearby
	Shopping areas within walking distance
	Easy access to freeway
	Good public transit service
Physical activity options	Bicycle routes beyond the neighborhood
	Sidewalks throughout the neighborhood
	Parks and open space nearby
	Good public transit service
Safety	Quiet neighborhood
	Low crime rates within neighborhood
	Low level of car traffic on neighborhood streets
	Safe neighborhood for walking
	Safe neighborhood for kids to play outdoors
	Good street lighting
Socializing	Diverse neighbors in terms of ethnicity, race, and age
	Quite a few people out and about within the neighborhood
	Considerable interaction among neighbors
	Economic level of neighbors similar to one's own level
Outdoor spaciousness	Large back yards
	Large front yards
	Availability of off-street parking
Attractiveness	Attractive appearance of the neighborhood
	High level of upkeep in the neighborhood
	Variety of housing styles
	Big street trees

Gottlieb (1995) conducted a study of firm location choices in New Jersey and found that firms consider the availability of amenities in categories such as business, traffic, crime, pollution, recreation, and public education and services in likely areas where their employees would locate. Segedy (1997) expanded on this concept, suggesting that firms consider “quality of life,” including such elements as clean air, vicinity to ski resorts, proximity to museums, and access to medical care. Finally, Mathur and Stein (2005) found that firms that locate within close proximity to amenities will attract highly skilled employees and raise production, and they further noted that the effectiveness of the amenity in attracting people is greatest when the amenity is desired by both high- and low-skilled workers. These findings suggest that smart-growth environments should be more attractive for firms as they consider where to locate their business.

2.2 Other Components of Smart Growth

To achieve the multiple benefits of smart growth, various other factors beyond land-use and transportation interventions are necessary to make areas attractive for people and firms to choose as places to locate. Five particular issues that do not directly affect goods movement are worthy of brief discussion: community collaboration, design elements, housing affordability and choices, preservation of green spaces, and streamlined permitting.

Community collaboration in any planning process is necessary to ensure that citizens are able to achieve their personal vision. Without a meaningful participation process, people may not be invested in a planned future, which can undermine the success of whatever initiative is put forward. Stated simply, people have to like the changes that will be implemented. Nonetheless, whether or not citizens are engaged with planning activities, they still require all of the goods that are delivered to them or to nearby stores.

Design elements, which may give a community a sense of place or make it attractive, similarly do not affect goods movement. Whether a house is a certain color, is oriented a particular way to the street, or has a unique architectural style also does not affect the amount of goods desired and required by its residents.

Housing affordability has a pronounced impact on passenger travel. In locations with high housing prices that are also centers of employment, employees who cannot afford to live in that location will have to travel long distances to get to work. However, wealthy or not, residences and commercial areas still have a demand for goods. Although affordable housing should certainly be addressed as part of land-use decisions, for the most part it, too, does not affect the demand for or distribution of goods. One potential minor exception would be in the case of large condominiums and apartment buildings, where high-end residences may have a door person to help facilitate deliveries, or separate entrances and elevators for deliveries, while more affordable housing may not have invested in such amenities.

Preservation of green spaces, whether on a small or large scale, works as the counterbalance to focusing growth. From a goods-movement perspective, it is only necessary to consider where the trip generators will be located and not where they will be absent. In other words, the demand for goods is quite small in environmentally sensitive, open space, or other protected lands. As such, it is sufficient to consider density and the mix of use where the activity occurs, rather than where the demand for freight is low.

Finally, a streamlined permitting process incentivizes development in some locations over others. It is intended to direct growth to locations where growth is desirable and places where smart-growth principles are already being utilized. While this tool helps jurisdictions implement smart-growth principles, much as with land preservation, it is sufficient to consider where growth

and development are occurring, rather than where it would be easier for development to occur in the future.

Given that some of the previous smart-growth features do not directly affect goods movement, separating out the components of smart growth that do, and do not, relate to goods movement is useful. Five key areas of smart growth have an obvious connection to urban goods movement:

1. Access, parking, and loading zones
 - Parking restrictions
2. Road channelization, bicycle, and pedestrian facilities
 - Accessibility by bicycling, walking, and transit
3. Land use
 - Density and compact design
 - Geography—where development will occur
 - Land-use mix
4. Logistics
 - Parking restrictions
 - Density and compact design
 - Geography—where development will occur
 - Street network connectivity
5. Network system management
 - Limited road construction
 - Street network connectivity

These characteristics, even without other smart-growth components, can be described as compact development, compact urban design, neotraditional development, or transportation-efficient land uses. The following section addresses the various factors that affect goods movement and discusses the impacts that these smart-growth components have on truck deliveries.



CHAPTER 3

Urban Goods Movement Definition

Urban goods movement refers to the movement of goods throughout an urban area. In modern society, jobs and people have specialized roles, meaning that every individual, every household, and every business relies on the trade of goods and services. Moving the people and products required for this trade is essential to a thriving economy and can have important consequences for a community.

3.1 Research into Urban Goods Movement

Because of the importance of urban goods movement, a number of different disciplines and sectors study it. For example, civil engineers are interested in providing an adequate infrastructure for these movements, while industrial engineers and logisticians look for ways to optimize their systems. The business community is interested in ways to reduce costs or improve the profitability of goods movement. The public sector looks for ways to plan appropriately for goods movement, while the private sector is often focused on cost reductions. Each of these sectors also has different planning horizons. The public sector is often concerned with long-term planning, while the private sector must concern itself with immediate profitability.

3.1.1 Research Areas

Urban goods movement is a very large subject, and research about it may take the form of behavioral research, research into relationships between health and the built environment, or models simulating the movement of goods. Quak, Van Duin, and Visser (2008, p. 40) outline 11 core research areas dealing with urban goods movement and city logistics (a term frequently used by non-U.S. academics):

1. Cooperation between or among companies
2. Consolidation centers
3. Transport reorganization
4. Routing improvements
5. e-commerce
6. Infrastructure, parking, and unloading facilities
7. Technological innovations
8. Licensing and regulation
9. Modeling
10. Review discussions
11. Data

In addition to the research areas outlined by Quak et al., there has also been recent interest in the environmental impacts of goods movement.

This report is focused on the relationship between the transportation of goods in the urban environment and land-use patterns. Research into this relationship can take many forms. For example, some academic research aims at reducing the number of vehicles required to move the same amount of goods (van Rooijen et al. 2008); some work aims at reducing costs (either monetary, environmental, or time costs) (Quak and de Koster 2007); and other research looks at the organizational structure of goods-movement systems—for example, Holguín-Veras et al. (2006) considered the motivations of the key stakeholders in choosing delivery times, and Vleugel and Janic (2004, p. 223) considered vehicle choice, trip planning, route planning, and the decisions of other actors as key decisions in the urban goods-movement system.

3.1.2 Evaluation Metrics

Depending on the stakeholders, the motivations for the research, and the variables under evaluation, many different metrics are used in research about urban goods movement. Indeed, an entire research area is dedicated to developing freight performance metrics. The purpose of the work presented here is not to develop or evaluate such metrics; however, identifying relevant metrics is necessary to quantify the impacts of various land-use forms. Common metrics used in logistics include vehicle miles or kilometers traveled (VMT/VKT) (Cairns 1998), driving time (Allen et al. 2003), greenhouse-gas emissions (Siikavirta et al. 2002), number of vehicles required (van Rooijen et al. 2008), monetary costs (Quak and de Koster 2009), and tonnage moved. In their study of urban freight, Marquez et al. (2004, pp. 194–5) identified the following as relevant performances measures: reducing the number of vehicles required to service the freight task, reducing the number of trips, reducing the trip length, reducing VKT for the given freight task, reducing fuel consumption, and reducing the rate of non-GHG emissions per liter of fuel consumed. They compared these measures with greenhouse-gas criteria: relative size of the GHG effect, market size affected, overall GHG emissions, and overall non-GHG emissions.

Of the above metrics, VMT, greenhouse-gas emissions, and the number of vehicles are relevant to this project, while others are not directly modeled or are only tangentially related to the study (tonnage is less relevant to urban movements, and detailed monetary costs are not practical to model within the regional modeling environment). It should be noted that travel, and particularly truck travel, can be viewed as a sign of economic strength, while the metrics highlighted here point to negative impacts. As we model the impacts of land-use scenarios on freight transportation in a subsequent part of this report, the economy will be held constant to allow for an understanding of the land-use and freight-transportation interaction.



CHAPTER 4

Intersection of Smart Growth and Urban Goods Movement

In general, no comprehensive studies have been documented that examine the relationship between smart growth and urban goods movement. In fact, as Woudsma found in 2001, little research is available that addresses land-use patterns and goods movement. The most comprehensive examination identified to date is the work of *NCHRP Synthesis of Highway Practice 320: Integrating Freight Facilities and Operations with Community Goals* (Strauss-Wieder et al. 2003). This effort was one of the first to consider the relationship of freight movement with its surroundings, but it focused primarily on long-distance freight movements, as opposed to the intra-city movement of goods. It also used a more traditional land-use perspective—instead of integrating land uses, it encouraged appropriate buffers (in time and space) between freight movements and residential neighborhoods. Allen and Browne (2010) have provided a more recent evaluation of the relationship between urban form and freight transportation, but they also have focused on heavier vehicles, and intra-city goods movement is only one of their focus areas. They argue that freight movements are less tied to urban form than passenger movements for three reasons: “. . . fewer modal options exist for freight than for passengers, the demand for freight transport is more inelastic with respect to price than for passenger journeys (and therefore less likely to alter or stop than passenger journeys when prices change), and relatively little freight is transported in residential neighbourhoods” (Allen and Browne 2010, p. 13). However, they do argue that settlement size, density, and mixed land uses affect freight movements since larger communities will produce greater demand and higher densities will potentially reduce distance traveled between origins and destinations.

While minimal research has focused on the interaction between smart growth and urban goods movement comprehensively, quite a bit of research has been conducted that looks at the relationship between specific aspects of smart growth and urban goods movement. This review will consider five areas of existing research between smart-growth-related subfields and urban goods movement:

1. Access, parking, and loading zones
2. Road channelization, bicycle, and pedestrian facilities
3. Land-use mix
4. Logistics studies
5. Network system management

These five areas describe subcategories of smart growth or smart-growth-related fields that can influence or be influenced by urban goods movement. They are not a comprehensive description of smart growth, nor are they intended to be. We have, however, identified research in these areas that informs our evaluation and modeling.

4.1 Access, Parking, and Loading Zones

The first area that has been examined with regard to smart growth and urban goods movement is the impact of access, parking, and loading zones. Using focus groups of truck drivers, Pivo et al. (1997) found a need for loading zones throughout the day and for improved way-finding to, and design of, existing loading spaces. Truckers in their focus groups wanted more loading zones that are larger and have longer allowable time limits. Morris et al. (1999) identified inadequate docking space and insufficient curbside parking for commercial vehicles as two of four major barriers to freight mobility consistent across sectors, as identified by logistics and transportation managers. They suggested increasing off-peak deliveries, increasing the available truck parking, and providing incentives for better docking facilities as solutions to these problems. Morris and Kornhauser (2000) and Morris (2004) followed up this work by surveying office managers of commercial office buildings, and they confirmed their earlier findings. Morris' 2004 work also looked at loading-dock regulations nationally and found that no recent changes have been made to regulations in the six cities studied (Atlanta, Boston, Chicago, Dallas, New York City, and Seattle) and that New York's requirements are far smaller than those in the other cities. As illustrated by the existing research in this field, a demand for adequate loading space exists and is a significant influence on driver satisfaction. However, the available research does not identify the appropriate balance between a need for adequate parking for goods movement and the other uses that road space can serve. It also does not consider the impact of different regulations on mobility and goods movement.

4.2 Road Channelization, Bicycle, and Pedestrian Facilities

A primary aspect of smart-growth development is design that fosters non-motorized mobility and multimodal environments. These types of designs include sidewalks along roadways, a well-connected bicycle network, and narrower streets that foster slower speeds and are perceived as more pedestrian friendly (Saelens et al. 2003; Handy 2007). Although most urban freight traffic is handled via small trucks and vans, freight vehicles typically have larger turn-radius requirements and field-of-vision limitations, which are factors that make traversing narrower roads with varied user groups more challenging. In summarizing the findings from a series of focus groups they conducted, Pivo et al. (1997) indicated that truckers were comfortable with pedestrians and sidewalk provision but felt challenged by the automatic right of way of pedestrians at crossings, which they felt creates sudden needs to stop. Truckers were more concerned with bicyclists, which they felt were erratic and were not held to any operational standards. Overall, what is not clear from the existing literature is the extent to which the potential for truck/non-motorized incidents is real or perceived—that is, do places with more interaction between trucks and non-motorized modes of travel have more crashes, or are these two sets of modes simply wary of their potential for collision?

To date, little research has been done that focuses on these types of street designs (including sidewalks along roadways, a well-connected bicycle network, and narrower streets) and their relationships to urban goods movement. However, a significant body of literature exists that looks at the impacts of these types of changes on the roadway environment in general. For example, Huang et al. (2002) looked at crash reductions following the installation of road diets and found some evidence of a reduction in the number of crashes. Ewing and Dumbaugh (2009) found that urban environments with narrower lanes were safer than suburban environments since they better communicate appropriate travel speeds. Reynolds et al. (2009) found that bicyclists had higher crash rates in pedestrian environments and were safest on dedicated infrastructure such as bike lanes or paths. These studies show that narrower street designs that

incorporate bicycle infrastructure and sidewalks may slow speeds and reduce crashes. So far, research has not shown that these effects extend to freight vehicles, but there is little reason to expect otherwise.

4.3 Land-Use Mix

Another key component of smart-growth development is interspersing land uses of different types. This integrated land-use design is intended to reduce travel distances and make non-motorized and multimodal travel more attractive. To some extent, proximate residential, retail, office, and industrial spaces may also reduce goods-movement travel needs following the same principles, but that effect has not been studied. Klastorin et al. (1995) found that when firms located near denser urban areas they had increased demand and revenues and that firms sometimes chose smaller vehicles to serve those types of areas. Morris and Kornhauser (2000) and Morris (2004) observed movements of freight vehicles at loading docks to determine time-of-day patterns, dwell time, and truck size. The 2000 study only looked at two buildings and did not allow for correlation between these variables and building descriptions or facility provisions. The 2004 study found strong correlation between the number of daily deliveries and rentable space.

Other researchers and practitioners have considered ways to estimate the number of truck trips generated by land use or facility type. *NCHRP Synthesis of Highway Practice 298: Truck Trip Generation Data* (Fischer and Han 2001) evaluated the state of the practice for truck trip-generation collection. They found estimating trips from commodity-based measures (like the Commodity Flow Survey) is challenging since doing so requires conversion rates between tonnage to trips and is not likely to accurately reflect movements in urban areas, which are often chained. This work found that actual truck trip-generation information was available in a limited fashion, but usually only for truck-intensive uses (for example, terminals and specialized warehouse and distribution facilities). Information regarding truck trip generation is generally not available for uses in urban centers (for example, office buildings and service or retail locations) or even suburban-type development (industrial parks, warehouses, and manufacturing facilities). Woudsma (2001) points out a need for standardization in data collection. The Institute of Transportation Engineers, in its 2008 edition of the *Trip Generation Handbook*, included a section on truck trip generation. The data presented includes information from a variety of land uses but relies on limited sample sizes.

To address this gap, studies for specific land uses must be completed. McCormack et al. (2010) looked at truck trip generation at grocery stores, collecting survey data and manual count information to develop an estimate of 18 trucks trips per day, with an average dwell time of 27 minutes for the sampled grocery stores. Unlike passenger trip generation, which is usually tied to land-use size, this study did not find a correlation between the size of the facility and the number of generated trips.

Regional travel demand models have incorporated truck trips on some level by including special generators for truck-intensive uses, but again these uses are frequently not in the urban core or do not reflect other uses such as office buildings or retail establishments.

A number of research areas associated with land-use mix and truck travel have not yet been considered. First, little research has been done on the impacts of truck travel in mixed-use environments. The relative benefit of trip reduction from mixed-use environments should be compared with the benefit of allowing off-hour service by trucks. In addition, the literature is sparse in terms of the relationship between land-use patterns and truck trip generation.

4.4 Logistics Studies

The research areas of logistics, operations research, and industrial engineering have a number of topic areas that are related to smart growth yet consider the movement of freight vehicles. These areas include research into time and size restrictions, vehicle choice, and warehouse locations.

4.4.1 Time and Size Restrictions and Vehicle Choice

These restrictions and decisions are either dictated or limited by policy restrictions or are decisions made by private-sector service providers. Restrictions imposed through public policy measures are often designed to reduce externalities, including congestion, air pollution, and noise pollution (van Rooijen et al. 2008). Private market motivations to reduce costs generally yield similar results because societal desires to reduce emissions and restrictions on private behavior usually result in higher emissions (van Rooijen et al. 2008; Holguín-Veras et al. 2013; Quak and de Koster 2007; Quak and de Koster 2009; Anderson et al. 2005; Siikavirta et al. 2002; and Allen et al. 2003 have all studied or commented on this relationship). Further, since delivery providers frequently choose their timing based on customer requirements, tools such as congestion pricing have been shown to be ineffective in changing truck timing (Holguín-Veras et al. 2006). Incentives that encourage receivers to accept deliveries during off-peak hours have been shown to be more successful (Holguín-Veras et al. 2011).

4.4.2 Warehouse Locations

Since warehouses (including storage and distribution centers) are frequently one of the end points for commercial trips, their location can significantly influence the distance traveled by goods-movement vehicles. Warehouse locations affect travel behavior, and land-use policies affect the location of warehouses. Research about the optimal location for warehouses is common. Crainic et al. (2004) found that the use of “satellite” warehouses to coordinate movements of multiple shippers and carriers into smaller vehicles reduces the vehicle miles traveled of heavy trucks in the urban center but increases the total mileage and number of vehicles moving goods within the urban center. This research illustrates the closer relationship between warehouse location and the vehicle choice problem. In contrast, Allen and Brown (2010) found that locating distribution facilities closer to urban centers would reduce the average length of haul and total vehicle kilometers traveled by freight vehicles in and to urban centers, and Andreoli et al. (2010) found that mega-distribution centers, located to serve multiple regions, increase the distance traveled between the distribution center and the final outlet.

While warehouse location is an important factor in the ultimate impact of urban goods movement on an urban area, Klastorin et al. (1995) found that the ultimate location of warehouses is determined by land costs, not transportation costs.

4.5 Network System Management

A final area of research that links smart growth’s congestion-reduction goals and urban goods movement is work that looks at the management of the transportation system to improve its operation. One of the main barriers to freight mobility identified by transportation managers is network congestion (Morris et al. 1999). Addressing this concern can be done by increasing the efficiency of the network through providing real-time information or metering of access. Marquez et al. (2004) looked at a number of different policies for reducing greenhouse-gas

emissions, including a number of network system-management strategies. Using volume-delay functions in a traditional modeling environment, coupled with emission-modeling tools, they identified modest improvements in carbon dioxide emissions and reductions in both vehicle hours of travel and trip lengths when better traffic management or real-time traffic information is provided.

4.6 Summary

While smart-growth development is a focus of today's urban planners and all stakeholders agree that goods movement needs to be explicitly considered within the planning sphere, a significant research gap exists in understanding how these two areas relate.

Despite a clear tension identified between truck drivers, who claim a need for additional parking and loading, and planners, who claim to be doing their best to balance that desire with other competing interests, no research is available that examines or develops an optimal balance of parking space and time regulations. The potential for conflicts between trucks and non-motorized modes is a primary concern for urban goods movement in smart-growth environments, yet it has hardly been considered in the literature. Another area of tension identified by this work is that between the trip-reduction and associated environmental gains fostered by mixed-use development and the lifestyle conflicts of having different uses in close proximity. Indeed, some other methods of achieving these types of gains—including off-hours deliveries or larger, more efficient vehicles—have specific impacts (air quality or noise pollution) that make them undesirable in mixed-use environments. Because of the risks identified in innovative distribution methods, additional research is required to illustrate their benefit and to identify ways to remove some of the existing barriers. Finally, efforts to manage the transportation system through real-time information and metered access are promising solutions to reducing congestion and thus reducing costs and environmental impacts. These efforts should be expanded to the extent possible to goods-movement services.

Learning from Goods-Movement Stakeholders

Issues of goods movement, whether related to urban or long-haul deliveries, are inherently complex and vary dramatically by specific industry and by geographic and political constraints. As is the case for any planning activity, engaging with stakeholders is invaluable. Freight-related stakeholders possess a level of expertise and a nuanced view of their daily operations otherwise opaque to researchers and practitioners. For example, while it might be generally understood that trucks climb hills more slowly than passenger vehicles, truck drivers can augment this knowledge with particular, location-specific information that illuminates issues of conflict between transportation modes, landscaping, or street design.

Drivers, operators, and logistics managers, among others, involved with moving goods in the urban context, may participate in stakeholder processes for a variety of reasons. Although some stakeholders may participate with concern for parochial interests (e.g., to improve a roadway or to resolve a conflict that is of particular concern for their firm), others might do so out of a sense of corporate citizenship. In any case, they do not engage in a planning process for the sake of the process itself but rather from a more action-oriented viewpoint about generally improving conditions for goods movement that will facilitate future operations (Plumeau and Jones 1998).

Over the last several decades, the freight community has been asked to participate in a number of academic studies to provide better understanding of their interests and perspective. Pivo et al. (2002) directly considered goods movement in urban settings. Among other findings, they learned of a hierarchy in preference for locations to park a truck, with internal loading docks being preferred over alleys, which in turn are favored over on-street options. In addition, they learned about potential conflicts between modes and about driver frustrations with bicyclists and pedestrians.

Pivo et al.'s study is the closest and only direct parallel to the work described in this report. Not surprisingly, little has changed in terms of preferences or potential conflicts.

Several studies have engaged with the freight community to consider issues of cost and congestion pricing. Golob and Regan (2000) worked with trucking firms in California to determine perceptions related to congestion-relief policies, for example, tolling and truck arterials. In a follow-up to this survey, Golob and Regan (2001) identified five factors that most concern the freight community in relation to congestion—"slower average speeds, unreliable travel times, increased driver frustration and morale, higher fuel and maintenance costs, and higher costs of accidents and insurance." Finally, Holguín-Veras and Wang (2011) worked with the freight community to better understand their perceptions of electronic toll collection in New York and New Jersey.

These studies highlight several important factors and indicate that freight-related users of the transportation system have unique needs and perspectives. Because goods movement is vital to

the well-being of economies and cities, careful attention should be given to addressing issues raised by these constituents. Although multiple objectives can be met by adopting smart-growth principles—for example, cleaner air, more active lifestyles, shorter commute trips—the more that areas densify, the more goods that will be demanded in those areas and the more changes that will be required in the method and design of goods-movement systems. Careful attention must be paid to ensuring that goods movement can thrive in dense urban areas to truly achieve the outcomes desired by smart-growth and growth-management principles.

5.1 Intent of Focus Groups

To further understand the relationship between smart-growth principles and urban goods movement, this study team consulted the actors most responsible for such movement. Six focus groups were conducted in May 2011—three in Seattle, Washington, and three in Philadelphia, Pennsylvania. In each metropolitan area, there was one for truck drivers, one for logistics managers, and one for planners, public officials, and developers. The participants included the people who drive the trucks and deal with the effects of public policy and the built environment, the logistics managers and schedulers responsible for organizing the distribution of goods and ensuring timely and cost-effective delivery, and the planners, developers, architects, and policy-makers who design and regulate the built environment in which goods must move. The underlying assumption was that the stakeholders most directly involved with goods movement would have important insights about the topic. The focus groups were separated into three groups in each city to keep the relative size of the group small (8 to 12 people is an ideal size for a focus group) and to allow discussion of slightly different questions (detailed further in this section) in each of the groups.

5.1.1 Study Areas

Philadelphia and Seattle were chosen as the study areas for several reasons. The study team is led by the Puget Sound Regional Council, a sophisticated metropolitan planning organization (MPO) with an established history of incorporating freight movement into its regional plans and funding allocations. It operates in one of the dozen growth-management states, in which the guiding policies are essentially smart-growth policies. In their study *Learning from Truckers*, Pivo and Carlson et al. (1997) conducted focus groups with Seattle-area truck drivers about goods movement in dense urban environments, and their results provide a baseline point of comparison of responses from 15 years ago. The Delaware Valley Regional Planning Commission represents a sister metropolitan planning organization in another region of the country, also with advanced involvement in freight movement. A better understanding of what the more generalized or localized concerns and issues may be can be gained by holding focus groups in more than one metropolitan area of the country.

5.1.2 What Did We Ask of the Three Different Groups?

The following questions broadly describe the types of topics addressed within the focus groups.

Truck drivers. What is it like to deliver in dense urban environments? What about road and curb space allocation to various modes? Does truck size matter? What makes for better or worse delivery situations?

Logistics managers from the transportation industry and related sectors. On the operational/logistics side, how do you accommodate denser urban environments and public

policies that restrict freight movement? Do you change delivery times, patterns, places, and/or equipment? What strategies do you employ to deal with congestion and competition from other modes? How do you deal with time-sensitive deliveries as opposed to others? What types of equipment do you use in various environments? On the business location side, why does your business locate in or ship to dense urban environments? Would you change your location if you could? Why? Where would you go? What is the relationship between your location and your ability to attract the kinds of workers you need? What about land cost and availability of space?

Developers, urban planners and designers, architects, and building managers. Are you thinking about moving goods? How do you know about freight needs? How do you design for them? What policies are in place to accommodate goods movement (1) in public rights of way and spaces and (2) around new and old buildings? How are policies enforced and by whom? What would you like to see in the future?

The list of focus group participants and the complete focus group guides are attached in Appendices A and B.

5.2 Findings from the Focus Groups

This section summarizes the findings of the six focus groups held in Philadelphia, Pennsylvania, and Seattle, Washington, in May 2011. The section is divided into multiple categories beginning with the demand for goods movement and a discussion of areas perceived as delivery desirable. The section then continues with a set of issues related to the difficulties of moving goods in a dense urban environment—parking, noise considerations, and modal conflicts. The remaining issues focus on potential solutions to alleviate these problems.

Stakeholders with divergent views participated in the focus groups. While truck drivers and logistics managers generally shared the same perceptions, drivers were focused on immediate issues—those outside their windshield—while managers were more concerned with cost and systemwide needs. Urban planners and city officials generally held different opinions and perspectives than those held by freight professionals, probably because this group is responsible for changing and managing infrastructure rather than using it. Although the focus groups were carried out in different settings, the views of similar groups were nearly identical, that is, truck drivers in Philadelphia appear to confront the same issues as those in Seattle. Nonetheless, differences were also apparent, largely because of different circumstances. For example, a set of parking restrictions has been implemented in Philadelphia through the parking authority, while such a tool is not in use in Seattle.

The narrative for each of the topic areas attempts to capture the perceptions and insights of all the groups. Where agreement did not appear, multiple viewpoints are discussed. This section concludes with implications for jurisdictions, urban-planning professionals, and travel-demand modeling. The questions posed in the focus groups are included in Appendix B.

“Without trucks, America stops.” Focus group participants who were engaged directly in goods movement generally conveyed frustration over a lack of consideration for, and accommodation of, trucks, both from the public at large and from the public sector with regard to land use and infrastructure decisions. At the same time, public-sector participants felt that they considered freight-related issues in their processes and that they were making significant accommodations for goods movement given the constraints of allocating limited right-of-way space and financial resources. Further, public-sector participants must consider other modes and attempt to improve the system for all users by improving traffic signal timing, considering speed limits, and so forth, in addition to considering the right of way.

If you bought it, a truck brought it.

(Logistics manager)

Despite whatever conflicts there may be between various stakeholders, all agreed that smart-growth principles and particularly the mixing of uses were useful strategies for cities to pursue. Indeed, one logistics manager noted that “Mixed use is a good strategy to get single-occupant vehicles (SOVs) off the road—and give us more parking spots.” Although the motivations may be different, all focus-group participants widely agreed that goods movement is vitally important to cities, that cities and the demand for goods were going to continue to grow, and that considerable effort should be given to addressing this topic.

Although truck drivers noted many challenges related to goods movement in dense urban environments, some preferred delivering to these locations. Driving a truck and making route decisions was often described as a puzzle, which drivers were proud to solve. As such, the challenges of urban delivery may outweigh the difficulty of delivering to dispersed locations with long distances between stops. Deliveries benefit from proximity—a consequence of smart growth.

The best places to deliver (from the perspective of the focus-group participants) have good access for trucks in terms of the ease of arriving at a destination and the availability of parking. Locations with loading docks internal to a building are most favored, especially when the loading docks are easily accessible, for example, through a lift that adjusts the height of the dock and through the thoughtful angling of the entrance into the roadway. In general, newer cities and neighborhoods are favored over established ones because they have wider streets that allow for more space away from parked vehicles and generally include grade separations that remove conflicts with trains and other traffic.

The worst places to deliver (from the perspective of the focus-group participants) are ones where one or more conflicts arise. In general, considerable frustration was expressed over issues related to truck parking. Given the limited space for trucks to load and unload goods, locations where passenger vehicles repeatedly occupy a loading area are problematic. At the same time, trucks are considered a nuisance when they double park or unload products in a right of way, when no alternative is available to them (see Figure 1).

We’re the bad guys because we double park.
(Truck driver)



Figure 1. Delivery truck parked in bicycle lane. (Source: Brian Porter)

The issue of parking is predominantly related to commercial areas, and particularly to retail. While shopping malls were described as having been easy to access in the past, there was widespread agreement that currently trucks are not welcome at shopping centers and are considered a visual blight or a noise concern.

Driver safety was also brought up as a concern. In addition to locations that are generally unsafe in terms of crime, delivery locations where it is difficult to offload goods were of concern to drivers and managers alike due to potential disability claims. In more crowded urban environments with narrower streets, automated equipment cannot always be used, forcing drivers to carry more of the physical burden for moving goods.

Parking is limited. The biggest concerns raised by truck drivers and logistics managers were related to the lack of parking, time restrictions for parking, and poor design of loading docks and zones. Newer environments, suburban areas without congestion issues, and newer buildings are reported to be considerably easier to deliver to than older, more established urban areas with older buildings. In older locations, there is a need to retrofit, induce market interventions, and reduce conflicts with goods movement. Conversely, newer areas should be built *right* from the start and properly consider goods movement. Nonetheless, design issues persist. Although planners, engineers, and architects report considering truck loading areas early in their design processes, those considerations seem limited to a decision of where trucks should go to load and unload, that is, how to separate the goods movement from other activities. Truck drivers and logistics managers believed that more direct consideration by these groups for the specific design of the docks themselves (angles of entry, height, clearance, etc.) would better facilitate the loading and unloading of goods.

Design of truck loading facilities is particularly important in new buildings, and internal loading docks in buildings, if properly designed, are clearly favored by drivers. The internal docks save time in terms of delivery, reduce fears of theft, are indoors and thus protect drivers from adverse weather, and diminish the distance drivers must hand-truck goods, which potentially reduces driver injuries. In addition, internal docks allow trucks to avoid on-street conflicts with bicycles and allow drivers to avoid conflicting with pedestrians on sidewalks while using a hand-truck.

When internal loading docks are not available, alleys are generally favored over on-street parking options. However, alleys also present challenges because large trucks have difficulties navigating them. Competition for alley loading time exacerbates the size issue when another vehicle needs the space and one vehicle must wait for the other to finish unloading. While mobility within alleys and space for parking can be mitigated by the use of smaller vehicles, these vehicles have lower capacities and may have different capabilities, which reduce efficiency and increase delivery cost. Another potential difficulty in using alleyways for deliveries is that in some locations alleyways are targeted for pedestrian uses through alley activation projects.

On-street loading areas are essential, but there was animated discussion about their placement, the number of them available, time restrictions, and enforcement. Generally, participants stated that there are not enough of these areas, that non-delivery vehicles often park in them illegally, and that they are not located near where a truck must deliver. Although truck drivers and logistics managers believe that there is insufficient space, planners must ensure that road space is maximally utilized. The issue is one of optimization—how to provide sufficient truck loading areas when trucks need them, and what to do with that space when they do not. Jurisdictions are often under pressure from businesses and residents to provide more passenger-vehicle parking. As one city official noted, “everyone wants curb space, and they want it for free.” In instances when curb space is not available for truck loading, planners and city officials recognize that loading might have to occur in a travel lane, though there is widespread agreement that this

Common courtesy doesn't exist in the streets; people look at trucks as a nuisance.

(Truck driver)

When William Penn designed Philadelphia, he wasn't thinking about 50-foot trailers.

(Logistics manager)

Goods don't vote, and goods don't buy.

(City official)

is less than optimal. Even so, some goods movement activity must occur in alleyways and not at the curb. “Back door” services, such as waste management, must go to where the goods are.

A large portion of the problems associated with on-street loading relates to regulation and will be discussed in another section of this chapter. The main concerns include the high cost of parking, including tickets, that trucking firms must bear as well as illegal use of loading areas by other vehicles. When drivers have no option but to use on-street facilities, they rely on familiarity with other drivers and their routes and attempt to deliver when they do not expect others to require the space.

Parking fines in particular were mentioned as heavily burdensome to companies. One company reported spending \$5,500 every 6 weeks on parking fines, and there was a general sentiment by the logistics firms that participated in the focus groups that the city ticketed the companies that paid. However, while acknowledging that the city charges heavy fines for parking violations and is familiar with all of the delivery companies and their concerns, city representatives believed that some deliveries had to be made from further away than a driver would like. The rationale from the city’s perspective was that the streets had to accommodate multiple purposes, that the freight community is continuously consulted on time of day restrictions, and that delivery drivers had to abide by them.

Due to limited parking, trucking companies are willing to bear the cost of fines as long as the drivers do not park near fire hydrants, lift gates, or handicapped zones, which the companies consider to be serious offenses. Nonetheless, logistics managers were quite cognizant of the implications of providing sufficient loading zones, particularly as it is related to the provision of bicycle facilities, because the use of space for one activity precludes another. Among the potential solutions offered was to incentivize early morning deliveries and implement time-of-day restrictions.

Customers drive the demand. Early morning and nighttime deliveries are often considered a solution to a set of problems associated with truck deliveries. Were trucks able to deliver in off-peak hours, there would be less competition for on-street loading areas, less roadway congestion, and less conflict between modes of transportation. In turn, off-peak-hour deliveries would improve air quality, reduce costs for trucking firms (and ultimately consumers), and allow for a transportation network that can better cater to active-living transportation modes.

However, the time for deliveries is limited to, and dependent on, times when customers can accept the deliveries. Distribution centers, often located away from residential areas, may be able to operate 24 hours per day, but most retailers do not have the ability to receive deliveries around the clock. If a business does not normally operate at night, accepting deliveries during the nighttime hours would require an employee (or employees) to be available during a particular delivery window—someone needs to unlock the door and accept the delivery. Creating new working hours for employees raises the costs for individual retailers. Even businesses that are open 24 hours per day (e.g., some grocery stores) generally only accept deliveries during the day. In addition, for businesses that do operate during the night, accepting deliveries may be inappropriate or infeasible due to noise or safety.

As an illustration, many bars and restaurants open for lunch and remain open late into the evening. These businesses generally do not accept morning deliveries because they do not yet have staff at the establishment. They also generally do not accept deliveries during the busy lunch and dinner hours, especially when the deliveries must come through the front door and not directly to a stock room. Because many establishments must, at the very least, verify that an order arrived complete and sign for the order, they cannot devote staff effort to these activities during busy times.

During late-evening hours, limited staff resources to accept deliveries are further compounded. For example, were a delivery to be made close to a business’s closing time, the delivery driver would

We’re working around our customers’ economy; your freight dictates your travel time.
(Logistics manager)

likely have to navigate through customers with a hand truck. This type of delivery may become particularly problematic at crowded bars. This illustration could be extended to a small corner store, where the limited staff of a mom-and-pop operation requires delivery during specific hours.

Nonetheless, drivers and logistics managers alike were in favor of more early deliveries—the earlier the better, in fact. For truck drivers, an early start means being able to get home to their families in the evening. If the proper incentives are in place—for example, sufficient parking for trucks—the trucking companies would support it. However, such incentives alone cannot overcome the reality of businesses that cannot or will not accept deliveries in the early hours, and many trucks cannot make all of their daily deliveries within a short time period (morning or otherwise).

Truck deliveries are noisy. In some instances, it may be possible for deliveries to be made in the nighttime hours, but for this to be feasible, a relationship needs be established between the business and the trucking firm, and keys or a secure external drop-off location must be provided. Assuming that such a relationship is feasible, noise concerns related to the deliveries must be overcome to allow a shift from daytime to nighttime deliveries.

In places where businesses are located near residences (a positive outcome of a mixed-use built environment), noise ordinances may prevent delivery of goods in the nighttime hours due to the noise generated by the trucks or by the movement of goods.

For safety reasons, trucks are equipped with a back-up beeper to alert nearby motorists and pedestrians that a vehicle is reversing. Such devices could potentially be turned off in the nighttime, assuming regulations would allow for this to occur. However, even if trucks were made much quieter (through electric engines, for example) and alarms could be silenced, the movement of some goods would still produce noise. For example, while a garbage truck may be made to be close to silent, the act of picking up, putting down, and emptying trash receptacles would still produce noise. On the other hand, trash receptacles could be manufactured from materials other than metal and thus could be less noisy.

The issues above highlight the variety and complexity of factors that need to be considered in a smart-growth world.

Competition. Retail businesses and trucking firms alike operate with tight profit margins. Given the difficulty of operating in the nighttime and off-peak hours, trucking firms must deliver when their customers are willing to accept the deliveries and when they are not barred from doing so by noise or other restrictions. Further, trucking firms must make a tradeoff between accepting the constraints placed on them and not conducting the delivery at all. Since there is considerable competition among trucking firms, if one is not willing to conduct the delivery, another one would take the business. Because retailers also often face tight profit margins, they are unlikely to be willing to accept any innovation or change to the delivery structure that would require them to incur additional costs.

The private sector has to create solutions. Given the limitations placed on trucking firms and truck drivers, each firm must find a way to innovate and find context-sensitive solutions for any particular delivery task they are charged with. Solutions for the varying problems may be small in scale and involve maintaining relationships with customers, other drivers, and parking enforcement officers. For example, some smaller deliveries might be made in an alleyway but require a special relationship and arrangement between the driver and the customer. Some drivers might choose to call or text message a customer. If a particular employee is available at the customer end to pick up the delivery (as opposed to requiring it inside), quicker deliveries may be possible. In other words, all the people involved must share ideas to overcome infrastructure problems. In dense urban environments, relationships between customers and drivers are key since the drivers serve as the information conduit for the final mile.

We're not in the trucking industry; we're in the people business.

(Truck driver)

Over time, you get to know police officers and other drivers. If you can't figure out how to make your job easier, you're just stupid; if you're not flexible in transportation, you might as well get out.

(Truck driver)

Potential solutions might also be large in scope and could include completely reconsidering a firm's logistics operations. Aside from the well-established use of communications devices, a variety of ideas were raised about urban distribution centers. Centers within urban areas could be operated to accept all deliveries for a specific business or for multiple businesses; deliveries of the last mile could be handled through electric vehicles, bicycles, or hand trucks. The intent of such approaches would be to allow trucks to deliver to centralized locations at off-peak hours.

Right-sizing vehicles. In dense urban environments, there are multiple concerns related to trucks: congestion, air quality, noise, and conflict with other transportation modes. Electric and hybrid vehicles have been offered as one potential solution to alleviate air quality and noise concerns. Given today's engine technology, electric and hybrid vehicles are very effective for small delivery vehicles. However, multiple trucking firms noted that given the weight of larger trucks, the electric and hybrid engine technology is not currently advanced enough to provide sufficient power, over long enough distances, for large delivery vehicles (longer than 20 feet).

In situations in which space is limited for deliveries by large trucks and there is a desire to reduce potential conflicts among large vehicles, small ones, and non-motorized modes, it may be desirable to convert part or all of the delivery fleet to smaller, hybrid, or electric vehicles. For example, when considering designing or retrofitting a roadway to a "complete street"—one that accommodates multiple modes—a smaller truck is considerably easier to accommodate due to the smaller necessary lane width and turning radius.

*The more you
touch freight, the
more you break it.*
(Logistics manager)

However, a switch to smaller trucks comes at a cost. A small truck can carry only a portion of what a larger vehicle is capable of carrying. The amount varies depending on the types of vehicles and the types of goods transported. In addition, the amount may vary based on the logistics decisions of individual firms, that is, a large truck that previously traveled half full can now be replaced by a smaller one, while a large truck that operates fully loaded would require more than one vehicle. One recycler parks a large vehicle at the central business district (CBD) periphery and picks up product in the dense urban center with a smaller truck, which then shuttles back and forth to the mobile depot for offloading.

While truck drivers need to negotiate small city streets with ever larger vehicles, there are (from a logistics perspective) multiple issues involved with a move to smaller vehicles. The demand for goods movement changes on a daily basis, which makes owning and operating a larger fleet of smaller trucks more expensive than a smaller fleet of large trucks, especially if a company may not need all the small trucks (and drivers) every day. The smaller vehicles require considerably more handling of goods, and with more trucks fighting over the same limited loading zones additional costs are created for tolls, fuel, and parking fines.

Nonetheless, logistics managers and truck drivers report that companies do use a variety of vehicles, depending on the location to which they are delivering. In some areas, large trucks cannot traverse the streets, which may be too narrow, and customers are unable to change the buildings in which they operate. Although trucking firms do adapt to the demands of their customers, the choice to use smaller vehicles is purely based on an inability to use larger ones and not their preference or economic advantage.

Consolidation. Among many potential solutions for alleviating issues related to congestion and truck parking is the idea of having small distribution centers within urban cores. This concept was presented to logistics managers, and they were asked to respond as to whether or not it would be effective. Distribution centers in urban cores may take the form of a single business (e.g., FedEx) having an office in a building, having a daily delivery to that office, and distributing the packages to the building from that office rather than from one or more trucks. Alternatively, the distribution center could take a different form in which multiple companies deliver to one

central location and local deliveries are made by either smaller vehicles or hand trucks to nearby businesses. One final approach offered would be for merchants to band together to establish a small delivery hub near their businesses. The merchants would then do their own final delivery (pick up), gathering the goods from the distribution center and bringing them to their retail stores. When queried on the potential for such an approach, logistics managers felt that, while it is novel, there are multiple potential hurdles to overcome for such an approach to be successful. First, and most important, logistics managers felt that they provided a service, and that customers wanted the goods delivered directly to them. The major technical issue to resolve would be determining which agent is responsible for the goods once they are no longer on the truck and until they are picked up or delivered to their final destination. Retail stores would need to agree to such an arrangement.

Protect industrial areas. As some land uses shift from industrial and warehousing to residential and commercial, multiple freight-related business owners and operators believed that it creates tension for the businesses that remain. For the businesses that are left in what were once predominantly truck-dependent activities, new issues of competition for rights-of-way space, modal conflict, pollution, and noise restrictions emerge.

Although this situation may happen whenever freight-dependent activities are proximate to other uses, the effects are particularly pronounced in locations that contain a cluster of freight activities and are close to major urban activity centers. For trucking firms that primarily move goods to urban areas, shifts in location choices are likely, and generally involve relocation to industrial areas further from an urban core. Similarly, manufacturing-related businesses, even in the absence of relocation, have to devote more time to traversing the transportation system to pick up or deliver their products. In either case, the end result of non-freight land uses being allowed (through zoning) to coexist with freight uses creates multiple issues that include land speculation, a mix of the wrong (from the point of view of the focus-group participants) land uses, longer transport distances, and additional delivery vehicles. These potential conflicts occur through the following process:

1. Speculation on potential development drives up the price of land in industrial areas.
2. A mix of land uses, if it is not an appropriate mix (again, appropriate defined by the focus-group participants), may drive some warehousing and industrial activities away from urban cores. For example, if a warehouse is turned into condominiums, the adjacent warehouse may begin to receive noise complaints about early morning activities that it had been conducting prior to the condominium development.
3. Longer transport distances for goods increase the cost of delivery. The initial costs (e.g., additional drivers and fuel) are borne by trucking firms, but the costs may in turn be passed on to firms that receive the goods and ultimately to consumers.
4. More delivery vehicles, driving longer distances, create more pollution and noise, and may conflict with other transportation modes.

Congestion. Like other vehicles, trucks have to deal with congested roadways. While the same problems of wasted fuel and additional pollution apply to trucks, due to a high value of time and the time-sensitive nature of deliveries, trucking service is more greatly impacted by congestion than passenger vehicles. Truck drivers often face few route choices when moving goods—they cannot change where they go because the distribution center is located in a specific location, as is the customer to whom they are delivering.

Changing the time of day of operations, where feasible, was offered as one potential solution to removing trucks from congested roadway networks. For example, the *Seattle Times* newspaper switched to morning paper delivery so that delivery of the newspaper to outlets and carriers could be done at night. Other solutions of interest to both planners and trucking-related professionals include providing truck lanes or allowing trucks to use bus lanes.

If you (a jurisdiction) want this (industrial area) to be something else, just tell us and we'll leave. If you do it slowly, it's just death by a thousand cuts.

(Freight business owner)

If what we're worried about is carbon footprint, we'd better start thinking about freight movement.

(Truck driver)

They (planners) don't stop and think about how to handle freight; get it in their heads, everything comes by truck.

(Logistics manager)

Of particular concern to drivers and logistics managers in the focus groups were issues of staging and communications. For example, large events at a convention center or at a ballpark occurring on the same day that large-scale lane closures and construction begin can cause significant delays that could be avoided by careful consideration of the timing of construction activities. Truckers are especially sensitive to congestion and to event-related delays due to the limitations of time-sensitive delivery and hours-of-service laws. Because truck drivers can only drive for a limited number of hours during a shift, they must conclude their deliveries or alternatively find an adequate place to pull over. Similar to the issue of parking to make deliveries, it was generally believed that there are not sufficient, convenient locations for truck parking, especially overnight parking close to where truck drivers need to deliver.

Education. Direct communication among truck drivers, logistic managers, and public entities would be beneficial for all involved. There are two distinct issues that would benefit from collaborative decision making: (1) the allocation of street space (either for rights of way or for truck parking) and (2) enforcement of regulations.

The truck drivers and logistics managers in the focus groups all believed that planners, engineers, public officials, and the public in general did not understand the difficulties of and issues involved with operating a large vehicle. A general consensus formed around the notion that it was impossible for anyone to understand drivers' issues in detail until one is sitting in the cab of a truck. Drivers particularly noted that their sight was quite limited. Broadly, the issues revolve around truck sightlines, blind spots, stopping distances, and turning radii, especially for larger trucks.

On a small scale, even under potentially ideal conditions, in which a truck has the ability to access a building through an internal loading dock, if a passenger vehicle (or another truck) is parked too close to the entrance of the building, the driver will have difficulty entering the loading zone. This type of problem could be resolved by demarcating the appropriate amount of curb space that is not to be used for parking and also enforcing that regulation by ticketing vehicles that do not adhere to the regulation. Many of the truckers interviewed voiced the opinion that it would be beneficial to educate the public, perhaps through licensing requirements, on these sorts of issues.

On a larger scale, those involved with goods movement believed that the allocation of rights of way was generally done without proper consideration for the requirements of trucks. Particular concerns involved complete streets, where trucks may come in conflict with other modes, especially bicycles. Among the issues raised, the width of lanes, which are sometimes considered too narrow for trucks, and turning radii, which sometimes come in conflict with pedestrian curb bulbs or traffic-calming circles, were described as examples of how planners and engineers favored other modes over trucking activities.

Conversely, urban planners described a basic challenge of having to allocate street space for multiple users and for multiple purposes. From a planning perspective, the task is to make places people friendly, with the problem of how trucks get there being secondary. To that end, as people are encouraged to walk, there is a need for curb bulbs to provide safety. Similarly, bicycle facilities are necessary to promote that mode of travel.

Planners also believed that it was unreasonable for trucking firms to expect local streets to accommodate high-speed trucks or interstate-size rigs, that is, not every vehicle needs to go everywhere. However, planners were cognizant that trucks should be able to get in somehow. In other words, fire and garbage trucks need to be able to traverse all parts of the road network, but perhaps large trucks need not be accommodated everywhere. Further, there was general sentiment by planners and public officials that, if necessary, trucking firms could use several smaller vehicles.

Enforce the right regulations. Enforcement of regulations was a topic of considerable discussion surrounding both the cost to trucking firms and issues of safety. For public officials, it was clear that ticketing trucks for illegal parking was a major source of revenue and for trucking firms a major expense. Trucking firms viewed this issue as one in which they had to bear the cost of insufficient or improper space allocation for their needs, while public officials viewed the issue as a failure of the trucking firms, and the private sector in general, to fully comprehend the need for space for other users, to appreciate the city's limitations for street space, and to fully innovate and consider ways in which they could improve their loading and unloading activities. In other words, public officials believed that trucking firms disregarded the needs of other system users and simply parked wherever they wished.

The issue of truck parking in general requires further consideration and collaborative decision making in terms of developing solutions that will be successful for all stakeholders. There was a general sentiment among truck drivers and logistics firms that they would be willing to trade off costs (a charge or time restriction) for reliability and certainty. In other words, if a space was always available in a reasonable location for their loading and unloading purposes, they would be willing to pay and/or adjust their practices to work within that framework.

A corollary to the issue of truck parking is the issue of parking for all other vehicles. Regardless of the allocation of curbside space, (e.g., taxi, 30-minute load), truck drivers and logistics firms believed that there was not enough enforcement and ticketing of vehicles that either parked illegally or remained in a parking space beyond the time allowed. This is in contrast to the fact that some trucking companies accepted ticket fines, highlighting each party's parochial interests. In some instances, the cause of this phenomenon might be due to the high cost of parking elsewhere, that is, the threat of a parking fine is not sufficiently high to dissuade vehicle operators from parking illegally. In other instances, the issue is who should be allowed to park in specific locations. For example, in 30-minute truck loading zones, the space might be used by a truck making deliveries or by a service vehicle (e.g., computer and printer repair) that has the appropriate license to utilize the space but does not require the proximity to a business to deliver goods. In either case, more clarity on the regulation and enforcement of those regulations would better facilitate the movement of goods.

Finally, considerable discussion centered on the issue of conflict between modes. Truck drivers were very concerned about safety and avoiding accidents, particularly with bicyclists, due to visibility issues and to cyclists behaving erratically or not following the rules of the road. Similarly, logistics managers detailed multiple measures by which their companies were considering safety, for example, installing multiple cameras on trucks. Potential solutions, such as using all-way walk at intersections that remove the possibility of pedestrians crossing the street while a truck makes a right turn, were viewed favorably.

The larger concern, then, is with bicyclists and pedestrians who may not abide by regulations. Specific examples include bicyclists traveling through red lights or the wrong way on one-way streets. Despite the evident tension between the trucking and bicycling communities, these modes of travel have more in common than might be immediately evident. Bicyclists, like trucks, are slow to climb hills and require greater effort than passenger vehicles to start and stop and start again. In general, freight-related professionals felt positively about bicycling, noting that they would prefer to see more people riding bicycles or buses in order to get more cars off of the road—"there would be more space for the people who need it." However, truck drivers generally believed that there was a need for separation of roadway users to reduce conflicts.

One final regulatory issue raised in the focus groups was anti-idling legislation. While truck drivers and logistics companies acknowledged the utility of such laws, they were concerned about the implications. Some companies even install automatic shut-off devices that turn off

We are more reactive than anything else; we are about management, not implementing new ideas.

(City official)

the engine after a few minutes. In cold weather, turning an engine off to avoid idling may force a driver to sit in the cold. There are some mechanisms that allow for an override of this situation, for example, equipment that can override the automatic shut-off at temperatures below 32 degrees, but for this to be truly effective and reduce noise and pollution, loading areas and parking facilities need to be equipped with plug-in facilities so that drivers can stay warm and utilize some equipment while turning off engines.

Additional innovations. While the focus groups catalogued grievances and dysfunctions of the current system, they also generated proposals for innovation and possible solutions to moving goods in smart-growth environments.

Bicycle delivery was raised as a potential tool for lighter deliveries. Companies such as Philadelphia's Pedal Co-Op¹ can perform some of the goods movement functions currently done by trucks. For example, Pedal Co-Op offers recycling services in which materials are hauled by bicycle. Similarly, Portland, Oregon, based Soupcycle² delivers soups by bicycle throughout the city. In addition to specific businesses, there was a general belief that bicycles (similar to what bike messengers do currently) could assist with the final-mile delivery of small packages, particularly if a business established small urban distribution hubs.

Another potential approach for alleviating truck traffic within urban areas is to use existing rail transit facilities when they are not utilized for passenger travel, as has been tested in San Francisco (Lu et al. 2007). For example, if a passenger rail line does not operate for some hours at night, the trains could be used to move goods into a central area. Once there, the goods could be delivered by small vehicles or bicycles. There are multiple issues that would need to be resolved, including whether a transit facility funded by transit dollars could operate for a freight purpose, but this remains an interesting possibility.

Finally, it was suggested that park-and-ride lots that operate at less than capacity could be used for consolidation purposes. Similar to delivering with passenger transit lines, the intent would be to reduce trip lengths for trucks. For example, if one truck serves to one neighborhood, it could meet another truck at some consolidation area and pick up more goods for locations that it would be traveling to anyway, thus saving the second truck unnecessary travel.

¹ Pedal Co-Op: <http://pedalcoop.org/> Accessed July 4, 2011.

² Soupcycle: <http://www.soupcycle.com/> Accessed July 4, 2011.

CHAPTER 6

Considerations for Smart Growth and Goods Movement

6.1 Policy and Planning Considerations

The responses garnered from the focus groups present the views of those involved in goods movement about the interaction between smart growth and urban goods movement. Great care has been taken to present the focus-group participants' views as their own, without embellishment. The following discussion revisits several of the topics covered in the focus groups and offers some direction in terms of policy issues, research areas, and general considerations.

6.1.1 Noise and Time Restrictions

Though serving a legitimate purpose and being well-intended, noise ordinances and other restrictions may have the unintended consequence of causing truck congestion. Noise ordinances and specific delivery-time windows do not allow truck deliveries to be spaced throughout the day. Instead, multiple trucks must attempt to deliver during the same time window. With limited parking accommodation for trucks, multiple drivers vie for the same parking locations in the loading dock space. In turn, the lack of parking forces drivers to double-park, circle the block for an available parking location, idle while they wait, or use hand trucks to deliver goods from a parking location that is further away than would otherwise be desirable. As cities continue to implement smart-growth principles, innovative solutions—for example, centralized warehousing or quieter vehicles—will ameliorate some of these issues. Although there may be a successful business case for a central urban distribution model, one does not exist in this format in the United States today. For such a proposal to be successful, it would likely rely on support from a jurisdiction that is willing to implement a pilot project.

Regardless, clarity is needed for private freight carriers to be able to understand their working environment and develop solutions tailored to their delivery requirements. For example, as a city implements parking restrictions, clarity of location of commercial parking and enforcement of parking limitations for on-street loading docks allow the individual firms and trucks drivers to adjust and make efficient decisions about their operations. Beyond efficiency considerations, large-scale changes to a firm's operations require investment, and the benefits must clearly outweigh the costs, given the often small profit margins involved.

6.1.2 Right-Sizing Vehicles

The destination of goods impacts the choice of whether to use large or small vehicles. For example, a fully loaded truck may go to only one customer or it may make multiple stops along a route, delivering to an assortment of customers. Given the complexity involved in decisions about truck routing, in some cases smaller delivery vehicles would necessitate additional truck trips.

A move to smaller delivery trucks may require more trucks and more drivers, putting a greater burden on the transportation system. As the cost to delivery firms increases, so will the cost to the businesses that receive the goods, and ultimately to the consumers who purchase them.

Any jurisdiction considering limiting the use of large vehicles, or requiring the use of smaller ones, should be aware of the potential implications. Some larger retail outlets may choose to keep consumer costs low while transport costs increase; the smaller profit margins may be offset by the larger volume of sales possible in dense urban areas. However, the same may not be true for smaller businesses that may have to raise prices.

If a truck restriction policy were only implemented in one specific area—for example, a downtown core—the relative attractiveness (in terms of cost) of shopping in that area may be reduced compared with other retail areas that do not have such a restriction. Indeed, such a restriction may be similar to cordon or congestion tolling, which is effective either in specific locations or under systemwide implementation. Were there to be a shift away from shopping or other activities in dense urban areas, such a result would be counterproductive to the desired outcomes of smart-growth or growth-management principles. In other words, great care should be given to ensure that goods can be moved into dense urban areas, rather than imposing additional costs on those movements.

6.1.3 Modal Conflicts

In allocating street space and considering freight, there is a need to be flexible and innovative. Working under the current paradigm, cities continue to attempt to make dense urban environments fit suburban standards, that is, wider streets that make goods movement simpler—that do not accommodate all modes of travel. Greater care should be given to identifying context-sensitive solutions. For example, an all-way crossing, which accommodates pedestrian travel and improves safety and reliability for trucks, may only be feasible in areas with a high demand for pedestrian crossings.

The tension among freight stakeholders, planners, and non-motorized transportation users is not unique to the persons engaged in the focus groups discussed in this report, nor is it insurmountable. In essence, there is a false dichotomy pitting trucks against bicycles. The difficulty in improving this situation is that best practices for bicycle facility and truck facility design are sometimes at odds with each other. As such, a single set of design guidelines will likely fail in multiple locations where these modes come in conflict, that is, there is no silver bullet.

To fully address these issues, context-sensitive and site-specific solutions are necessary rather than a one-size-fits-all solution. All the relevant stakeholders need to clearly identify their needs and priorities and be able to discuss ways to best address issues in specific locations.

Although there are likely many cyclists who do not currently obey the rules of the road, the reasons may be well founded. Ensuring that there are regulations that make reasonable sense to a bicyclist—for example, in some locations a stop might be warranted for motor vehicles, while a yield to pedestrians may be sufficient for cyclists—would reduce the conflict and potential conflicts between various travel modes. Similarly, ensuring that there are sufficient, reasonable, and attractive bicycle facilities would allow for a separation of modes where appropriate and clearer demarcation of the road space in others. Although cyclists are obviously allowed to use any part of the road they choose, attractive facilities, be they bicycle boulevards or roads with shared lane marking (sharrows), would incentivize a reduction in potential conflict. It is well worth noting that many truckers do not obey the rules of the road: double parking, parking in the middle of the road. However, their reasons may be well founded, requiring, for example, additional allocation of space for parking.

As more jurisdictions, particularly in smart-growth and dense urban environments, consider complete streets, it is necessary to do so from the perspective of serving all users, not just improving conditions for some. While general guidelines may be effective in accomplishing this task, the difficulty is considering site-specific requirements and treating every block and intersection for its specific needs. While jurisdictions consider appropriate guidelines, it is crucial to increase safety by enforcing whatever regulations are currently in place.

6.2 Research Gaps

Varied development patterns cause freight and passenger traffic to behave differently. However, while today's urban planners emphasize the topic of smart-growth development, and all stakeholders agree that goods movement must be explicitly considered within the planning sphere, a significant research gap exists in understanding how these two areas relate. As more resources are directed toward fostering smart-growth development, its impacts on urban goods movement, which is directly related to economic well-being, cannot be ignored. This report has identified five key areas and the existing gaps in the research that should be filled and considered by researchers and jurisdictions when addressing the intersection of smart growth and urban goods movement. Table 3 summarizes these findings.

While little research has examined the relationship between smart growth and urban goods movement, this report has identified a number of research topics that, if pursued, would significantly increase the knowledge base for this issue. This work has the potential to improve the livability of cities and reduce environmental impacts while maintaining or increasing economic vitality.

Table 3. Five key areas and examples of their existing gaps.

Research Area	Example of Existing Gap(s)	Focus Group Support
Access, parking, and loading zones	What is the appropriate amount of parking or size and number of loading zones to dedicate to goods-movement vehicles? Can time-of-day changes relieve demand for space? What is the optimal balance of parking space and time regulations?	There is a clear tension between truck drivers, who claim a need for additional parking and loading space, and planners, who claim to balance that desire with other competing interests.
Road channelization, bicycle, and pedestrian facilities	Does the number of crashes between goods movement vehicles and non-motorized modes increase when these vehicles coexist more frequently? What are appropriate tools or configurations to reduce modal conflicts?	The potential for conflicts between trucks and non-motorized modes is a primary concern for urban goods movement in smart-growth environments.
Land-use mix	How do the environmental benefits of passenger trip reductions associated with mixed uses balance against the environmental costs of time restrictions on goods-movement vehicles necessitated by their impacts on residences and other businesses? Can vehicle sizes be changed? What incentives encourage freight trip consolidation? Does density affect truck trip generation? Do mixed land uses change truck trip-generation rates?	How can trip reduction and associated environmental gains fostered by mixed-use development be balanced with the lifestyle conflicts of having differing uses in close proximity? Some methods of achieving these types of gains—including off-hours deliveries or larger, more efficient vehicles—have specific impacts (air quality or noise pollution) that make them undesirable in mixed-use environments.
Logistics		Because of the risks associated with innovative distribution methods, additional research is needed to illustrate their benefit and to identify ways to remove some of the existing barriers, including the potential offer of government subsidies.
Network system management	How can we best extend real-time information and metered access to goods-movement vehicles? Can transportation demand-management methods apply to urban goods movement?	Efforts to manage the transportation system through real-time information and metered access are promising solutions to reducing congestion and thus reducing costs and environmental impacts, and they merit further testing and evaluation.



CHAPTER 7

Urban Truck Freight Models

7.1 Introduction

This section reviews the status and application of urban freight-forecasting models to account for the impacts of smart growth. This review is limited to urban models that forecast trucks because the majority of urban goods movements are by truck, and because existing urban-level freight-forecasting tools in use do not have the capabilities to address freight movement by other modes. While there are existing and planned statewide freight models, which have a valuable role in providing input into urban models, these models are at a resolution that is impractical for the evaluation of smart-growth activities.

7.1.1 Municipal Freight Models

Given freight's importance to an urban economy and trucks' environmental and roadway-congestion impacts, the existing interest in planning for and forecasting freight activity is not surprising. Urban forecasting models that account for some aspect of freight are relatively common in large urban areas, with many of the modeling programs being operated by MPOs. The Transportation Research Board's *Special Report 288: Metropolitan Travel Forecasting—Current Practice and Future Direction* surveyed MPOs about travel modeling and noted: "Truck trips are modeled in some fashion by about half of small and medium MPOs and almost 80% of large MPOs." But it went on to state, "The treatment of commercial and freight travel is one area in which most travel-forecasting models need substantial improvement. The development of better models is hampered by a lack of data on truck and commercial vehicle travel both within and beyond the metropolitan area" (*Special Report 288*).

An important overview of the state of freight modeling is provided in *NCHRP Synthesis of Highway Practice 384: Forecasting Metropolitan Commercial and Freight Travel* (Kuzmyak 2008). This synthesis identified urban freight-forecasting methods in professional practice and presented the results of a survey of organizations with active urban freight-modeling programs. The report provided supplemental case studies that highlighted more innovative freight-forecasting methods and approaches, and it also discussed promising paths for urban freight forecasting based on existing research.

NCFRP Project 25, a recent effort that examines freight trip generation and land use, includes a number of tables that summarize a review of national and international freight-generation and freight-trip-generation modeling applications (The results of this project were published in *NCHRP Report 739/NCFRP Report 19* [Holguín-Veras et al. 2012]). The review found that a number of the planning-level models have truck components, and it forecast vehicle trips at the municipal level. Some of these models potentially could be used to evaluate some smart-growth

activities. However, one major challenge is that these models are very diverse, using a wide range of data sources and with different independent variables. Any accounting for smart-growth evaluation would require processes unique to each model.

7.1.2 Trucks and the Four-Step Modeling Process

NCHRP Synthesis of Highway Practice 384 noted that almost all MPOs and urban areas that model freight are actually forecasting trucks using an adaptation of the traditional four-step process common in passenger forecasting. The four steps and the model's adaption for truck forecasting are as follows (Virginia Department of Transportation n.d.):

1. *Trip generation (the number of trips to be made)*. For trucks, this can be an estimate of production or consumption linked to economic activity as represented by zones. Truck trips from internal locations or going or coming from locations external to the study area can be factored in at this point. A number of studies have found this linkage between land use and truck trips to be weak and in need of better data (e.g., Fischer and Han 2001).
2. *Trip distribution (where those trips go)*. Truck data are often integrated into the overall model during this step by the use of a zone-to-zone trip table (origin-destination matrix) that accounts for truck travel between zones. For a truck model, the external and internal trips are added, and flows are often sorted by truck size or type. This process creates a correspondence between actual and forecast link counts. Validating this step requires truck classification counts and survey data.
3. *Mode choice (how the trips will be divided among the available modes of travel)*. The mode-choice step is not commonly used for urban freight models because most goods move on trucks without a modal change.
4. *Trip assignment (predicting the route trips will take)*. Trucks, along with passenger vehicles, are assigned by type or class to the roadway network using the shortest path or the lowest-cost travel times, often by time of day.

Reviews of these adapted four-step freight models point out some notable limitations, a number of which can be expected to reduce the models' ability to accurately account for the impacts of smart growth. One significant limitation is that the four-step process fails to account for the trip and tour (chaining) behavior of truck activity in urban areas. Passenger movement can be reasonably modeled by capturing single trips in response to a few purposes such as work, home, or shopping. Freight movement is much more complex than human travel because multiple actors create a purpose for the goods to move (brokers, warehouses, trucking, and consignees), and truckers respond to these needs, which means that they must work within the limitations of the roadway network. In response to this complexity, and in support of efficient travel, many truckers make multiple tours with multiple trips in each tour, but existing four-step models do not account for this travel behavior. In terms of smart growth, this means many truck models might not be able to capture the intricacies of drivers' responses, at the level of urban streets, to smart-growth-driven network changes. For example, this type of model may do a poor job of capturing the impact of the growth in large consolidation and distribution centers and their impact on the patterns of urban truck travel (Kuzmyak 2008; Donnelly et al. 2010).

7.1.3 Accounting for Smart Growth in Four-Step Passenger-Transportation Models

A number of studies have presented techniques to incorporate the effects of smart growth into passenger-oriented four-step travel-demand models (Purvis 2003; Cervero 2006; DKS Associates

2007; EPA 2010). These studies recognize that many MPO modeling practices “have very little sensitivity to smart-growth land use or transportation strategies” (DKS Associates, 2007, p. 3). This study specifically noted the following model limitations that could limit sensitivities to smart growth:

- Trips not related (e.g., does not recognize “trip chaining”)
- Consideration of only vehicle trips
- Limited or no transit-modeling capability
- Limited or no modeling of walking and bicycling
- Fixed vehicle trip rates by land-use type
- Development design (building, street, and sidewalk layout) not reflected in traveler choices
- Zonal aggregation of decision-maker characteristics
- Focus on travel during peak periods
- Travel analysis zones often too large
- Land use not affected by travel patterns

Beyond trip chaining, several of these limitations hamper a four-step model’s ability to account for smart growth. In particular, given the importance of parking, curb space, and other street-level issues found in the focus groups, the lack of ability of many models to account for development design is relevant. In general, the methods to adjust for these smart-growth-related limitations in passenger models can be categorized as follows:

- Post-processors that run after forecasts are completed
- Stand-alone pre-processors for aggregate application of smart-growth trips and vehicle miles of travel elasticities
- Built-in changes or enhancement of the forecasting models
- Integrated land-use, economic, and transportation models

Each of these techniques requires intervention in the modeling process. Modelers in the San Francisco Bay Area assumed that smart growth would decrease the overall average trip length of vehicle traffic and increase transit use and non-motorized travel, which would shift the mode choice to a higher non-automobile share (Purvis 2003). To account for these impacts, they adjusted the socioeconomic databases, adjusted the model’s modal networks, and modified zone-to-zone travel times, distances, and costs. This study also proposed a peer group review panel to sign off on such changes to the models.

A study by Cervero (2006) highlighted a number of examples using post-processing to account for smart-growth impacts not accounted for directly in models. He noted that a four-step model’s traffic-analysis zone (TAZ) structure is too gross to pick up many of the impacts of smart growth. He suggests the use of both post-processing and direct models. The post-processing involved “tweaks” to adjust model output for smart-growth factors such as increased transit and pedestrian travel. Direct modeling, which is an off-line, stand-alone model, can be tailored to estimate travel for specific smart-growth areas. One advantage of off-line models is that they can be compared with standard model results and used as a “first cut” to enhance or direct the four-step model output.

Similarly, the *NCHRP Report 684* (Bochner et al. 2011), which attempted to capture trip estimates for mixed-use developments, suggests an improved methodology for internal zonal trip generation from mixed-land-use neighborhoods. The modification suggested in the report would “include the effects of proximity (i.e., convenient walking distance) among interacting land uses to represent both compactness and design.” If used as an input into a model process, the new input would likely reduce local overall automobile trips.

Table 4. Potential smart-growth adjustments for four-step models.

Smart-Growth Impact	Passenger Four-Step Model Adjustment	Freight Comment
Additional local travel by non-automobile models	Smaller transportation analysis zones, non-motorized mode choice	Requires better truck origin/destination data to account for greater conflicts with trucks.
Additional bicycle and pedestrian travel	Expand model mode choice, Assign bicycles to network pedestrian and bicycle networks	Mode choice does not account for trucks. Conflicts with trucks not accounted for in models.
More use of transit	More trip purposes	Neutral outcome, possible curb-space conflicts (limited relevance in regional models because of intra-zonal nature).
Constrained parking	Incorporate pricing in model steps; change level of automobile ownership	Reduced load/unloading opportunities for trucks (limited relevance in regional models because of intra-zonal nature).
Additional linked trips related to more local travel opportunities	Activity-based and tour-based modeling	Good for truck models.

The Environmental Protection Agency (EPA) supported a 2010 effort to “accurately predict the impacts of mixed-use studies” and suggests

. . . the potential vehicle trip reductions from Mixed-Use Developments (MUDs) were significant enough to demonstrate that conventional trip-generation methods could exaggerate roadway impacts . . . (Fehr and Peers brochure, undated).

The resulting trip-generation tool accounted for more internal zonal trips, more walk and transit trips, and shorter trip lengths. This spreadsheet tool was designed to update or replace the trip-generation rate that had traditionally been used, which was derived from the Institute of Transportation Engineers manual (2001), and it reduces the number of vehicle trips.

The techniques used in passenger-oriented, four-step models to account for smart-growth impacts can be modified to account for truck travel. Table 4 highlights these adjustments.

The following summarizes techniques that could help to capture the impact of smart growth on truck mobility.

1. Access, parking, and loading zones

Parking restrictions. Typical adjustment of the four-step model would occur by changing intra-zonal travel times for trucks. Locations in which it is difficult for trucks to park could receive a “penalty” added to a terminal cost. Such improvements to a model would require information about truck dwell times at locations where it is expected that truck trips are longer due to parking constraints.

2. Road channelization, bicycle, and pedestrian facilities

Accessibility by bicycling, walking, and transit. Intra-zonal travel times could be adjusted for slower truck travel. Empirical data demonstrating slower truck travel, as well as the extent of the slower travel, would need to be obtained for all areas where it is expected that trucks travel slower than they otherwise would because of intermingling and conflicts with other modes. If available, bike and transit volumes could be factored into the modal mix.

3. Land-Use Mix

Consolidated freight facilities. Special trip-generator zones such as ports or major warehouse areas could be added to a model to reflect freight-oriented land use and consolidated warehouse areas or facilities.

4. Logistics

Time and size restrictions. The impact of time-of-day or vehicle-size restrictions on a firm's logistics decisions can be reflected in a model network structure (such as road links limited to smaller trucks) and a trip-assignment step (time-of-day travel time limitations).

5. Network System Management

Operational efficiencies on a transportation network due to better traveler information or metering can be addressed by modifying a model's networks, volume-delay functions, and other model parameters.

7.2 Alternative and Future Modeling Approaches

Alternatives to the four-step model are both already in use and being developed. These models can be placed into two broad categories—activity-based and commodity-based (*NCHRP Synthesis of Highway Practice 406* [Donnelly et al. 2010] and *NCHRP Synthesis of Highway Practice 384* [Kuzmyak 2008]). Both styles of models have been used because they are seen as an improvement over the traditional methods of forecasting freight. In a number of cases, they also may be better at representing the impacts of smart growth.

7.2.1 Activity-Based Models

A number of activity-based models have been applied or are under development in the United States (*NCHRP Synthesis of Highway Practice 406*). This family of models, also known as trip-based or tour-based models, uses a demand-based approach. Unlike the traditional four-step model that uses single trips as the basic modeling step, these models forecast flow based on travel demand derived from activities that people (or goods) need to perform. Travel is based on the activities households or individuals wish to complete during a day and is modeled in terms of tours. This is a significant modification to the four-step approach.

Activity models offer a more effective approach to modeling smart growth because they recognize that trips made by truckers are not independent of one another but rather are often connected for efficiency or convenience.

7.2.1.1 Calgary's Tour-Based Commercial-Vehicle Model

For freight modeling, a notable example is the Calgary, Ontario, Canada, tour-based commercial-vehicle model (CVM) (Kuzmyak 2007; PB Consult Inc. 2007). The model was originally developed for passenger travel, and trucks were forecast by the scaling of truck flows for counts. The CVM is a combination of three distinct models. Taken together, these three market segments are estimated to account for about 10% of the total travel in the region. The elements include the following:

- A tour-based microsimulation model of internal commercial trips that captures travel for business purposes, such as delivering goods or performing services
- A fleet-allocator model that models travel business for vehicle fleet-management purposes, such as taking vehicles off-line for repair or returning them to the business establishment at the end of the day, as well as travel by establishments that use a large, coordinated fleet that tends to service an area rather than specific demands; examples include mail and courier service, garbage hauling, newspaper delivery, utilities, and public works
- An external trip model that captures travel to and/or from outside the region, as made by medium and heavy commercial vehicles

The tours simulated by this model are derived from travel-diary surveys conducted at 3,000 businesses. The numbers of trips in tours are decided by an aggregate trip-generation module, and then each trip is completed using a random (Monte Carlo) process. This model has a stop duration module that could also be modified to account for the smart-growth impacts such as limited curb space and significant interaction with non-motorized travel modes. Tours are also given start times, which allows flexibility in responding to time-of-day restrictions.

7.2.1.2 Atlanta Regional Commission (ARC) Model

The ARC model is a trip-based model with modules that are designed to work backward from truck-count data to create a zone-to-zone matrix of trips. This approach emphasizes truck counts. The model also has specific truck zones with truck stops, warehouses, distribution centers, and so forth. The purpose of identifying truck zones was to capture the higher truck-trip-per-employee rates that are likely to occur in those areas (as noted earlier, employment-based trip generation has been shown to be ineffective for truck trips). This model is activity based on and uses dynamic traffic assignment.

7.2.2 Commodity-Based Models

Freight movement is a derived demand related to the need to move commodities, not vehicles, in our economy. Critics of traditional freight models suggest that a commodity-based (as opposed to a trip- or vehicle-based) freight model is structurally superior. One major limitation to this family of models is a notable lack of commodity flow data—there are not any fully commodity-based urban freight models currently in use (Kuzmyak 2007).



CHAPTER 8

Modeling

To gain a better understanding of the relationship between smart-growth land-use developments and freight movements, the analytical tools available at the Puget Sound Regional Council (PSRC) were used to conduct a series of model runs. The tools available at PSRC include a blend of the state-of-the-art modeling tools, as well as more traditional analytical tools that would be familiar to other MPO or local jurisdictions. The tools were chosen because others could readily replicate the analysis in order to conduct policy analysis in their own regions.

The modeling tools available at the PSRC are described in Appendix C, with specific attention paid to the tools used for the analysis discussed in this report. Currently PSRC is converting their forecasting tools from traditional four-step models to activity-based models. Trips are initially developed as tours but are treated as individual trips within the later modeling steps (destination, mode, time of day, and route choice). Commercial vehicles are defined as any vehicle used for commercial purposes and can include autos, vans, sport utility vehicles, and small trucks, as well as medium and heavy trucks. These commercial vehicles are forecast using a truck model, which includes all commercial vehicles based on relative weight classes and separates light, medium, and heavy trucks for analysis purposes.

This section begins with details regarding the specifications of the two land-use scenarios used for the analysis, as well as the three transportation-investment scenarios utilized. The section then describes the results of the modeling effort, with specific focus on the impacts of the smart-growth land-use scenario on truck miles of travel, truck hours of travel, truck delay, truck trip length and travel times, and emissions. The section concludes with comments on the implications of these results for freight modeling and planning practice.

8.1 Description of the Land-Use Scenarios

The land-use scenarios employed in this analysis represent two different policy outcomes for the year 2040, measured from a base year of 2000. As the land-use scenarios were developed to determine the impacts of population distribution resulting from two different long-range planning policies, an appropriately long time period was required to perform the analysis. The scenarios were developed as a part of the VISION 2040 planning process. VISION 2040 is a comprehensive growth-management, transportation, and economic development strategy developed for the Central Puget Sound Region, created to address the impacts of the sprawling development patterns that have emerged in the region. VISION 2040 centers around the Regional Growth Strategy, an expression of smart-growth policies, which outlines how various groupings of the region's cities and unincorporated geographies should plan for additional population and employment growth. In particular, the growth strategy emphasizes growth in Regional Growth Centers and compact urban communities within the Urban Growth Area (VISION 2040 2012).

Regional Growth Centers are a VISION concept, described as “locations characterized by compact, pedestrian-oriented development, with a mix of different office, commercial, civic, entertainment, and residential uses.”³ Centers are small geographies, generally centered around downtowns or other vibrant urban neighborhoods within cities. The State of Washington Growth Management Act requires cities and counties to designate Urban Growth Areas, which are intended to concentrate growth as a means of controlling urban sprawl, and the areas must have sufficient capacity for absorbing forecast growth. Figure 2 shows the distribution of Regional Growth Centers and the location of the Urban Growth Areas within the region.

The scenarios for modeling these strategies apportion growth into a typology of cities and county areas, called Regional Geographies, which are defined as follows:

- **Metropolitan Cities**—Metropolitan cities are central cities that serve as civic, cultural, and economic hubs in the region. They contain one or more Regional Growth Centers.
- **Core Suburban Cities**—Core cities are other major cities that have Regional Growth Centers, serve as key multimodal transportation hubs, and already contain significant population and employment. They are intended to receive a significant share of future growth.
- **Larger Suburban Cities**—Larger cities are larger inner-ring suburbs with a combined population and employment over 22,500 people and jobs. These cities contain important local and regional transit stations, ferry terminals, and other transportation connections.
- **Smaller Suburban Cities**—Smaller cities represent a wide variety of communities from historic towns to growing new suburban cities, bedroom communities with limited employment activity and growth potential, and free-standing cities and towns separated from the region’s contiguous Urban Growth Area.
- **Unincorporated Urban Growth Area**—This is land within the county’s jurisdiction within the designated Urban Growth Area. The unincorporated Urban Growth Area contains the largest amount of land area for any of the urban regional geography categories. These urban areas are quite diverse, with both lightly developed fringe areas and neighborhoods that are much more urban and nearly indistinguishable from surrounding incorporated jurisdictions. Approximately 60% of the land in the unincorporated Urban Growth Area has been affiliated with cities for future annexation. These areas, which are closely related to their adjacent city, are expected to accommodate a larger share of overall unincorporated urban growth than unaffiliated areas.
- **Rural Area**—the Regional Growth Strategy calls for limiting the levels of development in the rural portions of counties, outside of the Urban Growth Area, in order to preserve rural character and resource uses supported by rural levels of service and infrastructure.

Two distinct development scenarios were created that attributed differing levels of development to the regional geographies to compare the impacts of broad policies such as smart growth and the Regional Growth Strategy on transportation investments.

- **Current Plans Extended**—This is a “business-as-usual” scenario that extends current growth patterns, without changes, to 2040; this scenario relies on individual jurisdiction comprehensive plan targets.
- **Regional Growth Strategy**—This is an expression of regional policy, countering past trends and refocusing growth in major cities and the densest urban areas, that is, regional *smart growth*. The differing levels of development apportioned to the regional geographies for the two strategies are shown in Table 5.

The Current-Plans-Extended scenario extends land-use goals from the 2005–2025 comprehensive planning cycle to 2040. Under the Growth Management Act (GMA), all cities in the

³Puget Sound Regional Council. (2008). *VISION 2040*, p. 14.



Figure 2. Regional context map.

Table 5. Percentage of 2040 regional growth by scenario.

Scenario	Metro Cities	Core Cities	Large Cities	Small Cities	Unincorporated UGA	Rural Area
Current Plans Extended—Population	26%	17%	9%	10%	24%	13%
Current Plans Extended—Employment	45%	28%	7%	9%	8%	3%
Regional Growth Strategy—Population	32%	22%	14%	8%	18%	7%
Regional Growth Strategy—Employment	42%	29%	12%	6%	8%	2%

central Puget Sound region must create comprehensive plans, which are to be updated every 7 years. The Washington State Office of Financial Management creates forecasts of population and employment growth for this time period, and cities craft comprehensive plan policies to accommodate this growth in accordance with policies within the GMA, as well as more specific regional and county planning policies.

The Current-Plans-Extended scenario assumes that growth will continue in a fashion observed in the previous comprehensive planning cycle, before a true smart-growth policy scheme had been implemented. This planning cycle was guided by the previous version of VISION 2040 (VISION 2020), which expressed similar concepts of focusing growth into the Urban Growth Areas and Regional Growth Centers, but without as strong an architecture for distributing growth. Cities and counties would continue to encourage growth in urban centers around the region but also in unincorporated and rural areas, and to a wider degree than under the Regional Growth Strategy. Many of the region's new jobs would locate in the largest cities, while medium-sized communities would also become larger employment centers. Many new apartments, condominiums, and townhouses would be built in downtown areas near job centers, and extensive residential growth would continue in the region's unincorporated urban and rural areas. The distribution of population and employment for the Current-Plans-Extended scenario are shown Figure 3.

The second scenario depicts the Regional Growth Strategy and represents an expression of smart-growth policies under which regional employment and housing growth are focused in cities that contain regionally designated growth centers. These regional centers are to be connected and served by a variety of transportation modes, including fast and frequent high-capacity transit service. Regional centers are intended to attract residents and businesses because of their proximity to services, jobs, well-designed housing, regional amenities, high-quality transit service, and other advantages. Locally designated town centers serve similar roles for smaller cities, but on a smaller scale than observed in the previous planning cycle (see Table 5).

The Regional Growth Strategy also stresses preserving existing manufacturing and industrial centers. These are locations for intensive manufacturing, industrial, and related uses. Stressing employment growth in manufacturing and industrial centers, along with more active Regional Growth Centers and city centers, can help the region achieve a better jobs-housing balance, allowing people to live closer to their jobs, minimizing long commutes, lowering costs for extending new infrastructure, and limiting the effects of unbridled development on natural resources and rural lands. The distribution of population and employment are shown in Figure 4.

8.1.1 How the Scenarios Were Constructed

8.1.1.1 Current-Plans-Extended Scenario

The distribution of the Current-Plans-Extended growth scenario was created by calculating the share that each city or unincorporated area had of the 2025 regional target total, 2025 being

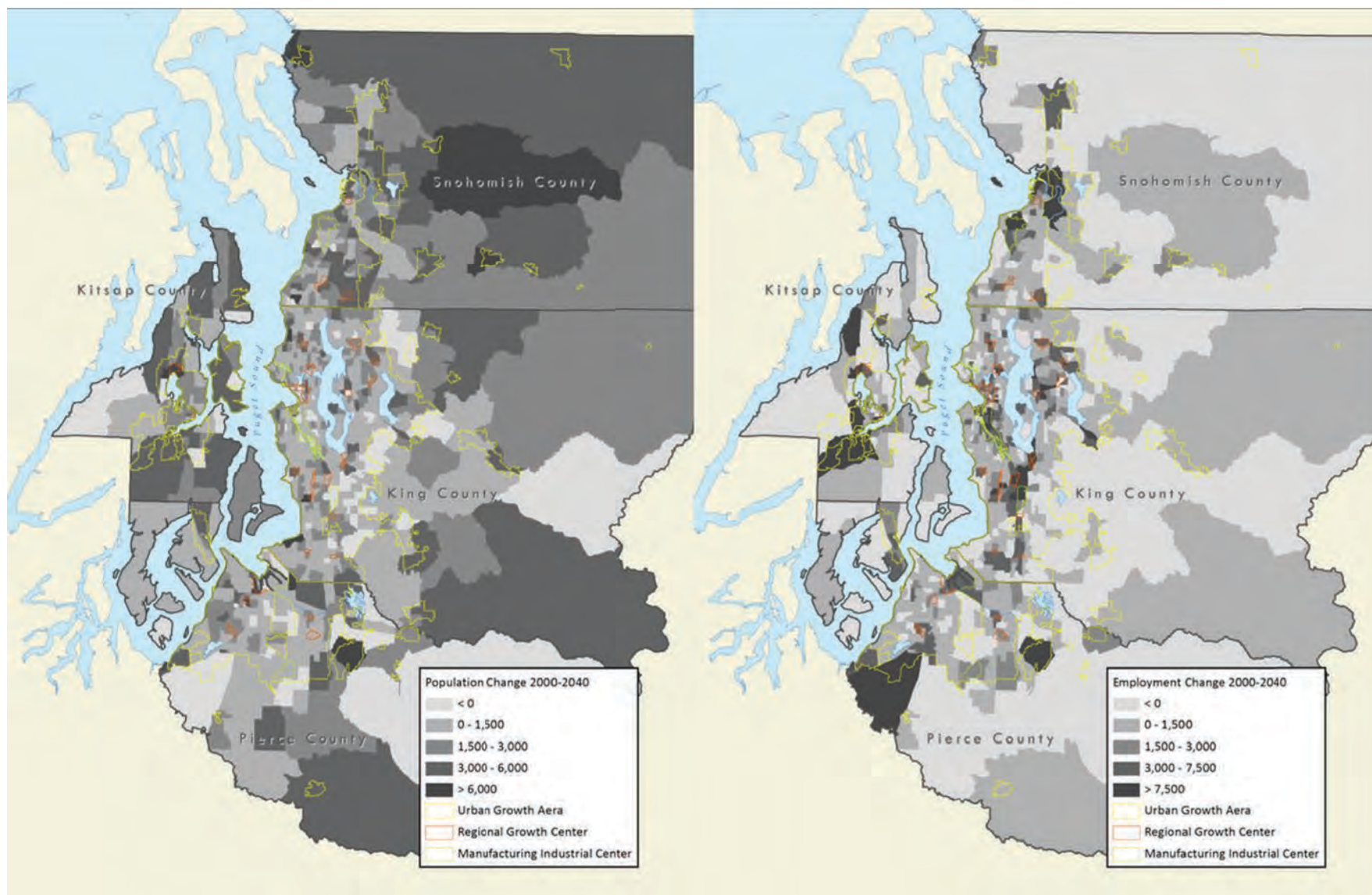


Figure 3. Scenario one—Current Plans Extended.

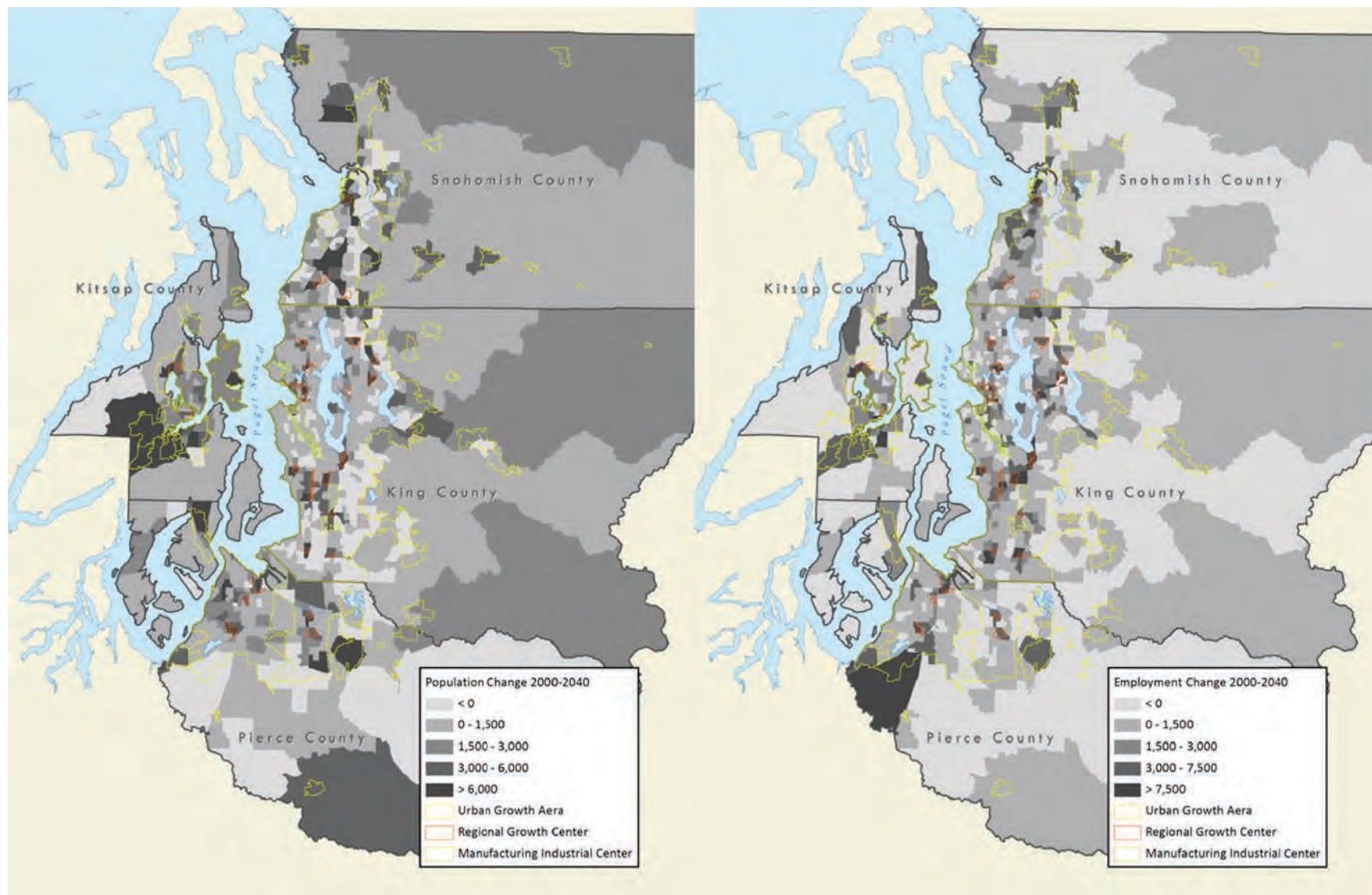


Figure 4. Scenario two—Regional Growth Strategy.



Figure 5. *Process for creating the Current-Plans-Extended scenario.*

the target horizon for the current planning cycle at the time of scenario creation. The assumption was that the share that a city or unincorporated area held in 2025 would remain fairly constant for the next 15 years, up to 2040. Growth was not allocated using each city or unincorporated area's growth rate between 2000 and 2025 because of the severe recession that had occurred in the early 2000s. Separate methods were used to create the population and employment inputs. The general process for determining the land-use distributions is pictured in Figure 5.

8.1.1.1.1 Population. Step 1: Adjust base-year population. Three out of the four counties used 2000 as the base year for setting their targets; only Snohomish County used 2002. To remain consistent among the counties, Snohomish's 2002 base year had to be adjusted to 2000. The most viable option was to use Census 2000 population figures as a substitute for Snohomish County's base.

Step 2: Standardize population targets. Kitsap and Snohomish counties had targets set to 2025, while King and Pierce counties had targets out to 2022. The targets had to be adjusted so that each county's numbers represented the year 2025. King and Pierce's targets were straight-lined out from 2022 to 2025. To do this, first the change between the 2000 base and the 2022 targets was calculated (2022 target minus 2000 base). The change between 2000 and 2022 was then divided by the number of years from the base (22) to get the actual population growth per year, which was then multiplied by the number of years needed to get from 2022 to 2025 (i.e., 3). This number was then added to the original 2022 target to create the 2025 proxy target.

Step 3: Determine city or unincorporated areas' share of regional target total. Once all the target years were set to 2025, the regional target total was calculated by adding up the targets from the four counties. The share that each city or unincorporated area held of the regional target was then calculated by dividing the city or unincorporated areas' targets by the regional population target total. For example, the regional target total for 2025 is 4,282,899, and Everett's 2025 population target is 123,060, giving Everett roughly a 2.9% share of the regional population total ($123,060/4,282,899$). See Table 6 for regional percentage shares.

Step 4: Distribute regional forecast change from 2025 to 2040. Using the calculated population share for each city or unincorporated area, the change between the 2025 regional population target total and the 2040 regional forecasted population total (705,101) was distributed. Using Everett again as an example, the 2.9% share that Everett held gave it approximately 20,260 of the regional population change. Adding this to Everett's 2025 target (123,060) gives the city a 2040 population total of 143,320. See Table 6 for 2040 population totals.

8.1.1.1.2 Employment. Step 1: Standardize base-year employment. Only two of the four counties, King and Snohomish, had set employment targets. Kitsap and Pierce did not have 2000 base-year employment numbers. To create a standardized base year, the 2000 employment data were used as the base for all four counties.

Step 2: Create proxy targets for Kitsap and Pierce Counties. To create proxy employment targets for Kitsap and Pierce, a straight-line method was used to produce a 2020 target. The 1995–2004 average annual change for employment was calculated. Because of significant fluctuations in the economy during those years, the city or unincorporated areas' shares of the county total from the

Table 6. Current Plans Extended population totals and shares.

Jurisdiction	% of Regional	2040 Population	% of Regional	2040 Employment		Jurisdiction	% of Regional Pop. Target	2040 Population	% of Regional	2040 Employment
KING COUNTY	48.90%	2,440,420	66.60%	2,045,207		PIERCE COUNTY	22.00%	1,096,635	15.10%	463,637
Unincorporated	9.10%	455,639	2.40%	73,479		Unincorporated	9.30%	465,994	3.40%	105,634
Uninc Rural	3.50%	173,001	0.80%	23,370		Uninc Rural	3.80%	188,075	0.80%	25,861
Uninc UGA	5.70%	282,638	1.60%	50,109		Uninc UGA	5.60%	277,919	2.60%	79,773
Incorporated	39.80%	1,984,782	64.20%	1,971,728		Incorporated	12.60%	630,641	11.70%	358,002
Algona	0.10%	3,831	0.10%	2,816		Auburn (Prc)	0.20%	10,497	0.00%	627
Auburn (Kin)	1.30%	64,103	2.10%	63,522		Bonney Lake	0.50%	23,194	0.20%	6,516
Beaux Arts	0.00%	358	0.00%	25		Buckley	0.10%	6,224	0.10%	4,502
Bellevue	3.08%	153,675	7.40%	226,399		Carbonado	0.00%	1,000	0.00%	119
Black Diamond	0.20%	8,223	0.10%	3,938		Du Pont	0.20%	11,654	0.20%	7,223
Bothell (Kin)	0.50%	23,786	0.60%	17,556		Eatonville	0.10%	3,360	0.10%	1,546
Burien	0.80%	40,372	0.60%	19,822		Edgewood	0.30%	16,688	0.10%	2,957
Carnation	0.10%	3,180	0.00%	1,136		Fife	0.20%	11,019	0.70%	20,952
Clyde Hill	0.10%	3,366	0.00%	613		Fircrest	0.20%	8,068	0.10%	2,170
Covington	0.40%	20,803	0.20%	4,751		Gig Harbor	0.30%	13,265	0.50%	14,301
Des Moines	0.80%	38,320	0.30%	10,684		Lakewood	1.70%	86,043	1.40%	42,036
Duvall	0.20%	9,112	0.10%	2,801		Milton (Prc)	0.20%	8,473	0.10%	3,624
Enumclaw	0.40%	19,501	0.30%	7,872		Orting	0.20%	9,858	0.10%	2,319
Federal Way	2.30%	113,668	1.70%	52,153		Pacific (Prc)	0.00%	0	0.10%	4,283
Hunts Point	0.00%	516	0.00%	51		Puyallup	0.90%	45,842	1.30%	38,890
Issaquah	0.50%	24,267	1.30%	39,539		Roy	0.00%	1,211	0.00%	392
Kenmore	0.60%	28,436	0.30%	10,040		Ruston	0.00%	2,212	0.00%	446
Kent	2.10%	103,032	3.30%	101,785		South Prairie	0.00%	1,038	0.00%	274
Kirkland	1.30%	65,626	2.20%	67,727		Steilacoom	0.20%	8,171	0.10%	2,848
Lake Forest Park	0.30%	16,642	0.10%	2,548		Sumner	0.30%	14,862	0.50%	16,254
Maple Valley	0.30%	16,972	0.20%	5,022		Tacoma	6.20%	307,056	5.70%	175,983
Medina	0.10%	3,507	0.00%	516		University Place	0.80%	40,243	0.30%	9,649
Mercer Island	0.60%	29,581	0.30%	10,712		Wilkeson	0.00%	665	0.00%	91
Milton (Kin)	0.00%	1,054	0.00%	1,390		SNOHOMISH	21.30%	1,064,763	13.50%	416,261
Newcastle	0.20%	11,472	0.10%	2,131		Unincorporated	11.60%	578,503	2.90%	88,076
Normandy Park	0.10%	7,444	0.00%	910		Uninc Rural	4.40%	218,410	0.70%	20,923
North Bend	0.20%	10,200	0.20%	4,777		Uninc UGA	7.20%	360,093	2.20%	67,153

(continued on next page)

Table 6. (Continued).

Jurisdiction	% of Regional	2040 Population	% of Regional	2040 Employment		Jurisdiction	% of Regional Pop. Target	2040 Population	% of Regional	2040 Employment
Pacific (Kin)	0.20%	8,706	0.00%	1,422		Incorporated	9.70%	486,261	10.70%	328,185
Redmond	1.60%	77,984	4.10%	126,538		Arlington	0.40%	20,218	0.60%	17,480
Renton	1.50%	74,081	3.80%	115,970		Bothell (Sno)	0.50%	25,622	0.60%	19,291
Sammamish	1.10%	53,046	0.30%	8,497		Brier	0.20%	9,072	0.00%	537
SeaTac	0.90%	43,484	1.90%	57,280		Darrington	0.00%	2,224	0.00%	560
Seattle	15.70%	783,068	28.00%	859,022		Edmonds	1.00%	52,269	0.50%	15,505
Shoreline	1.40%	68,345	0.80%	24,838		Everett	2.90%	143,320	5.10%	158,109
Skykomish	0.00%	289	0.00%	153		Gold Bar	0.10%	3,374	0.00%	260
Snoqualmie	0.20%	8,042	0.10%	4,403		Granite Falls	0.10%	5,555	0.10%	2,416
Tukwila	0.60%	28,943	2.90%	90,207		Index	0.00%	221	0.00%	86
Woodinville	0.30%	16,531	0.70%	22,093		Lake Stevens	0.20%	9,736	0.10%	2,157
Yarrow Point	0.00%	1,214	0.00%	71		Lynnwood	0.90%	44,850	1.30%	39,337
KITSAP COUNTY	7.70%	386,181	4.80%	147,096		Marysville	0.90%	46,259	0.50%	15,122
Unincorporated	4.80%	239,604	1.70%	53,204		Mill Creek	0.40%	18,738	0.20%	5,507
Uninc Rural	2.90%	142,478	1.10%	34,905		Monroe	0.50%	23,922	0.50%	14,283
Uninc UGA	1.90%	97,127	0.60%	18,299		Mountlake	0.50%	26,153	0.30%	10,309
Incorporated	2.90%	146,577	3.10%	93,892		Mukilteo	0.50%	25,622	0.40%	11,699
Bainbridge Island	0.70%	33,378	0.40%	12,005		Snohomish	0.20%	11,624	0.20%	6,228
Bremerton	1.20%	60,581	1.60%	48,941		Stanwood	0.10%	6,580	0.20%	5,702
Port Orchard	0.30%	13,152	0.30%	8,174		Sultan	0.20%	9,538	0.10%	3,484
Poulsbo	0.20%	12,289	0.30%	9,345		Woodway	0.00%	1,363	0.00%	113
Silverdale	0.50%	27,177	0.50%	15,426						

2004 employment data were also calculated. This percentage was then averaged with the average annual change between 1995 and 2004 to lessen the significant swings in the economy. The 2020 small-area forecast totals for each county were then distributed by the calculated change. For example, between 1995 and 2004, Bremerton's average annual change in employment was 30.3%. In 2004, the city accounted for 36.2% of Kitsap County's total employment. Averaging these two percentages together gives a percentage growth of 33.3. Kitsap County's year 2020 small-area forecast is 116,865, and Bremerton's share is 33.3% (33.27154%) of that, or 38,883.

Step 3: Roll back King and Snohomish Counties' targets to 2020. To achieve consistent employment targets, King and Snohomish County targets were rolled back to 2020 and based on the small-area forecasts, as were Kitsap and Pierce Counties'. To achieve this, the annual change of each county's targets was calculated, and this change was then multiplied by the number of years the target needed to be rolled back (King, 2 years; Snohomish, 5 years) to determine the amount of employment to be subtracted from the target. Once the employment was subtracted, the 2020 targets had to be controlled to the county small-area forecast totals. The percentage share of the city or unincorporated area of the county's total 2020 target was calculated. For example, the city of Everett had a 38% share of the county's total employment. (Everett = 120,495; Snohomish County = 317,233). The 2020 county small-area forecast total was then allocated based on these percentage shares.

Step 4: Determine city or unincorporated areas' shares of regional target total. Once all the target years were set to 2020, the regional target total was calculated by adding up the targets from the four counties. The share that each city or unincorporated area held of the regional target was then calculated by dividing the city or unincorporated areas' targets by the regional employment target total. For example, the regional target total for 2020 is 2,278,603, and Everett's 2020 employment target is 117,267, giving Everett roughly a 5.1% share of the regional employment total ($117,267/2,278,603$). See Table 6 for regional percentage shares.

Step 5: Distribute regional forecast change from 2020 to 2040. Using the calculated employment share for each city or unincorporated area, the change between the 2020 regional employment target total and the 2040 regional forecasted employment total (793,597) was distributed. Using Everett again as an example, the 5.1% share that Everett held gave it approximately 40,842 of the regional employment change. Adding this to Everett's 2020 target (117,267) gives the city a 2040 employment total of 158,109. See Table 6 for 2040 employment totals.

8.1.1.2 Regional Growth Strategy

Distributions of population and employment in the Regional Growth Strategy alternative were originally created using the sketch planning tool Index. The region was divided into 150-square-meter grid cells, to which users then ascribed one of 26 defined land uses, each of which carried specific population and employment values. Land uses were applied to demonstrate a particular distribution of population and employment to the region's cities and counties in the year 2040. Once the land-use inputs were distributed to the grid cells, these data were aggregated into Transportation Analysis Zones (TAZs) and Forecast Analysis Zones (FAZs) to be used as inputs to the region's Transportation Demand and Air Quality models. In addition, characteristic data required by the travel model on group quarters, income quartiles, and employment sectors were also added.

The following procedure was used to develop the detailed data inputs from the Index base data.

- *Convert the Index base geography from grid cells and cities to FAZs.* PSRC's Small-Area Forecast model is zone based and structurally limited to the 219 zones that the Puget Sound Region is currently divided into. The first step, then, was to sum the Index 2000 base-year data and the 2040 future-year data for each scenario for each of the 219 FAZs.
- *Expand the Index 2000 base-year data into the detailed data variables.* The original year 2000 data used for Index contained characteristic data on employment sector, household size, and

income required to run the model, and the characteristic data were translated to percentage shares. For example, in year 2000, the percentage of the jobs in each FAZ that were Retail, Manufacturing, and so forth, were estimated.

- *Apply the growth projected in the 2003 Small-Area Forecasts to each of the characteristic data variables.* The PSRC Small-Area Forecasts from 2003 include 2000 and 2030 forecasts by FAZ for each of the characteristic data variables. Using these endpoints, the percentage share that each characteristic variable represented of the overall base-data category was determined, extrapolated to the year 2040, and applied to the year 2040 Index base category total for that FAZ. For example, if the Small-Area Forecasts showed the percentage of Low-Income-Quartile households in FAZ 110 dropping from 25% to 18%, that reduction in “share size” was then applied to the Index data in 2040 to arrive at a preliminary estimate.
- *Balance the preliminary estimates with the regional forecasts for 2040.* PSRC’s forecast process is top-down, with the regional demographic and economic forecasts determined first and then allocated to a sub-regional geography. To control based on these forecasts, a factoring process adjusted the Index-based 2040 FAZ-level detailed data so that each Index scenario, as modeled, would match the regional forecasts as well.

8.2 Travel Network Scenarios

Three discrete transportation networks were modeled to accompany the two land-use scenarios. The transportation networks were intended to capture a status quo scenario, one that favors smart-growth investments, and one that favors traditional roadway investments.

The initial intent of the modeling exercise was to determine the impacts of land use on freight transportation. However, because smart-growth principles include transportation efficiency and land-use design, a transportation scenario reflecting a smart-growth orientation was included to model the interaction between land use and transportation. Finally, for the sake of completeness, a highway-heavy transportation-investment scenario was also evaluated.

The transportation networks were developed originally for *Transportation 2040*, the Puget Sound region’s long-range transportation plan adopted in 2010, and they were vetted as part of that process. The baseline scenario reflected existing conditions in the region and was chosen as the status quo alternative. Alternative Two of the original scenario analysis used for plan development was employed to characterize the roadway-heavy investment scenario type. The final, adopted, preferred alternative from the planning work was chosen as the smart-growth scenario because of its reliance on tolling and transit investments. These three scenarios are described in greater detail below.⁴

8.2.1 Baseline Alternative (Status Quo)

The baseline transportation network consists of the existing transportation systems and a limited series of future investments. This alternative is meant to illustrate what would most likely occur with the transportation system assuming there were no interventions. It is a useful starting point for comparison with the other transportation alternatives and is also a constant that allows for comparisons across different land-use policies (e.g., status quo vs. smart growth).

The baseline Alternative is funded almost completely with “current law” traditional revenue sources—gas tax, sales tax, state and federal grants and loans, local general fund revenues, permit and licensing fees, and limited tolling (on the Tacoma Narrows Bridge and the auto ferry

⁴ A complete discussion of the alternatives developed through the Transportation 2040 planning process and the specific facilities and investments included in each alternative may be found in Appendix A of the Final Environmental Impact Statement of the plan: http://psrc.org/assets/3694/Appendix_A_-_Transportation_2040_Alternatives_Report.pdf.

system). The baseline Alternative would build state highway projects funded under the state's "nickel" gas tax and Transportation Partnership Account (TPA) programs, plus Sound Transit's Phase 2 plan (ST2), approved by voters in November 2008. It would sustain existing ferry service and demand-management programs and make modest additions to transit service, including King County Metro's Rapid Ride and Community Transit's Swift bus rapid transit (BRT) system. Beyond "current law" funding, the baseline Alternative assumes that the region would find sufficient additional revenue to fully maintain and preserve the existing transportation system.

8.2.2 Alternative Two (Roadway Investments)

Of all the plan alternatives, Alternative Two adds the most roadway capacity through lane additions to existing highways, the creation of several new highways (SR 167 Extension, SR 509 Extension, and the Cross-Base Highway), and additional lanes on the regional arterial network. It adds considerable light rail capacity and a new auto ferry route across Puget Sound. It adds pedestrian and bicycle infrastructure in key locations. Its demand-management, bus service, and system-management investments are similar to the baseline Alternative. Its most significant management strategy is the establishment of a two-lane High Occupancy Toll (HOT) system on much of the regional freeway network (with some one-lane HOT facilities) to manage congestion and provide revenue to supplement traditional funding sources. Traditional funding sources would provide the majority of the financing.

8.2.3 Preferred Alternative (Smart Growth)

The Preferred Alternative is designed to improve the region's transportation system through a combination of investments in system efficiency; strategic expansion; transit, ferry, bike, and pedestrian improvements; and investments to preserve the existing transportation system. The Preferred Alternative financial strategy is based on a phased approach of transitioning away from current gas taxes toward the implementation of new user fees. The Preferred Alternative includes the following:

- More transit service than all other alternatives
- More miles of biking and walking facilities focused on access to transit stations and centers and completion of regional trail links than all other alternatives
- Current levels of vehicle ferry service and additional passenger ferries
- Replacement of several vulnerable roadways, including the Alaskan Way Viaduct and the SR 520 Floating Bridge
- Completion of missing links in the highway network such as SR 509, SR 167, and the Cross-Base Highway
- Expansion of local arterials and state highways in limited but strategic ways to service growth in Urban Growth Centers

8.3 Modeling Results

Six model runs were conducted to provide better understanding of the relationship between smart-growth land use, transportation system investments, and truck travel. The major findings, which are described in further detail throughout the remainder of the section include the following:

- Truck miles of travel are consistently lower under the smart-growth land-use scenario than under the alternative (status quo), regardless of time of day, roadway facility type, truck type, or transportation network investments.
- Truck hours of travel are consistently lower under the smart-growth land-use scenario than under the alternative, regardless of time of day, roadway facility type, truck type, or

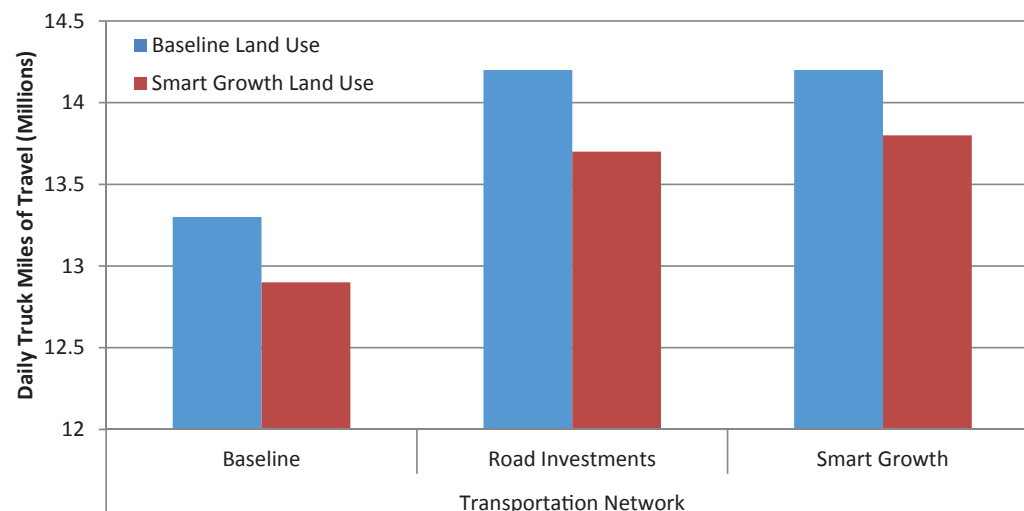


Figure 6. Daily truck miles of travel.

transportation-network investments. The lowest daily truck hours of travel appear in the scenario that combines the smart-growth land use with the smart-growth transportation investments (transit and non-motorized).

- Truck delay is seen to be somewhat higher in the smart-growth land-use scenario, but improvements to the transportation network have a pronounced impact in terms of delay reductions, with the smart-growth improvements performing better than the roadway investments.
- Truck trip lengths remain relatively flat across origin and destination pairs involving the movement of goods. However, when the destination involves a concentrated smart-growth area, truck trip lengths are longer under the smart-growth land-use scenario.
- Truck travel times remain relatively flat across origin and destination pairs involving the movement of goods. However, when the destination involves a concentrated smart-growth area, truck travel times are longer under the smart-growth land-use scenario.
- Pollution emission levels, particularly for carbon dioxide, are consistently lower in the smart-growth land-use scenario as compared with the baseline land-use scenario. Emission levels are at the lowest point when the smart-growth land-use scenario is coupled with smart-growth transportation investments.

8.3.1 Truck Miles of Travel

Across all three transportation networks, the smart-growth land-use patterns produce lower daily truck miles of travel (see Figure 6). This trend is also consistent across individual time periods, not just across an entire day (see Table 7).

Table 7. Daily truck miles of travel (millions) by time period.

Transportation	Baseline		Roadway Investments		Smart Growth	
	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
a.m.	2.7	2.6	2.9	2.8	2.9	2.8
Midday	5.6	5.4	5.9	5.7	5.9	5.8
p.m.	2.7	2.6	2.9	2.8	2.9	2.9
Evening	1.3	1.2	1.3	1.3	1.3	1.3
Night	1.0	1.0	1.1	1.0	1.1	1.0

Table 8. Daily truck miles of travel (thousands) by facility type.

Transportation	Baseline		Roadway Investments		Smart Growth	
Land Use	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Freeway	9,272	8,908	10,567	10,228	10,672	10,404
Arterial	3,066	3,019	2,608	2,534	2,550	2,462
Connector	974	934	976	936	976	936
Total	13,312	12,861	14,150	13,698	14,199	13,802

Notably, truck miles of travel are higher in the altered transportation networks (roadway and smart-growth investments) as compared with the baseline transportation network. These results may appear counterintuitive and presumably are due to the improvements to the overall transportation network leading to a rise in demand for travel. Both altered transportation networks see a marked increase in home-based work trip generation and distribution. The availability of improved roadway facilities stimulates the use of those facilities, and improved transit and non-motorized transportation facilities reduce passenger vehicle miles of travel.

If a policy goal were to reduce truck miles of travel, the conclusion should not be drawn that investment in transportation improvements increases truck travel. In all three scenarios, truck miles of travel are lower under the smart-growth land-use scenario as compared with the alternative.

In addition to the time of day, truck miles of travel are consistently lower across transportation facility type for the smart-growth land-use scenario than the alternative (see Table 8).

Although the truck miles of travel are consistently lower under the smart-growth land-use scenario as compared with the alternative, freeway travel increases and arterial travel decreases under the two improved transportation networks. For the investments in roadway facilities, the improved freeway facilities provide more favorable, less congested, and faster routes than were previously available. The smart-growth transportation investments stimulate a mode shift away from SOVs and again open up capacity on the freeways. However, truck travel on the connector facilities (smaller local roads) remains unchanged across all of the transportation investments. This is most likely because (1) truck origins and destinations are fixed and must use local facilities to arrive at the arterial and freeway facilities, and (2) certain types of trucking activities (e.g., package delivery, waste management) must travel on all roads for their freight-hauling purposes, creating an inelastic demand for use of those facilities.

The same trends in truck miles of travel by time of day and facility type are also seen across different types of trucks, not just the aggregate daily total (see Table 9). For each truck type (light, medium, or heavy) overall miles of travel are uniformly lower under the smart-growth land-use scenario than under the alternative, and this is also the case by time of day and facility

Table 9. Daily truck miles of travel (thousands) by truck type.

Transportation	Baseline		Roadway Investments		Smart Growth	
Land Use	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Light	3,090	2,931	3,656	3,509	3,685	3,587
Medium	4,950	4,772	5,099	4,904	5,140	4,949
Heavy	5,272	5,158	5,395	5,284	5,373	5,267

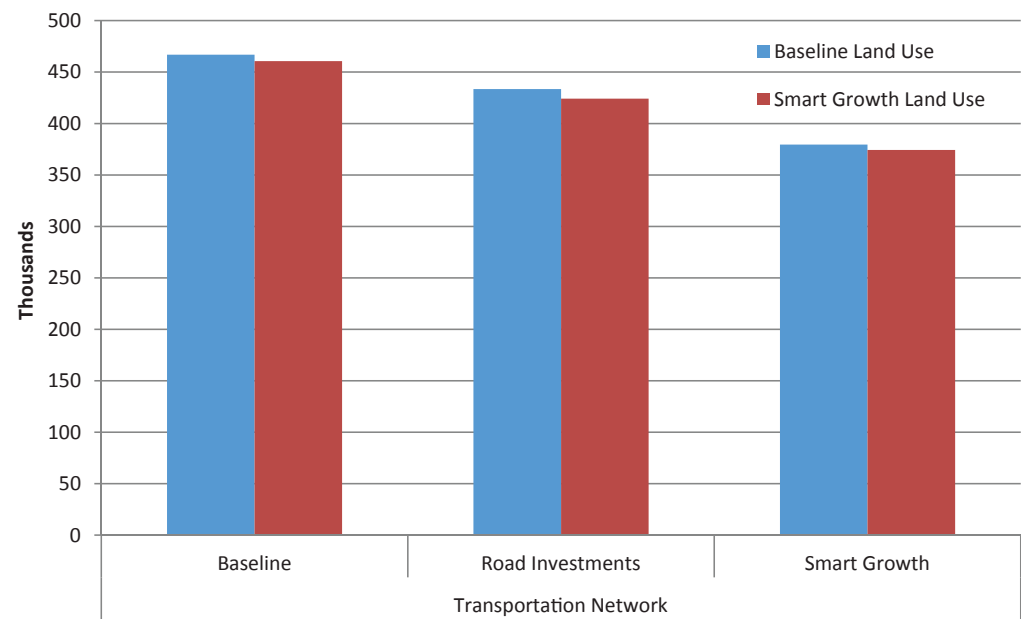


Figure 7. Daily truck hours of travel.

type. Transportation investment (roadway or smart growth) shifts more of each truck type to freeways and away from arterials, while each truck type’s miles of travel remains constant on collector facilities.

8.3.2 Truck Hours of Travel

Similar to truck miles of travel, total daily truck hours of travel are consistently lower (although only by a small amount) in the smart-growth land-use scenario than the alternative (see Figure 7). However, unlike truck miles of travel, investments in the transportation system considerably reduce overall truck hours of travel. This result is likely due to improved capacity of the transportation facilities, especially due to shifts away from non-single-occupancy travel for passenger modes because the smart-growth investments (transit and non-motorized) have a much more pronounced effect than the roadway-capacity improvements.

For the most part, the same results seen for total daily hours of truck travel can be seen across the various time periods—the smart-growth land-use scenario performs better than the

Table 10. Daily truck hours of travel by time period.

Transportation	Baseline		Roadway Investments		Smart Growth	
Land Use	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
a.m.	98,174	96,500	88,400	86,311	77,847	76,821
Midday	187,734	195,332	177,634	170,024	154,844	150,975
p.m.	113,721	105,466	102,819	103,555	85,604	86,094
Evening	37,768	35,273	36,830	35,759	34,513	33,927
Night	29,490	28,112	27,813	28,479	26,690	26,449

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

Table 11. Daily truck hours of travel by facility type.

Transportation	Baseline		Roadway Investments		Smart Growth	
Land Use	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Freeway	270,881	267,273	260,905	254,958	211,676	210,489
Arterial	146,579	146,622	123,049	122,279	118,238	116,849
Connector	49,427	46,789	49,543	46,890	49,586	46,928
Total	466,887	460,683	433,496	424,128	379,499	374,265

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

alternative (see Table 10). However, there are several exceptions (shown in bold) in which the smart-growth land-use scenario has a slight increase in truck hours of travel over the status quo scenario. The difference in hours of travel between the land-use scenarios is relatively small across the time period, but significant reductions are achieved by the transportation investments, particularly the smart-growth ones (transit and non-motorized) over roadway investments and no transportation investments. In terms of truck performance, the fewest truck hours of travel are seen under the smart-growth land-use scenario with commensurate smart-growth investments in the transportation system.

Truck hours of travel on different transportation facilities are also consistently lower under the smart-growth land-use scenario as compared with the alternative (see Table 11). Unlike miles of travel, the decrease in hours of travel is uniform across facilities and investments. Under the roadway and smart-growth transportation investments, both freeway and arterial hours of travel are reduced. And again, the biggest impact in terms of reduction of truck hours of travel is present under a smart-growth land-use scenario paired with transit and non-motorized transportation investments. Similar to truck miles of travel, hours of travel on collector streets are unchanged across transportation scenarios, reflecting the inelastic demand for those facilities.

Truck hours of travel for individual truck classes show similar results (see Table 12). The smart-growth land-use scenario generally provides a reduction in truck hours of travel from the level of the baseline land-use scenario. In addition, the smart-growth land-use scenario coupled with investments in transit and non-motorized transportation improvements leads to the largest potential reductions in overall truck hours of travel for all three classes of trucks as compared with the other potential alternatives.

Table 12. Truck hours of travel by truck type.

Transportation	Baseline		Roadway Investments		Smart Growth	
Land Use	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Light	124,244	120,097	124,155	121,741	114,102	112,911
Medium	178,786	176,064	160,643	156,145	137,224	134,091
Heavy	163,858	164,523	148,698	146,242	128,173	127,263

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

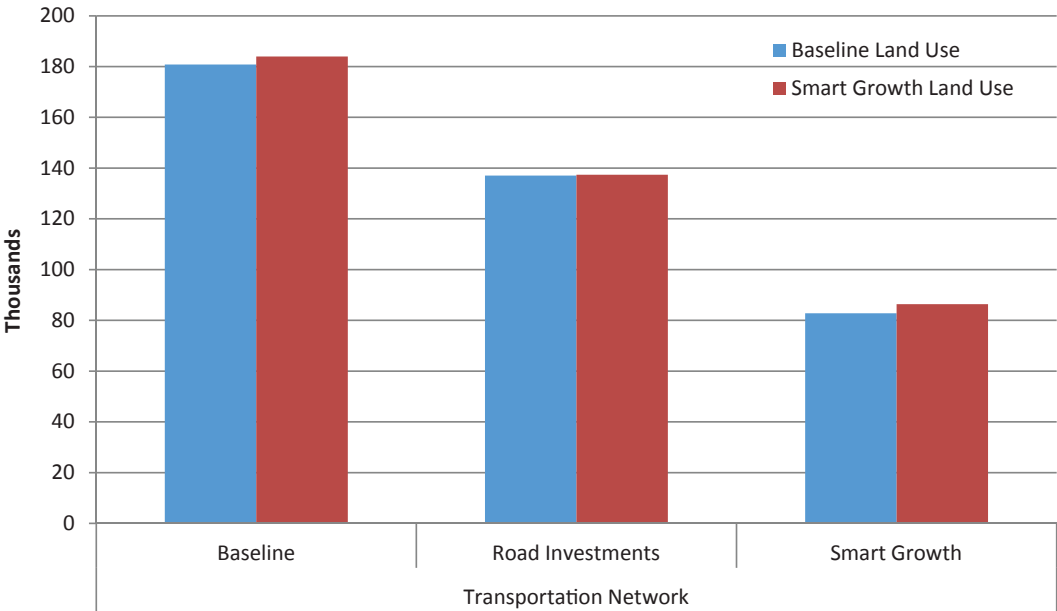


Figure 8. Total daily truck delay (hours).

8.3.3 Truck Delay

Overall daily delay for trucks is slightly higher for the smart-growth land-use scenario than under the baseline scenario (see Figure 8). Across all three sets of transportation systems (baseline, road, and smart-growth transportation investments) the delay under the smart-growth land-use scenario is roughly one half of 1% higher than the baseline land use. Given the magnitude of overall system delay, the results in delay between the two land-use scenarios is essentially indistinguishable. However, investment in the transportation system has a striking effect on delay, with the roadway investments reducing daily delay by 24% over the baseline, and transit and non-motorized investments reducing delay by 54% over the baseline transportation scenario. These results are repeated for the freeway and arterial facilities, in addition to the overall network.

The performance of the smart-growth (i.e., the Preferred) land-use scenario as compared with the baseline scenario in terms of delay has a fair amount of variance across time periods and transportation investments (see Table 13). There does not appear to be a distinguishable pattern across the transportation-investment scenarios in which specific time periods have more delay

Table 13. Daily delay by time period.

Transportation	Baseline		Roadway Investments		Smart Growth	
	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
a.m.	39,604	39,732	27,995	27,911	17,172	17,962
Midday	69,320	80,369	54,972	51,458	32,162	31,962
p.m.	53,522	47,496	40,620	43,252	23,243	25,551
Evening	10,677	9,255	8,450	8,370	6,136	6,418
Night	7,702	7,133	5,048	6,399	4,056	4,478

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

Table 14. Daily delay by truck type.

Transportation Land Use	Baseline		Roadway Investments		Smart Growth	
	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Light	45,844	45,277	37,468	38,363	27,201	28,567
Medium	73,818	74,714	54,593	54,178	30,928	31,828
Heavy	61,163	63,994	45,023	44,850	24,639	25,975

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

in one land-use scenario over the other. However, for the smart-growth transportation investments (transit and non-motorized), the smart-growth land-use scenario seems to have slightly more delay than the baseline scenario in most time periods despite the small overall impact.

The exception to the delay results is seen when examining delay by truck type (see Table 14). Medium and heavy trucks perform slightly better under the smart-growth land-use scenario compared with the baseline scenario in the context of the roadway-investment transportation scenario. This result follows the logic that an investment in freeway facilities will improve conditions for all users of the transportation system, including freight users.

8.3.4 Truck Trip Lengths

To understand the impact of the modeled land-use and transportation scenarios on truck trip length, the transportation analysis zones used in the analysis were separated into four categories as follows:

1. Smart-growth zones have high densities and are balanced in terms of jobs and housing.
2. Goods-dependent zones have a high concentration of freight-related employment (warehousing, communication, transportation, utilities).
3. The most concentrated goods-dependent zones have the highest concentration of freight-related employment.
4. All other zones were parts of the region that had neither significant freight-related employment nor other concentrations of activities.

The typology of analysis zones allowed consideration of the truck trip length by types of trips. For example, manufacturing trips or drayage trips likely would occur between two sets of goods-dependent locations. For trips originating and terminating within the region's most concentrated freight-related analysis zones, average trip lengths remained almost constant across the two land-use scenarios and the three different transportation-investment scenarios (see Table 15).

In contrast, trips originating in the region's most concentrated centers of freight activity and terminating in the smart-growth locations (downtown cores, urban villages, etc.), uniformly have longer distances under the smart-growth land-use scenario as compared with the baseline in all three of the transportation-investment scenarios (see Table 16). The preceding discussion of truck miles of travel showed that the smart-growth scenario consistently demonstrated fewer overall miles. This further examination of trip origin and destination highlights the results that, although overall trip length and truck miles of travel are reduced under the smart-growth land-use scenario, specific trips (which are likely to be deliveries to urban cores) would have longer trip distances under this type of land-use configuration. Indeed, trips between the most concentrated areas and the less-goods-dependent areas, as well as those analysis zones that are

Table 15. Average freight-related truck trip lengths.

Transportation Investment			Baseline		Roadway		Smart Growth	
From	To	Time	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Most Concentrated	Most Concentrated	M	23.6	23.5	23.7	23.7	23.8	24.0
Most Concentrated	Most Concentrated	MD	23.6	23.6	23.7	23.7	23.7	23.8
Most Concentrated	Most Concentrated	PM	23.7	23.5	23.8	23.7	24.1	24.2
Most Concentrated	Most Concentrated	EV	23.7	23.7	23.9	23.9	23.4	23.4
Most Concentrated	Most Concentrated	NT	23.6	23.7	23.9	23.7	23.6	23.6

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

not centers of activity, all have shorter truck trip lengths across all the time periods under the smart-growth land-use scenario.

8.3.5 Travel Times

In most cases, only minor differences in average travel times between different types of zones are observed when comparing the baseline and smart-growth land-use scenarios (see Table 17). The most notable change in travel times appears to be due to transportation investments rather than the configuration of land uses. As has been the case elsewhere, investments in roadway facilities reduce travel times, but investments in transit and motorized modes of transportation reduce travel times even further.

The most pronounced instances in which the smart-growth land-use scenario travel times exceed those of the baseline land-use scenario occur when the zonal pairs involve origins related to goods movement and the destination zones are Smart-Growth Centers, for example, downtown cores and urban villages (see Figure 9). This result is indicative of the great demand placed on the transportation network around smart-growth areas, where trucks must compete with all other vehicles for right of way, thus creating longer travel times to these locations.

Table 16. Average smart-growth-related truck trip lengths.

Transportation Investment			Baseline		Roadway		Smart Growth	
From	To	Time	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Most Concentrated	Smart Growth	AM	23.4	25.4	23.9	25.9	23.2	25.5
Most Concentrated	Smart Growth	MD	22.9	25.1	23.9	26.0	23.0	25.0
Most Concentrated	Smart Growth	PM	22.8	25.0	23.5	25.0	22.9	24.9
Most Concentrated	Smart Growth	EV	23.8	26.0	24.0	26.1	23.4	25.6
Most Concentrated	Smart Growth	NT	23.7	25.9	24.0	25.9	23.7	25.8

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

Table 17. Average truck travel times (minutes).

Transportation Investment		Baseline		Roadway		Smart Growth	
From	To	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
Most Concentrated	Most Concentrated	50.0	50.1	42.2	43.2	36.7	37.3
Most Concentrated	Goods Dependent	61.8	60.6	52.7	53.0	46.1	46.1
Most Concentrated	Smart Growth	50.9	54.5	43.9	47.6	38.0	41.1
Most Concentrated	All Else	66.4	66.5	57.3	58.6	50.5	51.6
Goods Dependent	Goods Dependent	70.5	69.0	61.0	60.9	53.4	53.1
Goods Dependent	Most Concentrated	62.0	61.3	53.2	53.5	46.3	46.3
Goods Dependent	Smart Growth	61.6	64.5	53.8	56.8	46.5	49.2
Goods Dependent	All Other	74.8	74.4	65.3	66.1	57.6	58.3

Bold indicates instances in which the baseline land-use scenario performs better than the smart-growth land-use scenario.

8.3.6 Air-Quality Benefits

Truck miles and hours of travel and truck delay have immediate impacts on trucking firms and goods-dependent businesses. A reduction in these costs ultimately has secondary impacts related to the price of goods and the economy. Similar to those secondary benefits, improvements in air quality present a societal benefit worth considering through the lens of the various land-use and transportation-investment scenarios.

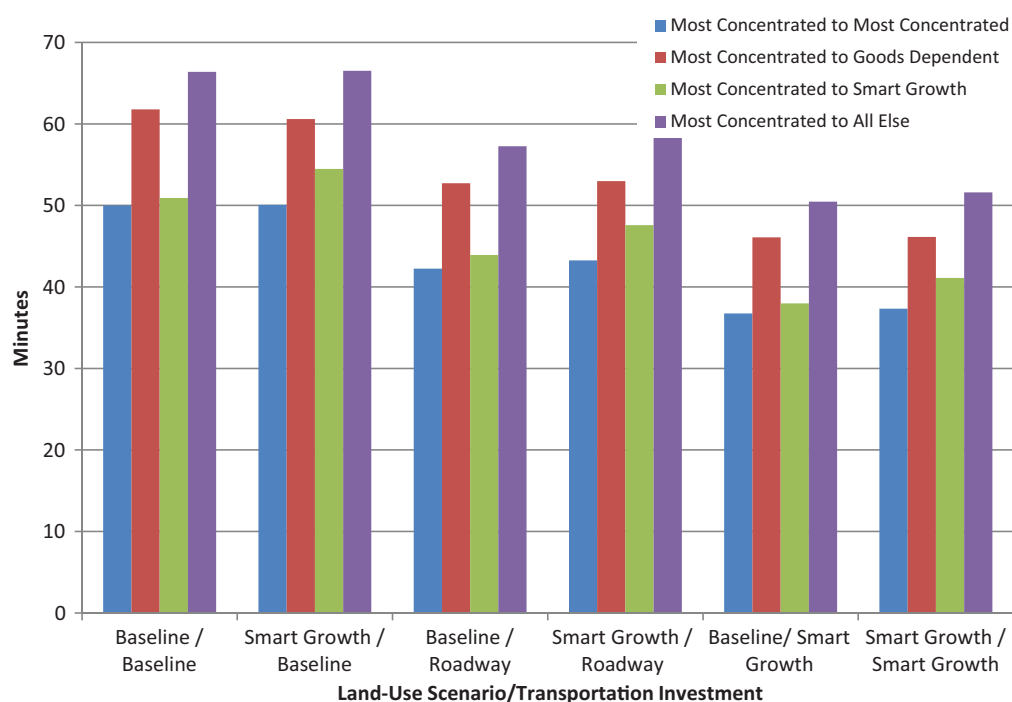
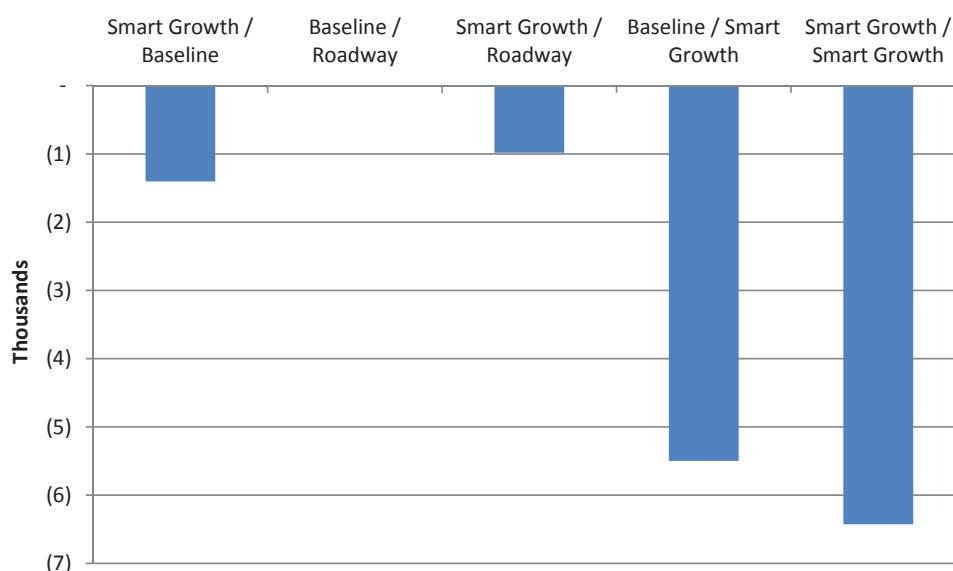
**Figure 9. Average zonal truck travel times.**

Table 18. Tons of daily pollution emission reductions by scenario (compared with baseline absolute value).

Transportation	Baseline		Roadway		Smart Growth	
Land Use	Baseline	Smart Growth	Baseline	Smart Growth	Baseline	Smart Growth
CO	1,294.09	(19.69)	86.51	72.12	(14.74)	(24.80)
NOx	45.81	(0.74)	3.02	2.45	0.36	(0.17)
PM2.5	1.76	(0.03)	0.10	0.07	0.00	(0.02)
VOC	59.40	(0.98)	1.68	1.24	(3.42)	(3.74)
CO2	79,643.42	(1,403.50)	(15.57)	(982.75)	(5,498.23)	(6,427.33)

The smart-growth land-use scenario creates large benefits in terms of emissions reductions as compared with the baseline land-use scenario. Table 18 summarizes the reduction from all the scenarios in terms of tons reduced (or gained) as compared with the baseline land-use scenario and the baseline transportation network. Not surprisingly, the roadway-investment transportation scenario incentivizes further driving, as evidenced by increased vehicle and truck miles of travel, which leads to an increase in most of the reported pollutants. However, because of the efficiency gains, as seen through reduced truck hours of travel, carbon dioxide emissions are decreased even under the roadway-investment scheme. Regardless, even under the roadway-investment transportation scenario, as is the case with the other transportation scenarios, emissions are consistently reduced more under the smart-growth land-use scenario than under the alternative.

The most notable reduction in pollution comes in the form of carbon dioxide (see Figure 10). The smart-growth land-use scenario has greater emission reductions under all three

**Figure 10. Daily reduction in tons of carbon dioxide emissions.**

transportation-investment scenarios, and, notably, the greatest gains appear to be when the smart-growth land-use scenario is coupled with the smart-growth transportation investments (transit and non-motorized). Assuming a value of \$32 per ton of carbon—the highest value on the European exchange (PSRC 2009)—the smart-growth land-use and transportation-investment scenarios in combination would annually generate \$53.5 million as compared with the baseline scenario, an increase of \$7.7 million over implementing the smart-growth transportation investments without the smart-growth land use.

8.4 Implications of the Modeling Results

The results of the six model runs suggest that in addition to the social benefits that a smart-growth land-use configuration may have on passenger travel, there are also benefits directly to, and stemming from, goods movement. The largest benefits can be realized when a smart-growth land-use scenario is coupled with commensurate transit and non-motorized transportation investments. For trucking and shipping firms, the benefits include a reduction in overall travel distances and hours on the road, both of which result in lower costs. Secondary benefits, related to overall travel, include reductions in pollutant emissions, especially carbon dioxide, as well as the potential economic gains from a more efficient and productive goods-movement system.

While great care was given to developing scenarios that could demonstrate the relationship between smart growth and goods movement, peculiarities about the Puget Sound region or the modeling tools used at PSRC may produce results that would be somewhat different under other circumstances. Because the State of Washington has had a Growth Management Act since 1990, requiring local comprehensive planning and transportation system concurrency, the baseline land-use and transportation networks may already, in some sense, represent a smart-growth regional pattern. To that end, modeling conducted with a sprawl-type land-use scenario for a baseline might show greater benefits than seen here. However, because the modeling described here did not show a general case, the benefits related to smart growth may not follow a linear function, and some levels of smart-growth land use, coupled with the appropriate land-use investment, may in fact show negative impacts. In other words, further research might show that there could be circumstances in which smart growth is *too* smart. Such research might include testing smart-growth scenarios in other jurisdictions using their regional modeling tools.

There are also several reasons that the modeling results presented in this report may underestimate the benefits of a smart-growth land-use configuration for goods movement now and in the future. As was discussed previously, current trucking models do a poor job of addressing truck trip generation, and four-step truck models do not include tours. As models more accurately depict the behavior of trucks and firms, they may estimate fewer trucks and shorter trips than is currently seen in the modeling results. Or, they may also be able to better distinguish between truck types, thus allowing for trade-offs to be made with smaller vehicles. However, in the absence of considerable data development and research to validate the improved models, it is unlikely that these models will be operational in the near term. Regardless, many important urban goods-movement issues (truck parking, delivery hours, etc.) are difficult to implement and perhaps are not often relevant for regional-scale modeling.

In a longer time frame, the planning profession may begin to better connect the principles of smart growth to goods movement. Based on the focus-group results, it is clear that freight stakeholders would benefit from better relationships among themselves, particularly between public-sector planners and private shipping and logistics firms. As smart-growth developments mature to include further consideration of goods movement, perhaps better incorporating warehousing and distribution closer to urban centers or allowing for more flexible delivery modes and times, the benefits of smart growth for and from goods movement will likely increase.



CHAPTER 9

Conclusions

This project reviewed the existing literature to identify documented connections between smart growth and urban goods movement as well as current research needs, conducted focus-group meetings with stakeholders in two different jurisdictions, and completed model runs to test current regional modeling sensitivity to smart-growth land-use patterns of truck behavior.

Reviewing the existing literature, we identified five ways in which smart growth and urban goods movement are related and a handful of research questions relevant to each. These findings were supported in the focus-group discussions (see Table 19).

Despite a clear tension identified between truck drivers, who claim a need for additional parking and loading, and planners, who claim to be doing their best to balance that desire with other competing interests, no research is available that examines or develops an optimal balance of parking space and time regulations. The potential for conflicts between trucks and non-motorized modes is a primary concern for urban goods movement in smart-growth environments, but it has hardly been considered in the literature. Another area of tension identified by this work is the trip reduction and associated environmental gains fostered by mixed-use development with the lifestyle conflicts of having differing uses in close proximity. Indeed, some other methods of achieving these types of gains—including off-hours deliveries or larger, more efficient vehicles—have specific impacts (e.g., on air quality or noise pollution) that make them undesirable in mixed-use environments. Because of the risks identified in innovative distribution methods, additional research is needed to illustrate their benefits and to identify ways to remove some of the existing barriers. Finally, efforts to manage the transportation system through real-time information and metered access are promising solutions for reducing congestion and thus reducing costs and environmental impacts. These efforts should be expanded to the extent possible to goods-movement services.

The results of the six model runs suggest that there are benefits directly to, and stemming from, goods movement. The largest benefits can be realized when a smart-growth land-use scenario is coupled with commensurate transit and non-motorized transportation investments. For trucking and shipping firms, the benefits include a reduction in overall travel distances and hours on the road, both of which result in lower costs. Secondary benefits related to overall travel include reductions in pollutant emissions, especially carbon dioxide, as well as the potential economic gains from a more efficient and productive goods-movement system.

9.1 Implications for Freight Planning

The modeling results show promising benefits to and from goods movement under a smart-growth land-use configuration. The urban-planning profession, particularly those interested in goods movement, should attempt to find ways to better explain the benefits of smart-growth

Table 19. Five key areas and examples of their existing gaps.

Research Area	Example of Existing Gap(s)	Focus Group Support
Access, parking, and loading zones	What is the appropriate amount of parking or size and number of loading zones to dedicate to goods-movement vehicles? Can time-of-day changes relieve demand for space? What is the optimal balance of parking space and time regulations?	There is a clear tension between truck drivers, who claim a need for additional parking and loading space, and planners, who claim to balance that desire with other competing interests.
Road channelization, bicycle, and pedestrian facilities	Does the number of crashes between goods movement vehicles and non-motorized modes increase when these vehicles coexist more frequently? What are appropriate tools or configurations to reduce modal conflicts?	The potential for conflicts between trucks and non-motorized modes is a primary concern for urban goods movement in smart-growth environments.
Land-use mix	How do the environmental benefits of passenger trip reductions associated with mixed uses balance against the environmental costs of time restrictions on goods-movement vehicles necessitated by their impacts on residences and other businesses? Can vehicle sizes be changed? What incentives encourage freight trip consolidation? Does density affect truck trip generation? Do mixed land uses change truck trip-generation rates?	How can trip reduction and associated environmental gains fostered by mixed-use development be balanced with the lifestyle conflicts of having differing uses in close proximity? Some methods of achieving these types of gains—including off-hours deliveries or larger, more efficient vehicles—have specific impacts (air quality or noise pollution) that make them undesirable in mixed-use environments.
Logistics		Because of the risks associated with innovative distribution methods, additional research is needed to illustrate their benefit and to identify ways to remove some of the existing barriers, including the potential offer of government subsidies.
Network system management	How can we best extend real-time information and metered access to goods-movement vehicles? Can transportation demand-management methods apply to urban goods movement?	Efforts to manage the transportation system through real-time information and metered access are promising solutions to reducing congestion and thus reducing costs and environmental impacts, and they merit further testing and evaluation.

policies to a sometimes skeptical freight community. Despite the benefits in terms of time and efficiency gains, as well as emissions reductions, planners should continue to diligently address the very real issues raised through focus-group discussions. Improving truck parking, providing proximate access from warehousing and distribution centers to urban centers, and incentivizing and allowing deliveries in off-peak periods will not only benefit the freight haulers but will also increase the benefits described through the modeling results—that is, with more focus on freight planning in the urban context, greater gains could be achieved.

The modeling results consistently showed that improvements to smart-growth transportation infrastructure, both transit and non-motorized, produced greater benefits to trucks than roadway investments. With limited financial resources, these types of investments could be supported over capacity enhancements because roadway facilities, even those that appear to be mostly designed to accommodate freight movements, generally have far greater benefits to passenger vehicles and may, as the modeling results show, reduce benefits to freight. In consideration

of freight, strategies that remove other vehicles from the roadway, maintain or preserve the existing system, or add strategic capacity for a defined purpose should be preferred over general roadway expansion.

Greater attention should be placed on freight planning for local streets. As seen in the modeling results, truck miles of travel remain unchanged on local facilities regardless of the land-use or transportation-investment scenario. Trucks will need to continue to leave their warehouses and use local streets to connect to the main parts of the transportation system; many trucks will also continue to need to make pick-ups and deliveries on local streets—for example, waste management or parcel delivery. More consideration for interaction and conflict resolution between freight and other modes of transportation would help facilitate better movement of freight.

Land-use planning should also consider the most appropriate locations for warehousing and distribution centers, particularly siting them in close proximity to urban centers. The modeling results show that truck miles of travel, though lower under a smart-growth land-use scenario with commensurate transportation improvements than the alternative, are higher due to increased travel because of the overall demand for access to urban centers. Indeed, trips from warehousing and distribution centers to concentrated areas of activity are shown to be longer in both distance and travel times under the modeling. Delivery trips from locations that are closer to urban centers or at times when demand is lower for transportation facilities would also improve the benefits of smart-growth developments for freight.

Finally, there are a variety of impacts that may not translate into regional benefits but may make smart-growth land-use developments more attractive to residents and employees, and may also reduce the tensions between the freight community, planning professionals, and other interests. Questions remain about how to handle freight interaction with other modes at the microscale and how to better resolve issues of the last mile in terms of conflicts with other modes, especially in terms of parking and noise. Nonetheless, for the system as a whole, the modeling results described in this study clearly suggest that smart-growth investments benefit truck movements.

9.2 Implications for Truck Modeling

One of the most pronounced results seen from the modeling conducted for this study is that trip length and travel times from goods-dependent analysis zones to smart-growth analysis zones are longer under a smart-growth land-use scenario. While this result appears entirely plausible, it is perhaps overly pronounced. Because truck trip generation is currently based on employment, the rise in employment concentrations in smart-growth areas translates into more trucks attempting to travel to those areas within the modeling framework. However, if better truck trip-generation data were available, the number of trucks used to make deliveries to these areas would potentially stay the same, or even conceivably be reduced, if trucking firms switched to larger delivery vehicles to meet demand.

In addition to truck-trip generation, truck models generally do not account for truck mode choice. However, as was demonstrated through the focus groups, trucking firms will use any vehicle that they need to, despite a preference for larger vehicles for the sake of efficiency. Allowing models to account for mode shift from large to medium trucks and vice versa would better represent goods movement in urban settings.

A further issue that may lead to the overestimation of truck travel, delay, and longer travel times to smart-growth areas may be caused by the lack of explicit tours for trucks in most truck

models. Because a four-step model represents individual trips, it cannot account for the synergies apparent in routing and trip planning available through the sophistication of logistics firms.

Most models do not adequately account for the need for freight to travel on lower-level, local streets for purposes such as warehouse access and local deliveries. Microscale models may address this, which will better reflect many smart-growth impacts.

Finally, microscale or intra-zonal issues of parking or modal conflicts, which may be the easiest to resolve because they can be handled as terminal costs without the need for wholesale model redevelopments, require research and data that are not currently available to properly inform an understanding of the impacts of dense land use on goods movement. While some truck stakeholders in the focus groups theorized that a reduction of general purpose lanes to accommodate a bicycle lane would reduce truck flows, there is insufficient evidence to prove or disprove such a claim and account for it in modeling. It is possible that future truck models will include a non-motorized network and will be able to forecast non-motorized travel, which may be able to account for truck-bicycle and truck-pedestrian congestion.



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APPENDIX A

Focus-Group Participants

Philadelphia: (all these focus groups were facilitated by Daniel Carlson)

Truck Drivers		Ted Dahlberg—Delaware Valley Regional Planning Commission
		Jim Runke—PA Trucking Association
		Bob Renner—Haines & Kibblehouse
		Mike Singer—UPS
		Gerry Coyle—Evans Delivery
		Tony Gemma—Roadway
		Eric Moses—John Curry
		Joe Bradford—Pepsi
Logistics Managers		Joe Carey—Campbell's Express
		Karl Engel—5K logistics
		Mark Peterken—NFI
		John Ward—YRC
		Tom Kenny—Gerace Enterprise
		Chris Pajaik, Rob Colgan, and Kevin Gorman—SYSCO
		Walker Allen—Delaware Valley Regional Planning Commission
Architects, Developers, Engineers, and Planners		Andrew Ludasi—New Jersey DOT
		Nando Micale—Wallace, Robertson, Todd
		Rick Dickson—Philadelphia Parking Authority
		Ariel Ben-Amos—City of Philadelphia
		Wes Ratko—Montgomery County Planning Commission
		James Mascaro—DP Partners
		Ted Dahlberg—Delaware Valley Regional Planning Commission
		Farroq Jan—Pennsylvania DOT

Seattle: (all these focus groups were facilitated by Daniel Carlson)

Truck Drivers		Warren Aakervik—Ballard Oil
		Curt Britton—Cleanscapes
		Mike Lindmer—FedEx
		Tony Cooper—Penske Logistics
		John Hervey—Charlie’s Produce
Logistics Managers		Jason Michaelson—Penske Logistics
		Martin Haskins—UPS
		Jim Rutt—Darling International Inc.
		Greg Hale—Waste Management
		Steve Kavanaugh—Essential Baking
Architects, Developers, Engineers, and Planners		Jessica Szelag—Commute Seattle
		Katherine Casseday—Casseday Consulting
		Ryan Avery—Parsons Brinckerhoff
		Sean Keithly—Collins Woerman
		Thomas Noyes—Washington DOT
		Geri Poor—Port of Seattle
		Christina Van Valkenburgh—City of Seattle
		Victor Stover—Nelson Nygaard



APPENDIX B

Focus-Group Guides

I. Truck Drivers

00-40 OPENING DISCUSSION

What is your favorite place to deliver? Why? What is your least favorite place to deliver? Why?

We're looking for comments in these areas:

- Traffic and congestion
- Parking and loading zones
- Getting along with other modes (pedestrians, bikes, buses)
- Time of day
- Land-use mix

Probe on time of day:

When is it most difficult to deliver (time of day)? Why?

Probe on physical location:

Where is it most difficult to deliver? Why?

40-50 CONGESTION

How do you manage congestion on your routes? Change route? Change time of delivery? In what areas do you have flexibility to shift patterns, and in what areas are you stuck? Does it alter the number of deliveries you are required to make? The time window in which you need to deliver? If you were able to, would you use a different kind of, or different size, vehicle (e.g., smaller van, motorcycle, bicycle)? Why?

50-65 TIME AND ENFORCEMENT

What would you say your shortest stop is? Your longest? What would be your average length delivery stop?

What would you do to shorten the length of each delivery? Some studies have found that downtown deliveries take over 30 minutes per stop and that much of that time is spent getting through office buildings to arrive at the final delivery point. In suburban shopping centers, finding and making a hand-truck delivery can be very time consuming. (These observations may already have been made by the group and can be referenced.) What are possible solutions to these time wasters?

Curbside delivery zones have a 30-minute time limit. Is this adequate? I assume your vehicles have City of Seattle stickers . . . or do you pay at the meter? Tell me about enforcement . . . do the police enforce the 30-minute limit, parking enforcement? Do you personally pay for fines, or does your company? (Modify for Philadelphia focus group.)

65-80 ZONING ISSUES

There are a variety of design and location factors regulated by zoning practices that could affect what you do. For example, zoning can segregate or mix uses, such as having residences over storefronts or housing next to offices. Are there certain mixes of uses which make it easier or more difficult to serve?

Set-back requirements may mandate parking in front of commercial retail facilities, other zoning codes require parking in back of the facility. Do you have a preference? Why? Parking can be either on-street or off-street. Do you have a preference? Why? Sign ordinances control the size and placements of signs. Is their placement an issue for you? Landscape ordinances require tree plantings. Do they affect your work? How?

What, if any, should the truckers' role be in the planning and permitting process?

80-90 LIVING WITH OTHER MODES

As we have discussed, when you operate in a congested, mixed-use environment, how do you get along with buses, bikes, pedestrians, service vehicles, other deliverers? Some truck drivers favor all-way cross walks like those at Pike Market and Alaska Junction. What do you think? (Modify for Philadelphia focus group.)

90-105 CURBS, ALLEYS, AND LOADING DOCKS

Do you make most of your deliveries/pick-ups from the curb, the alley, a middle turn lane of a road, or the loading dock? Do these have different time or space requirements?

Which do you prefer and why? Is there a difference by type of vehicle and service—for example, FedEx-type van vs. Darigold-type 22' box?

What impediments are there to curb access? Are there too many delivery vehicles, passenger vehicles, buses, pedestrians, bicyclists, corner curb bulbs? How do you react to these?

Do you presently use alleys for deliveries? In what situations do they work best, or worst?

Would you like to use them more? What would make them more usable? If every alley had a turn-out/by-pass point, would that make life easier? Is there a protocol for alley use? Who uses alleys most?

How does the presence of an alley impact time required for delivery? Your behavior?

Do you prefer loading docks inside buildings to curbside deliveries? Please describe loading-dock management issues: adequate number of docks, waiting times, proper design, height of entrances, advance notice of dock space availability, separation of courier/time-sensitive deliveries from other deliveries, space for service vehicles.

We know of two cities—Dallas, Texas, and Rochester, New York—that have underground freight loading facilities. Have any of you used them? Would such a facility make sense to you? Just to hypothesize, would the downtown bus tunnel offer advantages if it were open to freight delivery during the evening? How would this save you time? Would it change the vehicle you might use?

105-115 TECHNOLOGY and OTHER

For time-sensitive deliveries, would a central receiving office in a large office building work for you if they could sign for a package and route it internally in the building?

In class A—fancier office buildings—can deliverers use passenger elevators?

When do you need or choose to walk a significant distance from your vehicle? Why? How far do you walk?

II. Logistics Managers

00-25 OPENING DISCUSSION

THE GOOD

Q1. In what environment does your fleet have fewest problems with deliveries and scheduling? Why?

Q2. How does this benefit your company? Can you quantify the benefits?

25-55 THE BAD

Q1. In what environment do you have the most problems with deliveries and scheduling?

Q2. What accommodations do you make to manage these problems?

Q3. Do you add more time for deliveries? How much more time? Can you provide me with an example?

Q4. Do you expect drivers to make fewer deliveries? How many fewer? Can you provide me with an example?

Q5. Do you use different vehicles in these environments? Please explain. Can you provide an example?

Q6. Do you have specific policies or guidelines for managing operations in different environments? What are these? Are they strategic or operational? Can you place a cost on these policies?

55-65 TIME OF DAY

What time of day is the most difficult within which to manage your operations? Is this true everywhere? What accommodations do you make for this?

65-80 PRICING AND ENFORCEMENT

How does your company manage parking violations? Do you recommend to drivers that they double park if parking is not available?

How far do you suggest that drivers go from their vehicle? Do they leave it idling? Where do you hear about drivers needing to do this?

Do you have a policy about paying parking violation fees?

80-90 PEDESTRIANS AND BIKES

Do you have policies for your drivers regarding interaction with pedestrians and bicyclists? Do issues with these groups cause you to alter your scheduling, routes, or stopping locations?

90-100 INFORMATION AND TECHNOLOGY

What information would help you manage your fleet better? Would it help to have information about the availability of on-street parking, in-building loading dock space, or congestion? How would you like this information to be available? How would you or your drivers use this information?

Do you use hybrid vehicles? How do you employ IT, cell phones, or on-board computers?

100-110 TEST COMPANY CATEGORIZATION

Relative to other carriers, would you describe your deliveries as difficult, moderately difficult, or easy? Why?

What is it about your company that makes your deliveries more difficult? How could you change this? Or how could this be changed?

110 THANK YOU!

III. Architects, Developers, Engineers, and Planners

00-30 OPENING DISCUSSION

Deliveries by truck require a parking location. If the trucks are not parked on the street, they need to be in an alley, inside a building at a loading dock, or in an off-street truck parking area. How do you design and plan for these different types of facilities? Do you consult with trucking companies or drivers about design metrics, layout, protocols for use of space? Has this affected your design choices?

Probe: To what extent does goods movement enter into the discussion of design, build, manage, and regulate private and public space in the urban environment?

30-45 LOADING DOCKS AND ALLEYS

Please describe loading-dock management issues: adequate number of docks, waiting times, proper design, height of entrances, advance notice of dock space availability, separation of courier/time-sensitive deliveries from other deliveries, space for service vehicles, etc.

We know of two cities—Dallas, Texas, and Rochester, New York—that have underground freight loading facilities. Have you ever considered them? Would such a facility make sense to you? Just to hypothesize, would the downtown bus tunnel offer advantages if it were open to freight delivery during the evening?

- Could the number of trucks be reduced through greater consolidation of freight? For example, 7-Eleven has a policy to reduce the number of deliveries by requiring consolidation of some shipments.
- Is it feasible to design alleys with turn-out/bypass points?
- Is loading-dock status available to deliverers prior to entry?

45-55 TIME AND ENFORCEMENT

Some studies have found that downtown deliveries take over 30 minutes per stop and that much of that time is spent getting through office buildings to get to the final delivery point. What are possible solutions to these time wasters?

- Large office buildings usually restrict delivery access to a limited number of elevators. Others have loading-dock-level internal distribution centers. What's your experience with this? Do city codes encourage or speak to loading-dock and internal distribution systems?

Curbside delivery zones usually have a 30-minute time limit. Is this adequate? Tell me about enforcement. Do the police enforce the 30-minute limit?

55-70 ZONING ISSUES

Newer zoning encourages a mix of uses in compact spatial patterns. Tell me how you deal with or consider the following:

- Truck noise (including back-up beeper) at night in mixed-use residential areas
- Lighting
- Parking requirements
- Landscape and street tree requirements
- Sign ordinances

70-80 TECHNOLOGY

Do you employ:

- Advance wireless notice of loading-dock or curbside space?
- Hybrid or electric vehicles?

80-90 LIVING WITH OTHER MODES

As we've discussed, trucks need to operate in congested, mixed-use environments. How does goods movement get along with buses, bikes, pedestrians, service vehicles, and other deliverers?

- What about wide sidewalks and skinnier streets?
- Corner curb bulbs and tighter turning radii?
- All-way cross walks like Pike Pl Mkt and Alaska Jnctn?
- Interacting with bicyclists and bike lanes?
- Using the middle turn lane on re-striped road-diet arterials?

As more people live in urban centers, how can moving vans be best accommodated? Are one-way or two-way streets preferable?



APPENDIX C

Modeling Tools at PSRC

The Puget Sound Regional Council utilizes an integrated modeling system to conduct analysis of alternatives in the region (see Figure 11). These tools expand the capabilities to develop and analyze various alternatives, improve accuracy in the forecasts, and provide efficiencies in the analytical process. The capabilities are described for each of the tools that have bearing on the analysis in this report.

Regional Economic Model

The Puget Sound Economic Forecasting model produces regional and county economies as input to the land-use forecasting model. It consists of two sub-models: one projecting the regional economy and one forecasting the individual county economies. PSRC uses only the regional forecasts as inputs to the land-use forecasting models, given that local land-use trends, patterns, and plans need to be considered in developing a final county-level forecast.

Land-Use Model System

The new land-use forecasting model, UrbanSim, is a parcel-based, market-driven model.⁵

In addition to the new capabilities in this model, the model can be applied iteratively for each scenario or alternative to evaluate how the land use is affected by each transportation investment. This is a big shift in the analytical process, in which land use is assumed to be fixed for each forecast year. In addition, these new land-use models are sensitive to land-use and public policies so that the impacts of changes in policy on growth and transportation can be tested.

Travel-Demand Model System

The regional travel-forecasting model at PSRC has undergone changes to represent activities rather than trips. This is significant because travel decisions are all linked together around activities. For example, if a person goes to work, then stops for gas, food, and to pick up a child on the way home, the choice of mode, destination, timing, and even how many trips to make are all linked to this chain of events. These new models, called activity-based models, track individuals rather than groups of people, which makes them more behaviorally correct than trip-based models. PSRC has incorporated the trip-making component into the

⁵For further discussion on UrbanSim, please visit the UrbanSim website at <http://www.urbansim.org/Main/WebHome>

current regional forecasting process. This allows changes in the number of trips and stops by trip purpose for different transportation alternatives to be determined. PSRC has also implemented some other short-term models, and the complete modeling system is depicted in Figure 12.

Improvements include the following:

- Pricing/tolling—improved sensitivity in the models to cost
- Freight analysis—refined speeds and costs for trucks
- Modal-choice analysis—stratified transit modes into local bus, premium bus, light rail, commuter rail, and ferry
- Non-motorized analysis—added pedestrian and bicycle factors
- Speed and reliability impacts—added reliability and improved speed validation
- Greenhouse-gas emissions—used EPA Moves model to generate emission rates by type for different speed ranges



Figure 11. PSRC's model system.

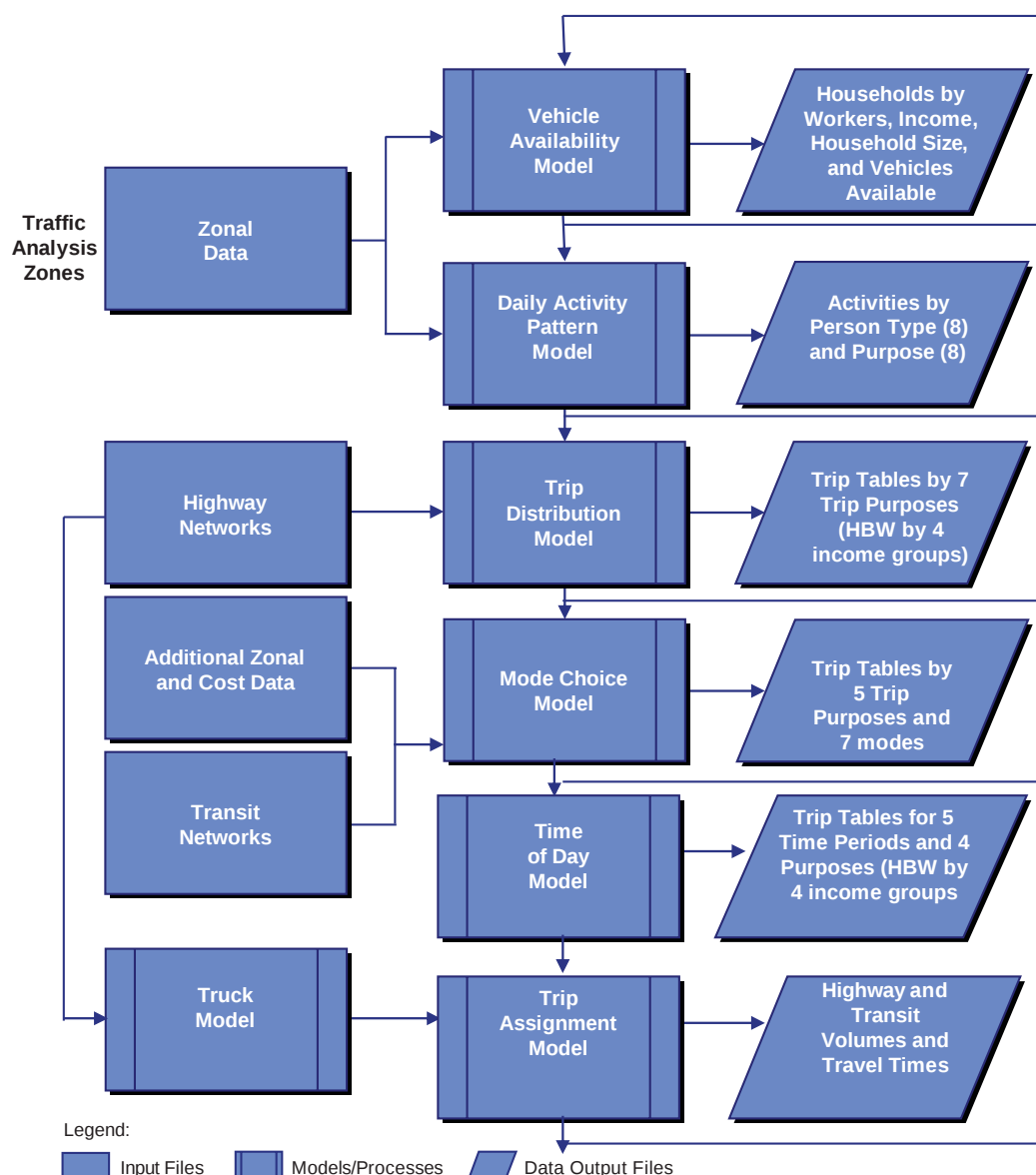


Figure 12. Travel model components.

User Benefit Analysis System

PSRC’s Benefit-Cost Analysis (BCA) tool compiles the benefits and costs of transportation measures. The BCA tool reports travel time and reliability benefits and compares these to operating, maintenance, and capital costs to determine the benefit-cost ratio of a program or project. It also reports accident costs and vehicle emissions costs so that these can be directly accounted for in the benefit-cost ratio. In addition, BCA is used to evaluate geographic, socio-demographic, and freight-equity issues by allocating benefits and costs to these market segments.

Model Framework

There are a series of assumptions in any analytical tool or model that provide a framework for understanding and interpreting the results.

Land Use

The land-use forecasting model (UrbanSim) produces forecasts of land use and buildings by type. There are 1.18 million parcels in the region, and there are 30 land-use types in six general categories, with each parcel in the Puget Sound region having a unique land-use type. In 2000, there were 23 building types and 1 million buildings in the region. There are a few land-use types that do not have any buildings (these are *italicized*), and there is one building type (outbuildings) that does not have a corresponding land-use type (see Table 20).

Table 20. Land-use and building types.

Food, Forest, Mining	Residential
- Agriculture	- Group Quarters
- Fisheries	- Mobile Home Park
- Forest, harvestable	- Multi-Family Residential
- Forest, protected	- Condo Residential
- Mining	- Single-Family Residential
Public	Industrial
- Civic and Quasi-Public	- Industrial
- Government	- Transportation, Communication, Utilities
- Military	- Warehousing
- Park and Open Space	- Water
- Recreation	- Right of Way
- School	- Parking
Retail and Service	Other
- Commercial	- Mixed Use
- Office	- No Code
- Hospital, Convalescent Center	- Vacant Developable
	- Vacant Undevelopable
	- Other/Outbuilding

Note: Land-use types without buildings

Demographics and Economics

The Puget Sound Economic Forecaster (PSEF) produces forecasts of population by age group (1–4 years, 5–19 years, 20–64 years, and 65 years and older), population by type (household or group quarters), number of households, personal income, and employment by sector. These forecasts are used as regional control totals in the land-use-forecasting process; they do not vary by transportation alternative.

The land-use-forecasting model produces a synthetic population database consistent with existing and future regional demographics, with the following characteristics for each household (see Table 21): age of head of household, number of children, number of workers, income, and number of persons. There were 1.28 million households and 3.2 million people in 2000, and there are forecasts of 2.19 million households and 5.0 million people in 2040. There are 19 employment sectors (see Table 22) represented in the economic and land-use forecasting models, 10 employment sectors in the truck forecasting model, and 6 employment sectors in the passenger-travel-demand forecasting model. There were 1.85 million jobs in the Puget Sound region in 2000, and the forecast is for 3.07 million jobs in 2040. The land-use forecasts are sensitive to changes in transportation investments and will demonstrate how growth patterns vary by investment package.

Travel Characteristics

Travel is classified by purpose, mode, and time period in the travel-demand forecasting models. Travel purpose is defined in two ways: first, by identifying the purpose of the primary destination of a tour (defined as the series of trips linked together that start and end at home), and second by identifying the individual purpose of a single trip (see Table 23).

The daily activity patterns generated for the tour purposes are sensitive to changes in transportation investments, toll policies, congestion, and growth patterns. The linking of trips into tours also reflects the fact that travel choices are made based on the whole tour rather than just

Table 21. Household and person characteristics.

Person Type	Number of workers
- Full-time worker	- Zero workers
- Part-time worker	- One worker
- Retired	- Two workers
- Non-worker	- Three or more workers
- University student	Income Group (2006\$)
- Student age 16+	- Under \$30,000
- Student age 5–15	- \$30,000 to \$55,000
- Child under 5	- \$55,000 to \$90,000
Household Size	- Over \$90,000
- One person	
- Two persons	
- Three persons	
- Four or more persons	

Note: Household income is assumed to increase with inflation.

Table 22. Employment sectors in economic, land-use, and travel models.

	Economic and Land-Use Forecasting	Truck Model	Passenger Model
Goods-producing			
	Natural resources and mining	Natural Resources	Manufacturing
		Mining	
	Aerospace	Manufacturing - Equipment	
	Other durable goods	Manufacturing - Products	
	Nondurable goods		
	Construction	Construction	WTCU
Service-producing			
Wholesale trade	Wholesale trade		
Transportation and warehousing	TCU		
Utilities			
Telecommunications			
Other information			
Retail trade	Retail trade	Retail trade	
Financial activities	FIRES	FIRES	
Professional and business services			
Food services and drinking places			
Educational services			
Health services			
Other services			
Government			
	Government	Education/Government	Government
	Education		Education
Notes	FIRES = Finance, Insurance, Real Estate, Services		
	WTCU = Warehouse, Communications, Transportation, Utilities		
	TCU = Transportation, Communications, Utilities		

Table 23. Travel purposes.

Tour Purpose (Destination)	Trip Purpose (Origin and Destination)
- Work	- Home-based work
- School	- Home-based school
- Escort	- Home-based college
- Personal Business	- Home-based shop
- Shop	- Home-based other
- Meal	- Non-home-based work
- Social/Recreational	- Non-home-based other
- Home	

an individual trip. The current PSRC model represents tours for the trip-generation component of the process but combines this with destination, mode, time of day, and route choice at the individual trip level. These individual trips are not linked together as tours and are therefore less effective in capturing travel decisions that are linked together. PSRC is currently developing the remaining tour models (also called activity-based models) to improve this process. PSRC can report on tours and trips at the household level, but we cannot yet track tours at the destination, mode, time-of-day, or route choice level.

Travel Modes

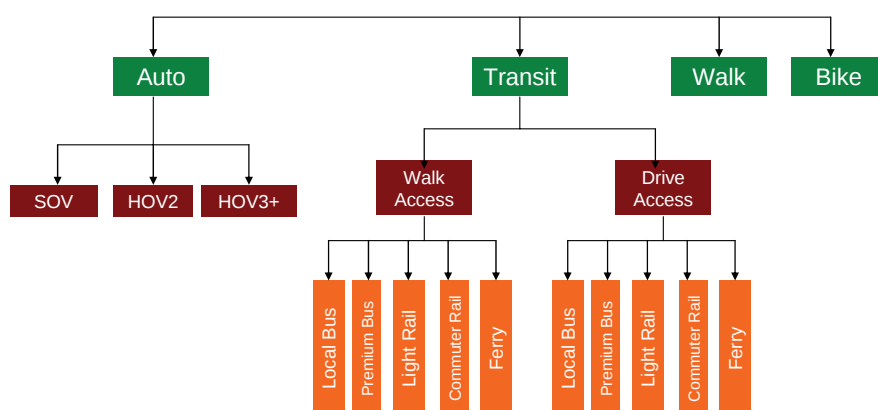
Multiple travel modes are represented in the passenger travel-demand forecasting model in three categories: auto, transit, and non-motorized. These are evaluated in a nested logit structure (shown in Figure 13) that groups modes that are more likely to provide trade-offs with one another.

Time Periods

There are 32 time periods in the detailed time-of-day choice component of the passenger-travel-demand models, and these are aggregated to five time periods for use in other modeling components (see Table 24). The more detailed time periods are used to determine the actual time of an individual trip, and these are aggregated to determine an average travel time, cost, and volume for the aggregated time periods. The more detailed time periods in the time-of-day models can be used in trip assignment, but this is best used for corridor-level analysis and not for regional planning purposes.

Travel Costs

There are four types of direct costs in the travel-demand forecasting models: auto operating cost, parking costs, tolls, and transit fares. Auto operating costs are applied at 14.4 cents per mile (in 2006 dollars) to all auto modes and to the auto-access-to-transit modes. Daily standard and



Notes:

- Single-Occupant Vehicle (SOV)
- High-Occupant Vehicle with 2 people (HOV2)
- High-Occupant Vehicle with 3 or more people (HOV3+)

Figure 13. Travel modes.

Table 24. Time periods.

Time-of-Day Models	Other Models
- a.m. peak (5:00 a.m. to 9:59 a.m.) in 30-minute increments	- a.m. peak (6:00 a.m. to 8:59 a.m.)
- Midday (10:00 a.m. to 2:59 p.m.) in 30-minute increments	- Midday (9:00 a.m. to 2:59 p.m.)
- p.m. peak (3:00 p.m. to 7:59 p.m.) in 30-minute increments	- p.m. peak (3:00 p.m. to 5:59 p.m.)
- Evening (8:00 p.m. to 10:59 p.m.)	- Evening (6:00 p.m. to 9:59 p.m.)
- Night (11:00 p.m. to 4:59 a.m.)	- Night (10:00 p.m. to 5:59 a.m.)

carpool parking costs are used in the work model. Non-work models use hourly parking costs. Ferry fares paid when crossing the Sound with a vehicle are also considered as auto operating costs. In 2006, there was only one toll bridge, the Tacoma Narrows Bridge, which charges \$3.00 in one direction. All occupants of shared-ride modes share the auto operating costs and parking costs equally. A zone-to-zone transit-fare matrix representing the fares for each transit mode also is used as input to the model. A bi-directional averaging procedure is used for cost, and all travel costs are assumed to increase with inflation, except parking cost, which assumes a 1.5% increase above inflation based on historical trends. A separate analysis of the impacts of increasing gas prices on travel behavior is being conducted to demonstrate the sensitivity of vehicle miles traveled to changes in cost.

Special Generators

Four types of special generators are added to the trip tables for passenger and truck models:

- Sports complex (the SoDo Sports Complex and the Tacoma Dome)
- Regional center (the Seattle Center)
- Ports (Sea-Tac Airport, Port of Seattle, and Port of Tacoma)
- Warehouse and distribution centers (located in the SR 167 corridor).

Trips to and from the ports of Seattle and Tacoma and the warehouse and distribution centers are input to the truck model, while trips to the other special generators are input to the passenger model. For the Port of Seattle, the trips between the Port and the intermodal yards are specified separately from remaining regional or external trips to and from the Port.

External Travel

Three types of external travel are added to the trip tables for passenger and truck models:

- Trips from outside the region destined to somewhere in the region
- Trips from inside the region destined to somewhere outside the region
- Trips from outside the region destined to somewhere outside the region, but that pass through the region on the way

There are 18 external stations in the Puget Sound region. Passenger and truck external trips are developed separately from observed data sources, and forecasts are based on relevant growth patterns.

Commercial Vehicles

Commercial vehicles are defined as any vehicle used for commercial purposes and can include autos, vans, sport utility vehicles, small trucks, and medium and heavy trucks. These are inclusive of all commercial vehicles, such as taxis, rental cars, school buses, ambulances, etc., but these special-purpose vehicles are not directly represented in the current model; instead, they are indirectly represented. These commercial vehicles are forecast using a truck model that includes all commercial vehicles based on relative weight classes and that separates light, medium, and heavy trucks for analysis purposes (see Table 25).

This truck model was developed using a conversion of truck volumes to passenger-car equivalents (PCE) for assignment purposes. This factor provides a means to account for the fact that larger trucks take up more capacity on the roads than passenger cars. This model is important to determine the effects on capacity and congestion for assignment of both trucks and passenger cars. The following assumptions were used:

- Light trucks are 1.0 PCE
- Medium trucks are 1.5 PCEs
- Heavy trucks are 2.0 PCEs

Vehicle Classes

Seven classes of vehicles are assigned in the multi-class assignment:

- Single-occupant vehicle (SOV)
- 2-person carpools (HOV2)
- 3+ person carpools (HOV3)
- Vanpools
- Light trucks
- Medium trucks
- Heavy trucks

In order to combine vehicle costs and times, the value of time for each vehicle class was stratified, and SOVs were further stratified by purpose and income class to capture differences in values of time for each market segment (see Figure 14). HOV and vanpool vehicles are further subdivided by time period because vehicle occupancies vary by trip purpose and time period, and this affects the overall value of time for each vehicle.

Table 25. Commercial vehicles classes.

Truck Type	Configuration	Gross Vehicle Weight
Light Truck	Four or more tires Two axles	Less than 16,000 lb
Medium Truck	Single unit Six or more tires Two to four axles	16,000 to 52,000 lb
Heavy Truck	Double or triple unit Combinations Five or more axles	More than 52,000 lb

Note: Light trucks also include non-personal use of cars and vans.

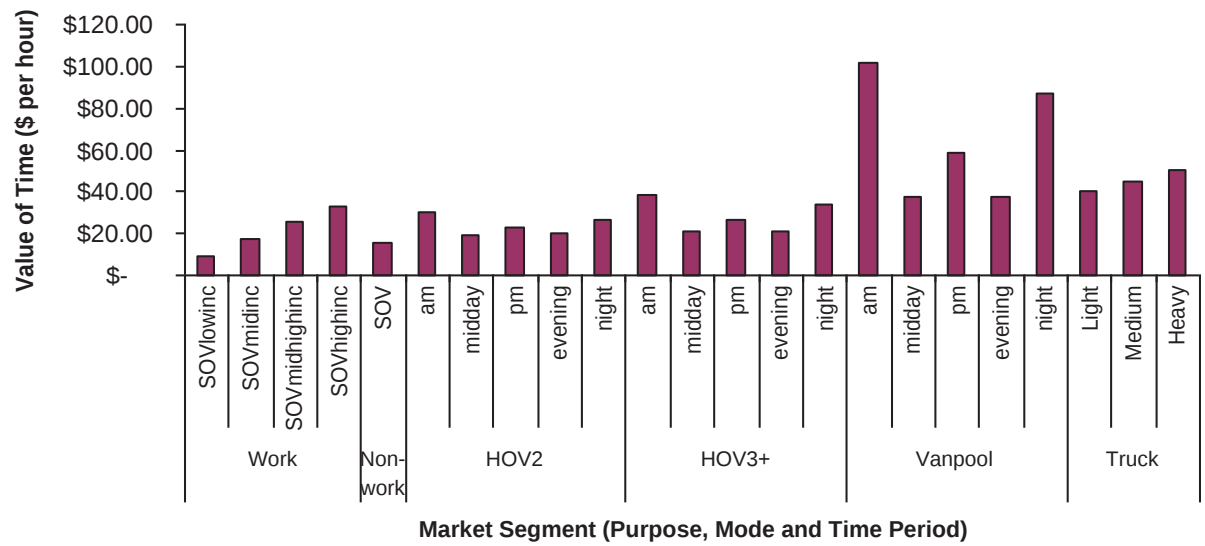


Figure 14. Value of time by market segment.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation