Developing a Multi-Criteria Prioritization Tool to Identify Promising Locations for Transit-Oriented Developments on WSDOT-Owned Park and Ride Sites

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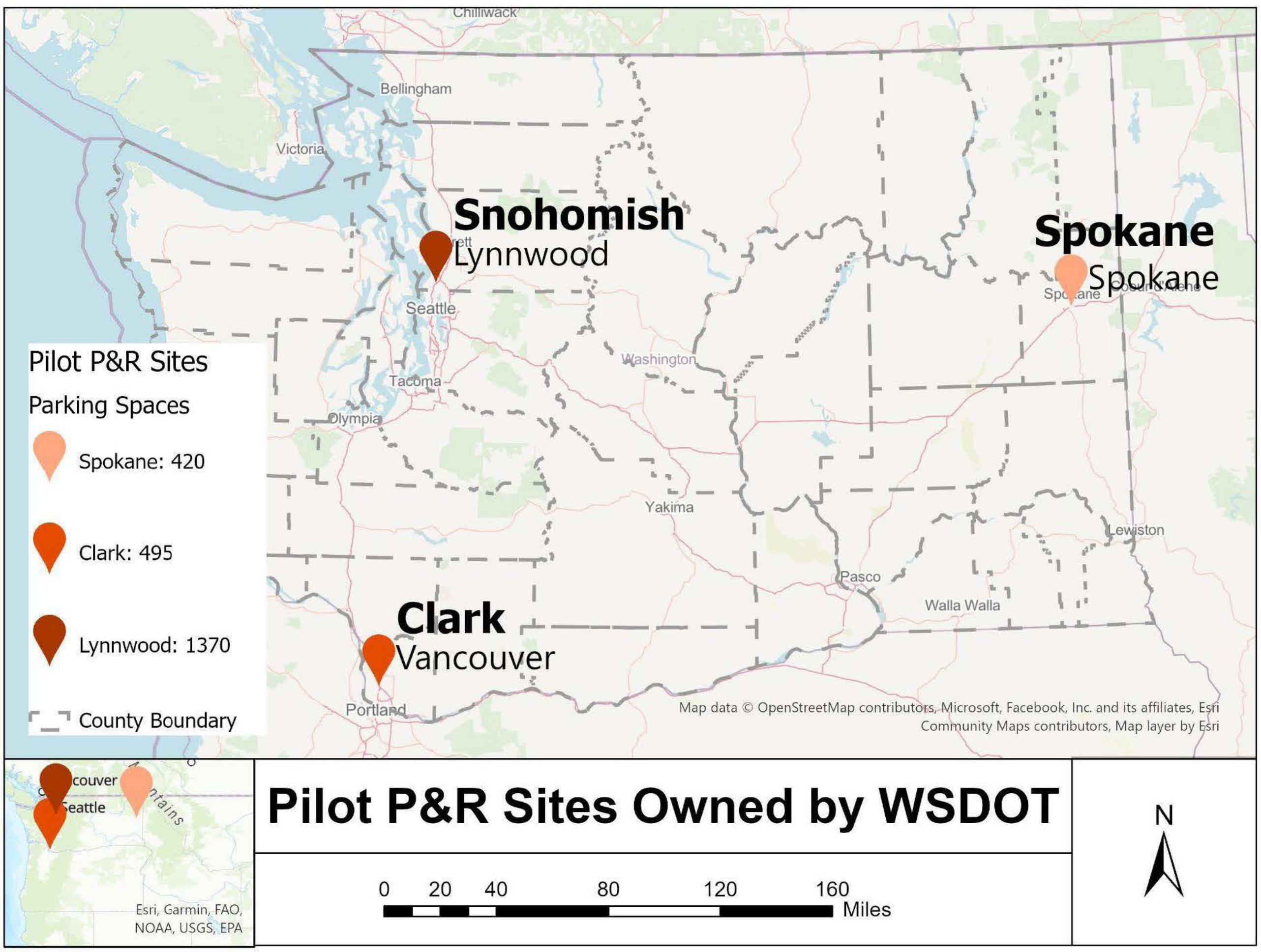

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DEVELOPING A MULTI-CRITERIA PRIORITIZATION TOOL TO IDENTIFY PROMISING LOCATIONS FOR TRANSIT-ORIENTED DEVELOPMENTS (TODS) ON WSDOT-OWNED PARK AND RIDE SITES

by

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16. ABSTRACT:

Public agencies can take a leading role in supporting TOD by making land available to developers (selling or leasing land, potentially below market prices). With existing access to transit systems and often large land areas, park and rides that are publicly owned can be leveraged to support TOD uses, such as affordable housing, office space, small businesses, and mixed-use buildings. To effectively support TOD planning, this research developed a multi-criteria prioritization tool to identify the most promising locations for TOD and tested it at three park and ride sites owned by the Washington State Department of Transportation. The tool was developed through the Delphi process, which is an effective and inexpensive approach for evaluating relevant indicators by synthesizing the opinions of experts from various backgrounds. Five categories with a total of 14 TOD indicators, including transit supportive land-use zoning, job accessibility, land price, land-use mix, and household income, were selected as measures of TOD suitability. The importance of these indicators varied with three different TOD scenarios: (1) emphasis on affordable housing, (2) emphasis on market-rate housing, and (3) emphasis on mixed-use development. Using the calculated suitability scores, this tool can prioritize potential TOD sites for further review.

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Problem Statement

Transit-oriented development (TOD) can be leveraged to support state and local government policies intended to reduce vehicle miles traveled (VMT) and shift away from the expansion of parking facilities that contribute to increased traffic congestion. Mixed-use TOD contrasts with transit-adjacent and single-use developments that do not support transit use and do not promote sustainable, livable, and equitable communities that are compact, walkable, bikeable and accommodating of various forms of micro-mobility services, and accessible to diverse housing and local businesses. A key component of TOD is multi-family housing near the transit system. This can create affordable residential and travel options in newly developed suburbs of large cities that have become increasingly transit-poor and auto-dependent over the past century.

There is a growing public interest in implementing TOD where appropriate and cost effective. Evaluating the potential for TOD around locations near public transit stations is influenced by changing conditions in the transportation system, population composition, the real estate market, and the built environment in urban areas, as well as state and local policy preferences. The Washington State Department of Transportation (WSDOT) is uniquely positioned to effectively catalyze TOD in Washington state. It can leverage its resources, including significant land holdings for parking and other transportation facilities, to build partnerships with regional transit agencies, municipalities, and private developers to initiate TOD. By planning and implementing TOD projects in a timely manner, public agencies can continue to promote environmentally responsible and socially equitable transportation services while also making important contributions to alleviating the affordable housing shortage. To help achieve this goal, WSDOT urgently needs a screening tool that could help determine the locations that might be the most promising for TOD among the park and ride sites that it owns.

Research Objectives and Questions

The goal of this innovative project was to develop and test an effective planning support tool that can help WSDOT identify the most promising park and ride sites on which to focus its TOD efforts. The project sought to develop an analytical approach that could identify the potential benefits associated with leveraging WSDOT-owned park and ride sites to facilitate TOD. According to WSDOT, there are at least 28 sites in the Department's current inventory where TOD might be appropriate. There are a variety of challenges underlying the placement of TOD. The prioritization tool developed as part of this research is intended to create a first-step screening that would help WSDOT further qualify the feasibility of any or all of the sites initially identified. TOD at high-priority park and ride sites is intended to promote the use of public transit, facilitate a sustainable urban transportation system, contribute to equitable workforce development by improving access to jobs, increase ethnic and socioeconomic diversity in transit-accessible areas, and reduce the potential for displacement of current residents. By providing this TOD prioritization tool for Washington state and even other states to apply to practical projects, this research could help agencies effectively make use of scarce land resources and limited funding sources to promote a people-oriented, multimodal transportation system. With an effective prioritization tool, WSDOT could avoid devoting extensive resources to evaluating each individual property and instead focus its efforts on the most promising sites.

This project sought to fill research gaps in TOD planning and implementation by answering the following questions:

- What indicators should be included to measure the suitability of public land for TOD?

- How do these indicators contribute to TOD suitability?
- With regard to the future progress of TOD on public land in similar or different geographic contexts, how can the use of this tool be extended?

Methods

The prioritization tool was designed to support TOD planning and implementation before WSDOT ultimately decides what will be built on the park and ride sites it owns. A TOD project typically takes several years to be fully implemented. This implementation process can involve complex interactions between the public and private sectors, as well as among public sector agencies. WSDOT is most interested in understanding the current conditions for TOD so that it can make good use of its own land for TOD. Therefore, the research team chose to focus on measuring current conditions for TOD, which are collectively referred to as TOD readiness.

To develop a generally applicable prioritization tool for examining the potential for TOD at WSDOT-owned park and ride sites, the research team considered a range of physical and location characteristics, sociodemographic indicators, and planning and policy actions on the sites. The researchers first identified TOD-related indicators that incorporate these factors by conducting a systematic literature review. Through a Delphi process, input from nine experts with diverse backgrounds and professions was collected and synthesized to evaluate the relative importance of the indicators for measuring TOD potential. Among the nine experts, four were professors from academic institutions, specializing in real estate development, transportation policy, and urban planning, while the other five experts were professionals from planning organizations and transportation agencies in the State of Washington. The potential for TOD was discussed under three designated scenarios that emphasized different types of housing units and land uses as the predominant component of development at the park and ride sites. The final lists of the TOD indicators for the three scenarios and their relative importance (i.e., indicator weights) derived from the rankings and ratings provided by the experts constituted the TOD prioritization tool.

To test the resulting tool, the research team then used it to measure and compare the TOD potential at three selected WSDOT-owned park and ride sites. The three selected park and ride sites were located in Snohomish, Clark, and Spokane counties in Washington state. Their locations in growing metropolitan areas of Washington suggested their potential to create sustainable, livable, and equitable neighborhoods near the transit system by dedicating a portion of available parking spaces to the development of diverse buildings and housing units. Using the TOD prioritization tool, each park and ride site received a TOD suitability score, which could be used to compare the TOD potential of the evaluated sites and determine the most promising ones.

Results and Contributions

The TOD prioritization tool developed by this project team measures five key dimensions of a location's TOD potential:

(1) public transportation services supply and demand,

(2) adjacent land uses and walkability,

(3) sociodemographic attributes of the local population,

(4) real estate market conditions, and

(5) supportive state and local transportation and land-use policies.

Each of these dimensions is measured by at least two indicators. The final list of TOD indicators includes supportive land-use zoning and policies, job accessibility, population and employment densities, land price, transit network connectivity, land-use mix, racial diversity, household income, walkability, special generators of transit demand, housing unit rent, and home value.

This comprehensive list of TOD indicators allows for comparisons of TOD potential among places in different geographic contexts.

The tool can help facilitate the use of public transit and support a more sustainable urban transportation system by prioritizing the locations with higher levels of transit service, denser population and employment, more diverse land uses, higher land values, and a more transit-supportive regulatory environment. The tool can also contribute to improvement in quality of life for racial groups by prioritizing the locations with greater racial diversity, better job accessibility, and higher walkability. Because it was designed around three TOD scenarios in which different housing units and land-use types primarily provided for different groups of people, the tool is more generally applicable to various TOD projects in practice.

This TOD prioritization tool can be customized and applied to measure the TOD suitability of and development priorities for a broader set of park and ride sites in Washington and elsewhere. For future research, additional park and ride sites owned by WSDOT or other public lands owned by government agencies could be included in the analysis. The tool can be further developed by improving the measurement of the TOD indicators through the use of new data sets.

Introduction

To address the shortcomings of car-dependent urban living and suburban traffic in American cities, the concept of transit-oriented development (TOD) was first introduced by Peter Calthorpe, who called for pedestrian-oriented development and a balance between transit and automobile use (Calthorpe, 1993). TOD, commonly characterized as compact, mixed-use development located around transit hubs and accessible to walkable neighborhoods, can be adopted as a strategy to encourage the use of public transit. It integrates commercial and residential uses in a walkable area near transit, making it convenient and economical for employees and residents to travel. A TOD zone can be scaled from 400 m (0.25 mile, a 5-minute walk) to a maximum distance of 2,400 m (1.5 mile, a 30-minute walk) from transit stations/stops, with 400 m (0.25 mile), 800 m (0.5 mile) and 1600 m (1.0 mile) typically used in TOD case studies (Zhang et al., 2017; Shen et al., 2018). A TOD project can be a single building or a group of buildings, or it can encompass multiple blocks.

Public authorities can play a leading role in catalyzing TOD in market economies, especially in regional growth centers where every inch of land is valuable and in suburban areas that hold promise for future intensive development. They may own land that is vacant, underutilized, or no longer used for its original purpose, even in areas where land resources are scarce. These public lands can be made available to developers, potentially at a reduced cost, in exchange for a commitment to develop a portion of the land for affordable housing or other uses deemed consistent with community goals. Public agencies can use such land as a catalyst for TOD, working with developers to make TOD projects financially feasible while helping to create mixed-income, mixed-use neighborhoods with economic, social, and environmental benefits. This idea has been implemented in American cities. In California, for example, the Surplus Land

Act requires the public sector to give preference to developers who commit to constructing at least 25 percent of their units as affordable housing on the land to be developed (California Department of Housing and Community Development, 2021). Sound Transit, a major transit agency in Washington state, is required to set aside 80 percent of its surplus land for affordable housing development upon completion of transit station construction (Sound Transit, 2018).

Park and ride (P&R) facilities are a common form of publicly owned land that provides spaces for people to park vehicles and transfer to public transportation, such as rail and bus rapid transit. Many public transportation authorities own large tracts of land that are used as surface parking, and the value of these is increasing as a result of urban growth and transportation improvements. Some of this land can be suitable for affordable housing and commercial or mixed-use development, and thus catalyzing TOD, while continuing to serve the parking function of the P&R through multi-story parking structures. P&R sites often have good potential for TOD because of their proximity to both residential communities and transit, although this potential varies depending on the land area, location, market conditions, and regulatory environment.

In this context, the Washington State Department of Transportation (WSDOT) can use its owned P&R facilities to catalyze TOD throughout Washington state. WSDOT currently owns a number of P&R sites in three metropolitan regions (Seattle, Vancouver, and Spokane) (Washington State Department of Transportation, 2021). Many WSDOT-owned P&R sites are located along the I-5, I-405, and I-90 corridors, while others are located within designated transit station areas. The list of WSDOT-owned P&R sites has changed as highway widening projects have progressed. WSDOT has purchased them from private owners to play an active role in shaping future land use along major corridors. Some P&R sites have been transferred to other transit agencies when the land was needed to expand parking to support transit services.

Because TOD often involves the development and management of multiple properties, interagency cooperation can be a major challenge for TOD projects at P&R sites. However, it is still possible. WSDOT has completed a feasibility study on implementing TOD at the Kingsgate P&R site, which is in a designated regional growth center in the Puget Sound region (Washington State Department of Transportation, 2018). The study was conducted in collaboration with local government, transportation agencies, and other key stakeholders. This multi-agency partnership helped to integrate the perspectives of developers, communities, local government, planning agencies, and transit agencies, making the TOD project more feasible and the study more applicable to other P&R sites.

What Washington state lacks is an effective tool to support the planning and implementation of TOD on publicly owned P&R land, which would be especially useful because land and financial resources are limited. Therefore, there is an urgent need to develop a practical tool to support the public sector's efforts to envision and plan for TOD on these sites. TOD planning and implementation on P&R sites must consider the following: (1) potential travel demand, (2) transit service provision and operation, (3) transit ridership enhancement, and (4) other supportive land uses. The goals are to increase transit ridership, reduce congestion, and create walkable environments for residents and pedestrians while addressing the pressing needs for affordable housing throughout much of the state.

To help identify the most promising P&R sites for TOD, this research developed a multi-criteria prioritization tool and tested it on selected P&R sites owned by the Washington State Department of Transportation. The resulting tool can be used to identify P&R sites that are most suitable for TOD, as well as to prioritize other forms of publicly owned land that are potentially suitable for TOD. To achieve this goal, the research sought to answer three questions:

(1) What indicators should be included to measure the suitability of public land for TOD?

(2) How do these indicators contribute to TOD suitability?

(3) With regard to the future progress of TOD on P&R sites, how can the use of this tool be extended?

We chose the Delphi method as the key component of our research methodology because it is an effective approach for selecting important indicators by building consensus among experts from different backgrounds. Three scenarios (Scenario (1) affordable housing emphasis, Scenario (2) market-rate housing emphasis, and Scenario (3) mixed-use emphasis) were designed to stimulate discussion of different land-use plans and to help experts reach consensus on the relative importance of the indicators. The resulting tool was used to calculate TOD suitability scores to determine the priority for TOD at three P&R sites.

Literature Review

Challenges in TOD Planning and Implementation

In practice, the implementation of TOD can face several challenges. First, development near transit hubs often takes developers a long time to complete because of the cumbersome approval process for land acquisition. Meanwhile, developers may also have to deal with land assemblage and control issues because there are usually multiple property owners on the sites (City of Seattle Department of Planning and Development, 2013). This may result in developers facing high land development costs to create TODs, making TOD projects less attractive to them.

Second, in densely populated areas, TOD developers must pay for scarce and expensive land resources, while in sparsely populated suburban areas, developers often do not consider TOD market-ready. Developers and public agencies may prefer to implement TOD in non-residential areas, which has been shown in previous TOD case studies that have focused on these areas (Cervero and Dai, 2014; Dumbaugh, 2004; Yang et al., 2016), often with trade-offs in terms of environmental qualities. This may be because authorities and developers want to avoid opposition to TOD projects from residents in surrounding neighborhoods, while still being able to control urban growth (Ibraeva et al., 2020). Unfavorable market conditions may make these urban areas less attractive to authorities and developers, resulting in inequitable transit-oriented development.

Third, local transportation policies may prioritize development for parking spaces in transit station areas. Much of the land around high-capacity transit stations/stops is used primarily for parking and lacks the upfront infrastructure to support TOD. It encourages the use of automobiles rather than a people-oriented public transportation system, making future TOD less promising. In addition, there is competition for TOD among potential locations because of limited funding (Atkinson-Palombo and Kuby, 2011). This competition requires public authorities to be more effective in allocating resources to the most suitable areas.

To address these issues, public agencies can redevelop the land they own to achieve higher land use densities and offer a part of the land to developers, potentially at a below-market price. The P&R lots owned by public agencies can be used more efficiently by concentrating parking spaces (potentially eliminating some, depending on use) and providing additional space for the development of housing units and local businesses. This can facilitate TOD in regional central areas where there is an imbalance between demand and supply of transit services, as well as in low-density suburbs or urban fringes. It is also worth considering how the potential for TOD in one location can influence the development priorities of other, competing locations. Efforts can be focused on areas with higher TOD potential to maximize the social benefits of redevelopment.

Assessing TOD Potential in Urban Areas Using Criteria Identification

TOD provides vibrant streetscapes and pedestrian- and bicycle-friendly built environments that make it convenient and safe for people to travel. It can help create more sustainable, livable, and equitable communities by increasing the use of public transit, spurring economic development, and leading to better health outcomes. To assess the potential for TOD around a specific location in urban areas, the literature has identified different dimensions of TOD and the specific metrics associated with them.

Cervero and Kockelman (1997) first developed criteria for evaluating the conditions for TOD from three main dimensions of the built environment: density, diversity, and design ("3Ds"). These three dimensions were thought to influence residents' travel rates and mode choices. The three main dimensions were later expanded to five main dimensions by adding accessibility and distance to transit ("5Ds") (Ewing & Cervero, 2001; Ewing et al., 2009). Demand management and demographics have also been identified as two additional dimensions for assessing TOD potential ("7Ds").

Common metrics used to measure the density for TOD include population, residence, and employment densities (Cervero and Kockelman, 1997; Singh et al, 2014). Measures of entropy of land uses and population groups can be used to characterize the diversity of TOD. Design characteristics, including walkability, cyclable streets, and network intersections, should also be considered to assess the walking and bicycling environment for supporting TOD (Cervero and Kockelman, 1997; Vale, 2015; Lyu et al., 2016). The actual performance of nearby transit systems is essential to characterizing a TOD area, which can be quantified by the metrics of transit ridership, frequency of transit service, job accessibility, and distance to the central business district (CBD). Providing accessible public safety facilities is also necessary for equitable TOD. (Wey et al., 2016).

In addition to these measurements, land use and fiscal policies, such as assigned TOD districts for financing the improvement of public transportation and TOD supportive zoning for encouraging the development of adjacent housing units, can also contribute to the success of TODs (Kim and Li, 2021; Mathur and Gatdula, 2023; Renne et al., 2011). These policy tools help integrate TOD into the overall urban planning system. (Cervero et al., 2002). The lack of supportive and fiscally health zoning can be a major barrier to TOD planning and implementation. Meanwhile, TOD is closely related to adjacent land and home values. TOD has been shown to have a significant positive impact on adjacent property values, while high property values can generate high tax revenues that contribute to local public finances (Shen, et al., 2018; Sharma and Newman, 2018; Conrow, et al., 2021). To put WSDOT-owned P&R sites to good use, we need to pay attention to TOD characteristics related to the supply and demand relationships of transit services, housing choices, and land uses. These supply and demand relationships are also influenced by supportive TOD policies and the sociodemographic composition of surrounding neighborhoods. Meanwhile, housing supply may also be influenced by the real estate market in the region. Therefore, this research identified indicators in five categories to measure TOD potential: public transportation services and demand, land-use mix and walkability, socio-demographic characteristics, real estate market conditions, and planning context.

Evaluating the Importance of TOD Indicators Through a Delphi Process

To develop a multi-criteria analysis tool, it is often necessary to evaluate the relative importance of each indicator in the list. Although previous studies have considered uncertainty in the weights of TOD indicators and conducted sensitivity analyses to examine this uncertainty, a practical method for calculating weights is still lacking (Singh et al., 2017). The Delphi method can provide generally reliable results for identifying criteria and quantifying the relative importance of indicators while requiring a limited budget and small number of participating experts (Boulkedid et al., 2011). It is a systematic and qualitative approach used to predict outcomes by collecting opinions from a group of experts through several rounds of evaluation. Specifically, it can be used to select and weight a list of indicators to measure a target. This method has been widely used in the analysis of urban issues. Musa et al. (2015) developed a list of environmental well-being indicators for assessing urban sustainability in Malaysia through a two-round Delphi survey with 45 experts. Perveen et al. (2019) systematically selected 23 transport impact indicators from the literature and assessed their importance in quantifying spatiotemporal patterns of urban growth through a two-round Delphi survey with 29 international experts.

The Delphi method can be used to identify criteria for transit-oriented development. Focusing on TOD in U.S. inner cities, Loukaitou-Sideris (2000) conducted a three-round Delphi survey in which a panel of 25 experts was asked about the various goals and objectives of TOD practice, as well as the preconditions and constraints of such development in economically disadvantaged inner city areas (Loukaitou-Sideris, 2000). Wey et al. (2016) used a fuzzy Delphi method to select TOD evaluation criteria that meet the principle of sustainable transportation and applied a fuzzy analytical network process to determine the weights of relevant planning criteria (Wey et al., 2016). In a manner similar to the form of the Delphi process, Searle et al. (2013) conducted semi-directed interviews with urban stakeholders for various TOD case studies and evaluated the implementation process and outcomes of TOD projects according to various criteria (Searle et al., 2013). These studies suggest that the Delphi method is an appropriate approach for identifying TOD criteria and assessing their relative importance.

Developing a TOD Planning and Implementation Support Tool

In TOD case studies, different formats of planning tools have been developed for TOD planning and implementation. First, TOD typology based on identified criteria has been widely used in previous studies to inform regional TOD planning (Reusser et al.,2008; Chen and Lin, 2015; Monajem and Nosratian, 2015). TOD typology indicates the full potential for TOD in a given location. Locations that are closer to the urban core and have more balanced transportation demand and supply have a higher full potential for TOD, as they can contribute to a more sustainable transportation system. The best-known approach for creating TOD typology is the node-place model (Bertolini, 1996; Bertolini, 1999). This approach uses the accessibility of a station (node) in the transit network and the land-use mix in that station area (place) to compare and identify the roles of potential stations in regional transit-oriented development. The node-place model has been modified by incorporating a more comprehensive list of TOD indicators (Kamruzzaman et al., 2014; Groenendijk et al., 2018).

A practical implementation tool has been developed to separately assess the existing level of TOD and the full potential for future TOD (Capital Metropolitan Transportation Authority, 2013). The existing level of TOD represents how much a location has been developed to support TOD, while the future potential for TOD indicates how much progress that location can make in facilitating TOD in the future. This tool can be used to prioritize potential TOD locations by measuring how far their current level of TOD is from the highest achievable level. Capital Metro, a transit agency in Austin, Texas, applied a TOD place typology to reflect the full TOD potential of transit stations based on their place-related characteristics, including land-use intensity, transit connectivity, and building form. Four categories of metrics were then identified, including current connectivity, market strength, land availability, and government support, to calculate a TOD readiness score. This TOD readiness score indicates how far a station has progressed toward its full TOD potential and how far it still has to go. A high score means that this transit station currently has characteristics similar to its place typology and is close to reaching its full TOD potential. Therefore, this transit station has a high priority for TOD.

The previous studies have major implications for the development of a priority tool for identifying TOD potential on public land in transit station areas. First, the TOD typology differentiates TOD sites by considering their competition and synergy effects in a given market area. The efforts made for TOD in one location will influence the efforts made for other locations. However, this method relies on either knowledge of future development of the entire urban area or the classification results from data analysis. Second, criteria for measuring the current conditions for TOD (i.e., TOD readiness) and the full potential for achieving the highest levels for TOD should be distinguished. TOD projects typically take several years to be fully implemented. Therefore, public agencies tend to be more interested in the current conditions for TOD on available sites. Assessing TOD readiness using quantifiable indicators is an important planning effort for prioritizing potential TOD sites.

Data and Methodology

Developing TOD Suitability Criteria Using the Delphi Method

Development of the TOD Prioritization Tool consisted of the following three steps. First, we identified a list of TOD-related indicators that are important in measuring the TOD suitability of a particular location. The importance of the TOD indicators was evaluated through the Delphi process, in which the inputs from multiple experts were obtained and synthesized, building consensus on indicators that are key to the success of TOD. Second, we measured and normalized the values of the identified TOD indicators for the selected P&R sites, which were then used to calculate TOD suitability scores. Finally, we used the obtained TOD suitability scores to determine the priority for TOD at selected P&R sites. The conceptual framework for developing the TOD priority tool is shown in Figure 1.

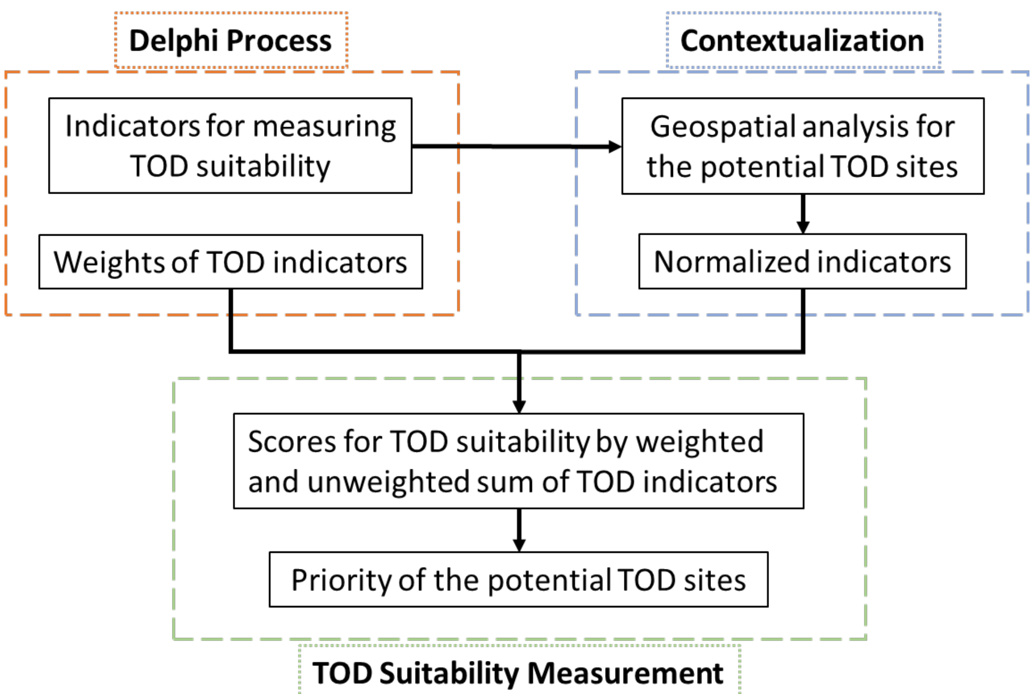


Figure 1 Framework for developing the TOD prioritization tool

The process of identifying the TOD suitability criteria was as follows. First, we developed an initial list of potential TOD indicators through a systematic review of the literature (Cervero and Kockelman, 1997; Ewing and Cervero, 2001; Cervero, et al., 2009; Singh, et al., 2014; Wey, et al., 2016; Singh, et al., 2017), which produced a list of 25 indicators organized into five categories: public transportation services and demand; land-use mix and walkability; socio-demographic characteristics; real estate market conditions; and planning context). This initial list of the TOD indicators was then used in our Delphi process, which consisted of three rounds of evaluation. We invited nine experts[1] with backgrounds and work experiences in urban and regional planning, real estate, and transit demand forecasting and management to participate in the evaluation process. In the first two rounds of evaluation, the nine experts were asked to rate and rank the importance of the indicators and return the results via email. No discussion between the participants was allowed in the first two rounds. After each of the first two rounds, the research team summarized the results of ratings and rankings provided by all experts and sent a summary report to them. The experts were encouraged to comment on the existing indicators and suggest additional indicators, resulting in a total of 28 indicators (Table 1). On the basis of these first two rounds, the third-round evaluation consisted of a 90-minute Zoom session in which the experts were invited to discuss the relative importance of the indicators. After that, the final list of the TOD indicators and their weights in different scenarios were obtained.

Because the experts with different professional backgrounds had different opinions about the relative importance of each TOD indicator, in the third round three alternative TOD scenarios were presented in which the indicators could be rated as having different levels of importance.

[1] Composition of the experts: four experts were professors from academic institutions, specializing in real estate development, transportation policy, and urban planning; the remaining five experts were professionals from planning organizations and transportation agencies in the state of Washington.

Scenario (1) emphasized affordable housing to meet low-income housing demand, for which TOD would provide a majority of the housing units for lower- and middle-income families. Scenario (2), in contrast, emphasized market-rate housing to generate more revenue to support public transit service expansion. Finally, Scenario (3) emphasized mixed-use development to improve transit accessibility to jobs and services and enhance residents' quality of life. The relative importance of the indicators under each scenario was discussed.

Table 1 Potential TOD indicators included in the Delphi process ("x" means the indicator was eventually eliminated from the list through the Delphi process)

No.	The domain of indicators	Indicators	First Round	Second Round	Third Round	Final List for Priority Tool
1	Public transportation services and demand	Population in proximity to P&R site and current adjacent transit services	√	√	√	√
2		10- or 20-years population projection in proximity to P&R site and planned adjacent transit services	√	√	×	×
3		Current transit ridership at P&R site	√	×	×	×
4		Job accessibility from P&R site and current adjacent transit services	√	√	√	√
5		Job accessibility from P&R site and planned adjacent transit services	√	√	×	×
6		Commute travel time	√	×	×	×
7		Non-SOV commuters	√	×	×	×
8		Distance to CBD	√	×	×	×
9		Traffic volume	√	×	×	×
10		Transit network connectivity	×	√	√	√
11		Presence of special generators of transit demand (universities, colleges, or hospitals)	×	√	√	√
12	Land-use mix and walkability	Land-use mix	√	√	√	√
13		Walkscore	√	√	√	√

No.	The domain of indicators	Indicators	First Round	Second Round	Third Round	Final List for Priority Tool
14		Street intersections	√	×	×	×
15		Neighborhood safety regarding crime	×	√	√	×
16	Sociodemographic characteristics	Employment	√	√	√	√
17		Car ownership	√	×	×	×
18		Racial diversity	√	√	√	√
19		Household income	√	√	√	√
20	Real estate market conditions	Land price/value	√	√	√	√
21		Housing unit rent	√	√	√	√
22		Home value	√	√	√	√
23		Commercial Market	√	×	×	×
24	Planning context	Transit supportive policies	√	√	√	√
25		Transit supportive land use zoning	√	√	√	√
26		Future upzoning potential	√	√	√	×
27		Housing affordability	√	×	×	×
28		Development activity	√	×	×	×

The experts were asked to rate the entire list of indicators using five levels of importance in the first two rounds and nine levels of importance in the third round. The five-level ratings consisted of (1) most important, (2) more important, (3) moderate, (4) less important, and (5) least important. For the nine-level ratings, four intermediate importance levels between two consecutive levels of the five-level ratings were added as compromise options. The rating results were then used to calculate the inter-rater agreement to determine the degree of agreement between the experts on the rating of each of the indicators. Given the overall low inter-rater agreement for the indicators using the five-level ratings, we consolidated the "most" and "more important" levels, as well as the "less" and "least important" levels, to obtain three-level ratings. The calculation of the inter-rater agreement was based on the three-level ratings. Inter-rater agreement ranged from 0 to 1, with a higher value indicating a greater degree of consensus. The inter-rater agreement was measured by using the following equations.

$$IR_{ij} = \begin{cases} 1 & if\ R_i = R_j \\ 0 & if\ R_i \neq R_j \end{cases} \quad (1)$$

$$IR = \frac{\sum_{j>i}^{n} \sum_{i=1}^{n-1} IR_{ij}}{n_{ij}} \quad (2)$$

where R_i and R_j ($i < j$) are, respectively, the rating of the ith and jth experts; IR_{ij} is the comparison between R_i and R_j; IR refers to the value of the interrater agreement; and n_{ij} is the number of pairs of i, j.

The inclusion and exclusion of potential TOD indicators depended on the results of the ratings and rankings. The indicators rated as less important and having a low ranking with a high inter-rater agreement were considered for elimination from the next round of evaluation. In this study, a low ranking was defined as an average above a threshold (which was 10 for the final round) with a high inter-rater agreement defined as above 0.4.

The eliminations of potential TOD indicators in the three rounds of evaluation are shown in Table 1. At the end of the first round, ten indicators were eliminated from the list because they were rated as moderate or less important and had a relatively low ranking, although only five of them had an inter-rater agreement above 0.4. As one of the aims of the Delphi process is to narrow a list to more important indicators, the indicators rated as moderate or less important and with a lower average ranking were eliminated without meeting the high level of agreement. Meanwhile, three additional indicators were added to the list based on the experts' suggestions: transit network connectivity, the presence of special generators of transit demand (universities, colleges, or hospitals), and neighborhood safety related to crime. These three indicators were not evaluated in the first round, but they were included in the second and third rounds.

At the end of the second round, the research team proposed to consolidate the two population-related criteria and the two job accessibility indicators. The reason for proposing the consolidations was that it is difficult to forecast population and job accessibility because of a lack of available data sets for future conditions. Meanwhile, the previous two rounds had shown that the two indicators measured the same factor and were generally of similar importance across the list. This proposal for consolidation was then voted on and adopted in the next round. In addition, to provide a more comprehensive list for discussion in the online session, the other indicators listed were retained for the third round.

After the online discussion session (i.e., the third round of evaluation), the experts were asked to rate and rank the indicators again. The results of this final round of evaluation were used by the research team to determine the final list of TOD indicators (Table 1). According to the results of the evaluation, future upzoning potential and neighborhood safety related to crime were dropped from the list, while one additional indicator was dropped from each scenario. The additional dropped indicators were home value for Scenario (1), and racial diversity for Scenarios (2) and (3). This list retained 14 indicators because they were rated as more important, with a high inter-rater agreement and a relatively high ranking at the end of the Delphi process. Each of the five domains was measured by at least two indicators. Among these indicators, 12 were identified as common indicators used in all three scenarios, while two were optional indicators used only in some of the scenarios.

Measuring TOD Suitability Using the Prioritization Tool

To measure the TOD suitability of the P&R sites, we computed the values of the TOD indicators in the final list (shown in Table 1) for 0.5-mile (i.e., 800-meter or about a 10-minute walk) and 1-mile (i.e., 1600-meter or about a 20-minute walk) buffer areas around the P&R sites using geospatial data. These buffer areas were slightly larger than the boundaries that had been defined in some previous studies (Calthorpe, 1993; Guerra, et al., 2012) because the centers of the buffer areas were the centroids of the P&R sites rather than the TOD stations/stops, while the nearest TOD stations/stops were included in the buffer areas. The data sources and measurements of the TOD indicators are shown in Table 2.

Table 2 Data sources and measurements of the TOD indicators selected through the Delphi process (* refers to the auxiliary variables used to measure the selected TOD indicators)

No.	**Category**	**Indicator**	**Measure(s)**	**Unit**	**Data source**	**Data resolution**
1	Master indicators	Transit network connectivity	Mean of the Z-scores of transit routes and transit frequency	Z-score	Derived from transit routes and transit frequency	Census Block Group
		** Transit routes*	*Total number of transit lines that pass through the buffer area*	*Number of transit routes*	*WSDOT Geospatial Database – Transit Routes*	*Line*
		** Transit frequency*	*Average of transit frequency density of the intersecting block groups by their proportions in the buffer*	*Transit frequency density per hour during evening peak period*	*2021 Smart Location Database of US Environmental Protection Agency*	*Census Block Group*
2		Presence of special generators of transit demand (universities, colleges, or hospitals)	Whether there exists at least one special generator intersects with the buffer	0: no special generator nearby 1: at least one special generator nearby	OpenStreetMap	Point
3		Job accessibility in proximity to P&R site and adjacent transit services	Mean of the Z-scores of the job accessibility within 10, 20, 30 minutes transit and auto travel time	Z-scores	Derived from the job accessibility within 10, 20, 30 minutes transit and auto travel time	Census Block
		** Jobs within 30 minutes transit travel time*	*Total number of accessible jobs from the centroid of the P&R site*	*Number of jobs*	*Accessibility Observatory of University of Minnesota*	*Census Block*
		** Jobs within 20 minutes transit travel time*	*Total number of accessible jobs from*	*Number of jobs*	*Accessibility Observatory of*	*Census Block*

No.	Category	Indicator	Measure(s)	Unit	Data source	Data resolution
			the centroid of the P&R site		*University of Minnesota*	
		** Jobs within 10 minutes transit travel time*	*Total number of accessible jobs from the centroid of the P&R site*	*Number of jobs*	*Accessibility Observatory of University of Minnesota*	*Census Block*
		** Jobs within 30 minutes auto travel time*	*Total number of accessible jobs from the centroid of the P&R site*	*Number of jobs*	*Accessibility Observatory of University of Minnesota*	*Census Block*
		** Jobs within 20 minutes auto travel time*	*Total number of accessible jobs from the centroid of the P&R site*	*Number of jobs*	*Accessibility Observatory of University of Minnesota*	*Census Block*
		** Jobs within 10 minutes auto travel time*	*Total number of accessible jobs from the centroid of the P&R site*	*Number of jobs*	*Accessibility Observatory of University of Minnesota*	*Census Block*
4		Population density in proximity to P&R site and adjacent transit services	Average population density of the intersecting block groups by their proportions in the buffer	Density of household persons	2020 American Community Survey 5-Year Estimate	Census Block Group
5		Transit supportive land use zoning	Proportion of the land with transit supportive zoning type (including mixed use, multi family, downtown, commercial/office)	%	GIS Open Databases of Snohomish, Clark, and Spokane County	Land Use Parcel
6		Transit supportive policies	Lynnwood: Regional Transit Authority Tax in Snohomish Spokane: Multi-Family Tax Exemption (MFTE) Zones/Boundary; special taxing districts - Public Transportation Benefit Area (PTBA)	Number of relevant policies	Comprehensive plan/MPO of Snohomish, Clark, and Spokane	County

No.	Category	Indicator	Measure(s)	Unit	Data source	Data resolution
			Clark: None			
7		Land price/value	Mean land value per acre of the intersecting tracts by their proportions in the buffer	Price per square meters	Federal Housing Finance Agency 2020 land value dataset	Census Tract
8		Housing unit rent	Average of median gross rent of the intersecting block groups by their population proportions in the buffer	Median monthly gross rent per unit (dollars)	2020 American Community Survey 5-Year Estimate	Census Block Group
9		Land use mix	Land use entropy[2] in the buffer area; Land use types include single family, multi family, mixed use, downtown, commercial/office, industrial, school/public facilities, water, parks/wildlife refuge	Land use entropy ranged from 0 to 1	GIS Open Databases of Snohomish, Clark, and Spokane County	Land Use Parcel
10		Walkscore	Walkability to nearby amenities at a location	Score ranged from 0 to 100	Walk Score	Point
11		Household income	Average income level of the intersecting block groups by their population proportions in the buffer	Median household income (1000 dollars)	2020 American Community Survey 5-Year Estimate	Census Block Group
12		Employment density	Average density of employees living in the intersecting block groups by their population proportions in the buffer	Density of employees	2020 American Community Survey 5-Year Estimate	Census Block Group

[2] The land-use entropy was calculated as in the equation: $Entropy = -\frac{\sum_{i=1}^{k} p^i ln(p^i)}{ln(k)}$ where p^i is the percentage of each land-use type in the buffer area, k is the total number of land use types.

No.	Category	Indicator	Measure(s)	Unit	Data source	Data resolution
13	Choice indicators	Racial diversity	Average race diversity of the intersecting block groups by their proportions in the buffer	Race entropy[3] ranged from 0 to 1	2020 American Community Survey 5-Year Estimate	Census Block Group
14		Home value	Average median home value of occupied housing unit of the intersecting block groups by their proportions in the buffer	Median house value per unit (1000 dollars)	2020 American Community Survey 5-Year Estimate	Census Block Group

TOD policies have been adopted to support TOD in Washington state, although they vary from one jurisdiction to another. For example, residents of King, Pierce, and Snohomish counties who live within the Sound Transit District have been required to pay the Regional Transit Authority (RTA) tax on vehicle purchases or renewals since 2016. This tax helps fund the construction and operation of transit services by Sound Transit, one of the largest transit agencies in Washington state. Another example is that to encourage more market-rate housing and affordable housing options in areas with higher percentages of low-income households, the City of Spokane offers multi-family residential property tax exemptions (MFTE) to developers that meet a number of requirements, thereby contributing to a greater mix of incomes and housing types as intended by state law. Similar policies have been implemented in other cities and counties. Special taxing districts have also been established to invest in public transit in the cities of Airway Heights, Cheney, Medical Lake, Millwood, Liberty Lake, Spokane, and Spokane Valley.

[3] The race entropy was calculated as in the equation: $Entropy = -\frac{\sum_{i=1}^{k} p^i ln(p^i)}{ln(k)}$ where p^i is the percentage of each racial group in the buffer area, k is the total number of racial groups.

We selected three P&R sites to test the TOD prioritization tool. The three sites were located in the regional growth centers of Snohomish, Clark, and Spokane counties in Washington state, as shown in Figure 2. They were selected for the following reasons.

(1) The Snohomish County site is a transit center in the City of Lynnwood. It had a relatively large parking area and is close to the planned Link light rail station (operated by Sound Transit). Lynnwood, part of the Seattle metropolitan area, is 16 miles north of Seattle and 13 miles south of Everett, near the intersection of Interstate 5 and Interstate 405, making the P&R site, with its large number of available parking spaces, important for TOD.

(2) The Clark County site, the only WSDOT-owned P&R site in the region, is near the City of Vancouver and is also important for TOD because of its location. Vancouver is part of the Portland-Vancouver metropolitan area, near the intersection of Interstate 5 and Interstate 84. It is the largest city in Clark County and the fourth largest city in the state of Washington.

(3) The Spokane County site was chosen because the City of Spokane, where the site is located, is the second largest city in Washington state after Seattle, and the site is relatively centrally located within that city. It is a critical region in the far east of the state of Washington, bordering the state of Idaho.

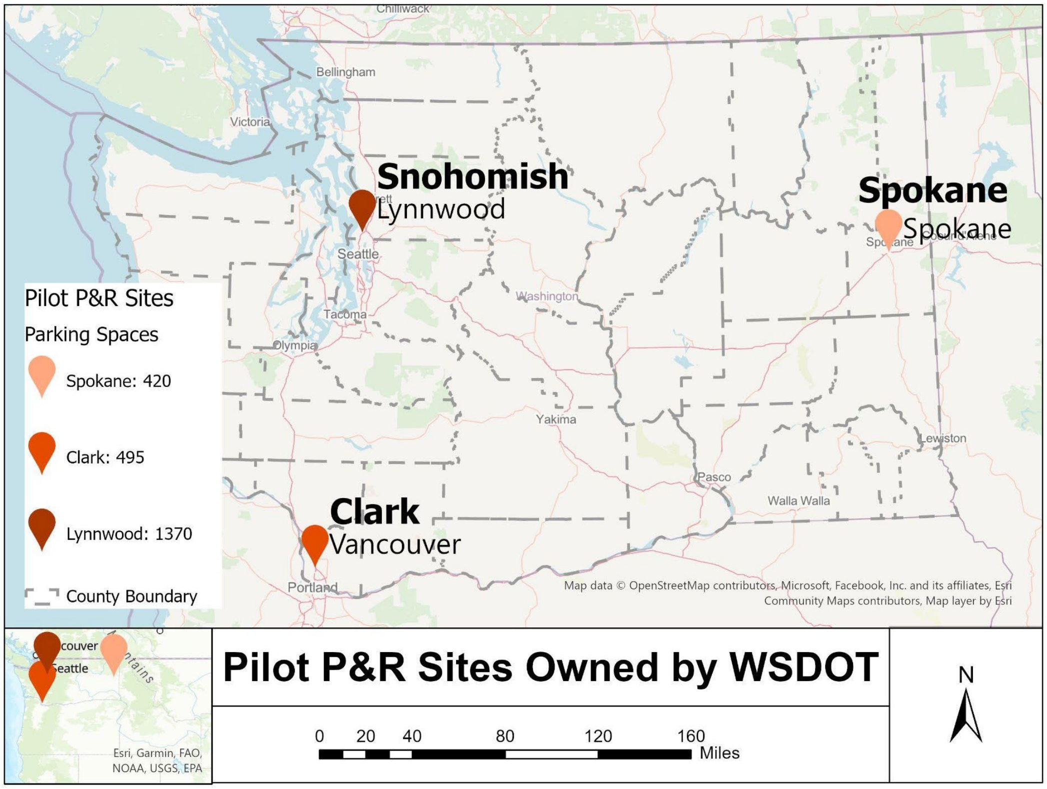


Figure 2 Distribution of the selected P&R sites owned by WSDOT

As an application of the TOD prioritization tool, we calculated the weighted and unweighted sums of the z-scores of these indicators to obtain a TOD suitability score for each site. We identified the most promising site for TOD by comparing their suitability scores.

$$S_i = \sum_{j=1}^{n_j} \beta_j Z_{ij} \tag{3}$$

$$Z_{ij} = \frac{(V_{ij} - Aver(V_{1j}, V_{2j}, V_{3j}))}{Std(V_{1j}, V_{2j}, V_{3j})} \tag{4}$$

where S_i is the TOD suitability score of the site i; β_j is the weight of the indicator j; n_j is the number of the TOD indicators; V_{ij} and Z_{ij} are the values of indicator j and its z-score of the site i; V_{1j}, V_{2j}, V_{3j}, respectively, refer to the values of indicator j for the three sites; $Aver(V_{1j}, V_{2j}, V_{3j})$ and $Std(V_{1j}, V_{2j}, V_{3j})$, respectively, refer to the mean and the standard deviation of V_{1j}, V_{2j}, V_{3j}.

The weights of the TOD indicators were derived from the principal right eigenvector of the pairwise comparison matrix of indicator importance levels obtained from the rating results. The concept of the pairwise comparison matrix came from the Analytic Hierarchy Process (AHP) method, which can be used for complex decision making based on ratings (Saaty and Katz, 1990; Strong et al., 2017). Specifically, the nine levels of TOD indicators' importance were assigned values of 1 to 9, where 9 referred to the most important and 1 was the least important. For each expert, the values of the indicator importance levels were compared in pairs to obtain that expert's pairwise comparison matrix. The principal right eigenvector of the pairwise comparison matrix was then computed to obtain the indicator weights given by that expert. Finally, the indicator weights used to calculate the TOD suitability score were obtained by averaging the weights derived from the rating results of all experts. The pairwise comparison matrix was calculated as in Equations (5) through (7).

$$C_{ij} = R_i - R_j + 1 \quad \text{if} \quad R_i \geq R_j \tag{5}$$

$$C_{ij} = \frac{1}{R_j - R_i + 1} \quad \text{if} \quad R_i \leq R_j \tag{6}$$

$$C_{ij} = \frac{1}{C_{ji}} \tag{7}$$

where C_{ij} refers to the value in the ith row and jth column of the comparison matrix; R_i is the importance value of the ith indicator; and R_j is the importance value of the jth indicator. C_{ij} is the ratio of the weight of the ith indicator to the weight of the jth indicator. If C_{ij} is equal to 1, then the ith and jth indicators are equally important and have the same weight. If C_{ij} is greater than 1, then the ith indicator is more important than the jth indicator and therefore has a lower weight. Conversely, if C_{ij} is below 1, then the ith indicator is less important than the jth indicator and thus has a smaller weight. In addition, the eigenvalue corresponding to the principal eigenvector is the largest eigenvalue of the pairwise comparison matrix.

The pairwise comparison matrix obtained by comparing the importance levels of the indicators was then normalized by dividing by the sum of the values in each column. The principal right eigenvector of this matrix was obtained by calculating the sum of each row. It was also the vector of the factor weights. Since the TOD indicators in the list were grouped into five domains, we also calculated the weights of each domain by using the average importance levels of the indicators in the domain. The method used to calculate the domain weights was the same as that used to calculate the factor weights. The final weights of the TOD indicators were equal to the factor weights multiplied by the domain weights.

Results

Evaluating the Importance of the TOD Indicators

Table 3 shows the rating and ranking results of the final round of evaluation for the TOD indicators. The mean rating and inter-rater agreement were measured based on the three-level Likert scale. For Scenario (1), all indicators in the public transportation and planning context domains were rated and ranked as relatively more important in the list, with an agreement level higher than 0.4. Housing unit rent, walking score, household income, employment density, and racial diversity were rated and ranked lower, and with a level of agreement lower than 0.4. As for Scenarios (2) and (3), transit network connectivity, the presence of special generators of transit demand, and transit-supportive policies had lower mean ratings and rankings than in Scenario (1), where the level of agreement on the importance of these indicators became lower than 0.4. The other indicators in the public transportation and planning context domains were still considered more important, with a higher level of agreement. Land-use mix and household income became more important in Scenario (2), whereas job accessibility and the land-use mix became more important in Scenario (3). In addition, the other indicators in the list still had a level of agreement lower than 0.4 in Scenarios (2) and (3).

Table 3 Rankings and ratings of the TOD indicators for different scenarios

Indicators	Scenario 1: Affordable housing			Scenario 2: Market-rate housing			Scenario 3: Mixed-use development		
	Mean rating	Inter-rater agreement	Mean ranking	Mean rating	Inter-rater agreement	Mean ranking	Mean rating	Inter-rater agreement	Mean ranking
Transit supportive land use zoning	1.11	0.78	3.56	1.11	0.78	3.28	1.11	0.78	3.39
Job accessibility (both by transit and automobile)	1.44	0.44	5.78	1.44	0.44	6.17	1.22	0.61	5.33
Population density	1.44	0.44	7.72	1.22	0.61	5.61	1.11	0.78	5.28
Transit supportive policies	1.22	0.61	7.94	1.56	0.36	8.17	1.56	0.36	8.39
Land price/value	1.44	0.61	6.89	1.33	0.58	5.28	1.33	0.5	6.06
Transit network connectivity	1.22	0.61	6.89	1.56	0.36	7.06	1.67	0.33	8.17
Land-use mix	1.44	0.44	6.72	1.22	0.61	6.72	1.33	0.5	5.83
Household income	1.78	0.28	9.06	1.44	0.44	8.22	2	0.25	10
Walkscore	1.78	0.36	8.61	1.89	0.28	9.28	1.78	0.28	8.89
Presence of special generators of transit demand (universities, colleges, or hospitals)	1.33	0.5	6.61	1.67	0.33	8.56	1.56	0.36	7.44
Housing unit rent	1.78	0.36	10.06	1.56	0.44	9.44	1.67	0.33	9.83
Employment density	2	0.33	11.67	2	0.33	11.28	1.78	0.36	10.72
Home value	2.22	0.36	11.28	1.67	0.33	10.56	1.67	0.33	10.39
Racial diversity	1.89	0.28	9.61	2.44	0.44	11.94	2.56	0.44	12.44

Table 4 shows the weights of the TOD indicators, which varied among the scenarios. The weights ranged from 4.5 percent to 13.9 percent. The public transportation and planning context domains were generally considered more important than the other domains in the three scenarios, while the socio-demographic characteristics domain was considered less important. Transit supportive land-use zoning had the highest weight in all three scenarios, followed by job accessibility by both transit and automobiles. The indicators with the lowest weights differed among these scenarios. In comparison to the other indicators in the list, employment density in proximity to the P&R sites had a relatively lower weight in all three scenarios.

Table 4 TOD indicators' weights in different scenarios

No.	Category	Indicators	Scenario (1): Affordable housing (%)	Scenario (2): Market-rate housing (%)	Scenario (3): Mixed-use development (%)	Average weights of the scenarios (%)
1	Common indicators	Transit supportive land use zoning	13.56	13.85	13.76	13.02
2		Job accessibility (both by transit and automobiles)	10.36	9.29	10.2	9.44
3		Population density	8.98	11.6	12.05	10.32
4		Transit supportive policies	8.67	8.81	8.02	8.06
5		Land price/value	8.29	9.28	8.66	8.3
6		Transit network connectivity	8.26	7.79	6.1	7
7		Land-use mix	7.39	7.12	7.55	6.98
8		Household income	6.94	7.48	5.88	6.42
9		Walkscore	6.4	4.92	5.17	5.21
10		Presence of special generators of transit demand (universities, colleges, or hospitals)	6.13	4.48	5.01	4.94
11		Housing unit rent	5.21	5.55	6.04	5.31
12		Employment density	4.61	4.69	5.16	4.57
13	Optional indicators	Home value	/	5.13	6.39	5.46
14		Racial diversity	5.22	/	/	4.95
Sum of weights			100	100	100	100

Measuring TOD Suitability for Park and Ride Sites Using the Prioritization Tool

Figure 3 and Figure 4 show, respectively, the unstandardized and the standardized values (i.e., Z-scores) of the TOD indicators for the 0.5-mile and 1.0-mile buffer areas of the three P&R sites. For some of the indicators, the values for the 0.5-mile and 1.0-mile buffers of a given P&R site were obviously different. Specifically, for the Spokane site, the densities of population and transit-supportive zoning areas within the 0.5-mile buffer area were significantly higher than those within the 1.0-mile buffer area. In contrast, the average household income, racial diversity, and average home value within the 0.5-mile buffer area were substantially lower than those within the 1.0-mile buffer area of the Spokane County site. For the Lynnwood site, the density of transit zoning areas and average household income were higher inside the 0.5-mile buffer area, while population density, average housing rent, employment density, racial diversity, and average home value were higher inside the 1.0-mile buffer area. For the Clark site, only the average housing rent was significantly lower for the 0.5-mile buffer than the 1.0-mile buffer.

In comparing the results in Figure 3 to those in Figure 4, it is worth noting that the orders of the TOD indicator values among the three pilot P&R sites were consistent between standardized and unstandardized results, as well as between the results for the 0.5-mile and the 1.0-mile buffer areas. To make the indicator values directly comparable across different sites and different scenarios, standardized values should be used to measure TOD suitability.

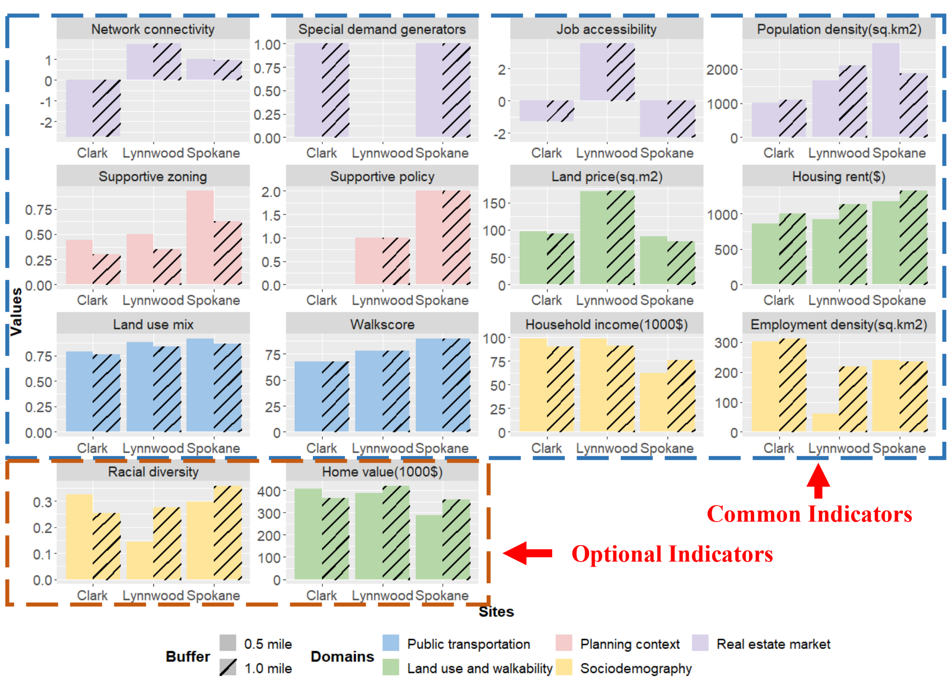


Figure 3 TOD indicator values for the 0.5-mile and 1.0-mile buffer areas of the P&R sites (not standardized)

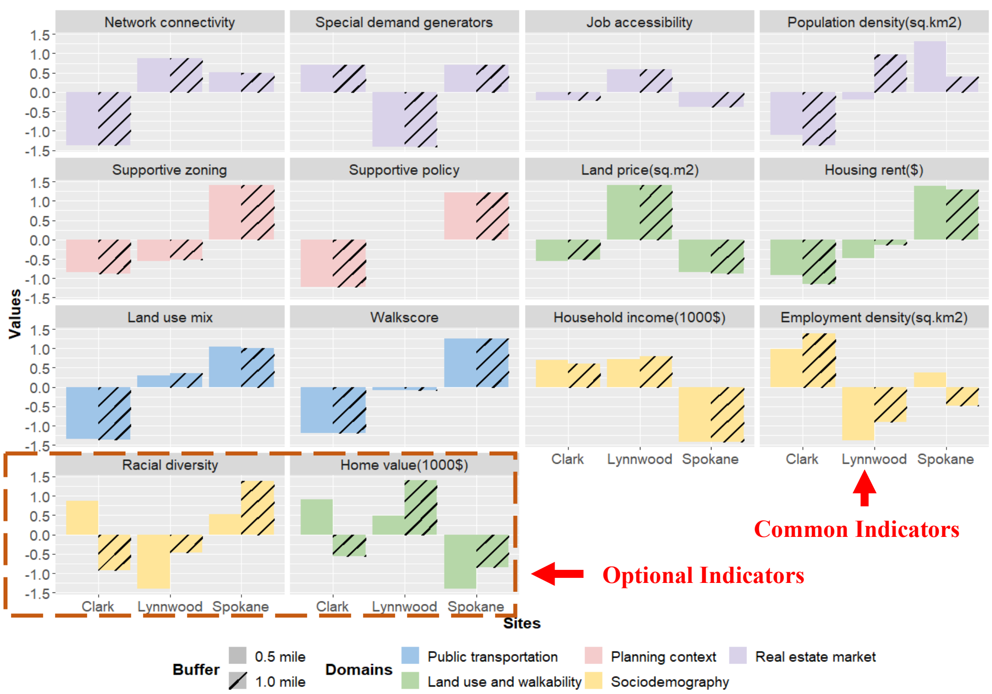


Figure 4 TOD indicator values for the 0.5-mile and 1.0-mile buffer areas of the P&R sites (standardized to Z-scores)

Figure 5 and Figure 6 show the TOD suitability scores for the three scenarios at the P&R sites. To ensure the robustness of the resulting suitability scores, both the weighted and unweighted sums of the Z-scores of the TOD indicators were calculated and compared. Theoretically, the TOD suitability score had the same range of values as the Z-score multiplied by 100.

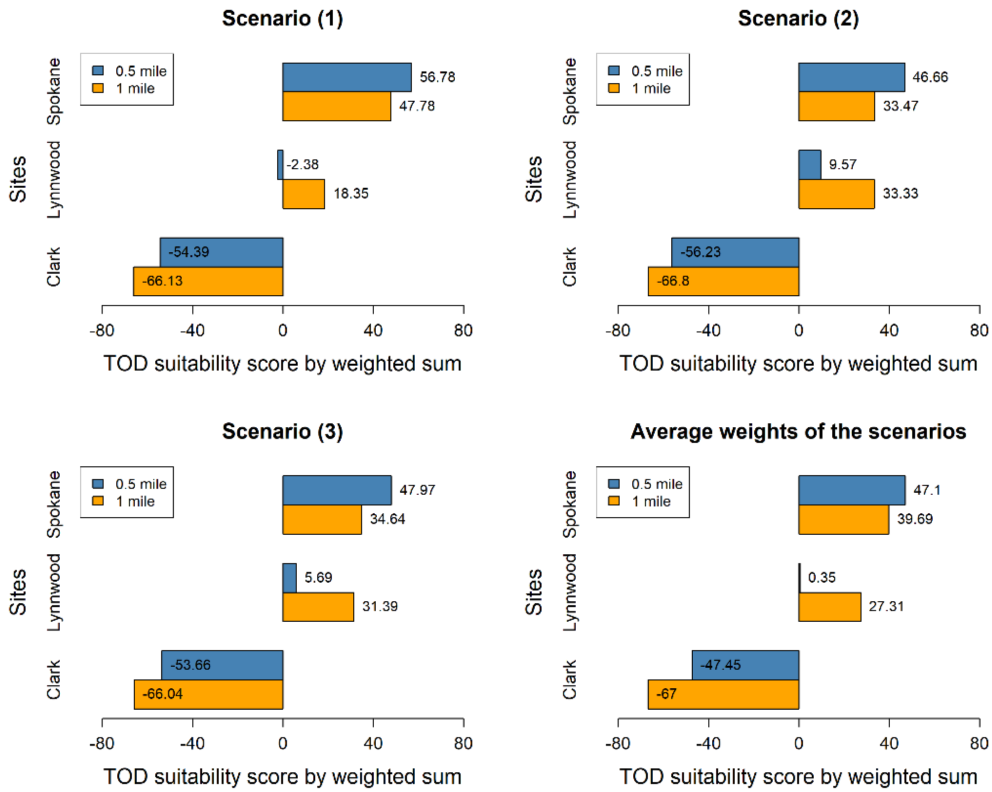


Figure 5 TOD suitability scores for different scenarios at the P&R sites (weighted)

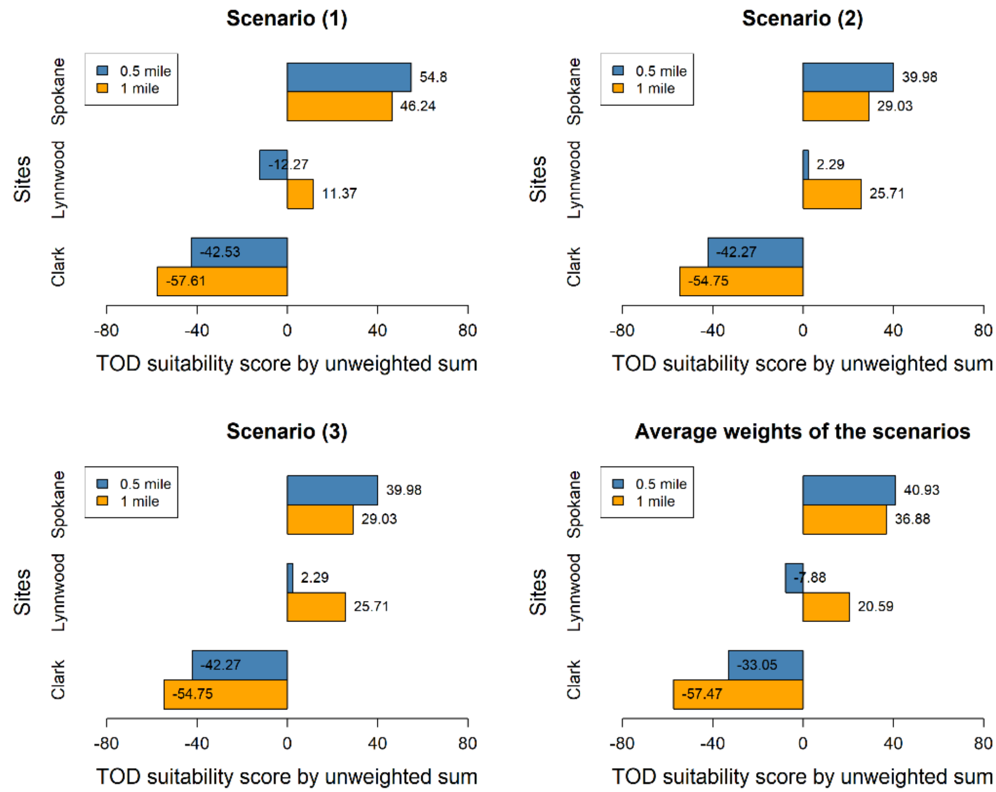


Figure 6 TOD suitability scores for different scenarios at the P&R sites (unweighted)

The unweighted sum means that all indicators listed had the same weight and the sum of the weights was 100 percent. As Scenarios (2) and (3) had the same list of TOD indicators, the unweighted sum of these two scenarios was the same, whereas the weighted sum was different. In addition to the scores for the different scenarios, we also calculated the TOD suitability scores by using the average indicator weights of the three scenarios. Average indicator weights were calculated for all the 14 indicators (the 12 common indicators and two optional indicators, shown in Table 3) across the three scenarios and normalized to a sum of 100 percent. The average indicator weights were intended to be used for a more general case in which the implementation scenario of a TOD project was not clearly specified.

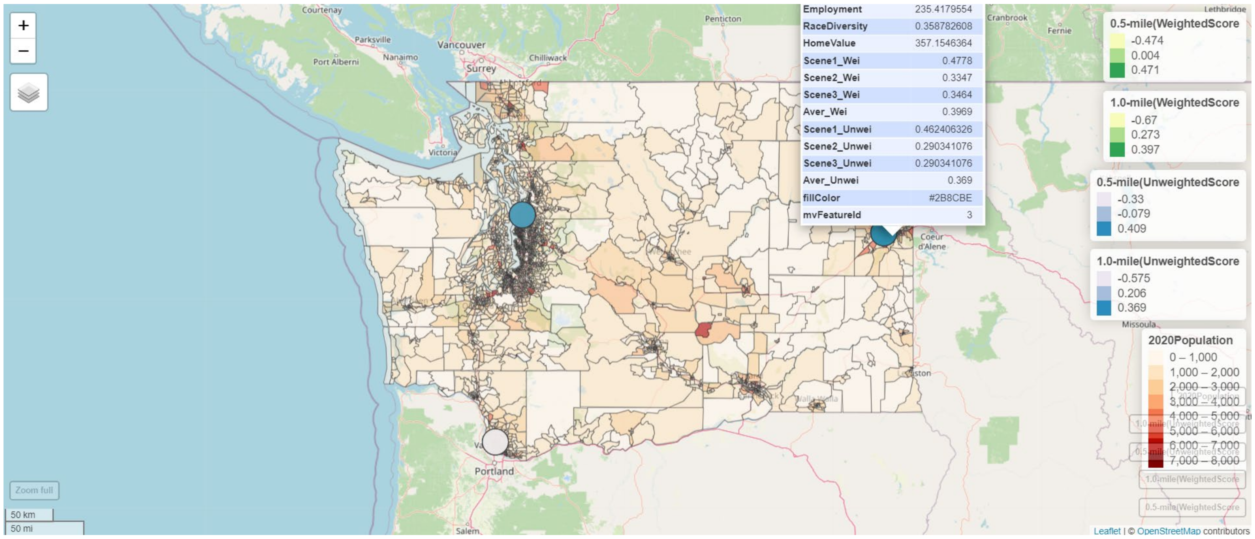
As shown in Figure 5, the TOD suitability scores of the three pilot sites ranged from -100 percent to 100 percent. Among the three P&R sites, the Spokane site had the best suitability for

TOD in each of the three scenarios, but the Lynnwood site had only a slightly lower score for the 1.0-mile buffer area for Scenarios (2) and (3) that respectively emphasized market rate housing and mixed-use development. The Lynnwood site showed a clear difference between the TOD suitability scores for the 0.5-mile and 1.0-mile buffer areas. This difference in suitability scores was due to the significantly different population densities, housing rents, employment densities, racial diversity, and home values in the two buffers (shown in Figure 4), especially the population density with a high weight. For the Spokane and Clark sites, TOD suitability within the 0.5-mile buffer was slightly better than within the 1.0-mile buffer for all three scenarios, while the opposite was true for the Lynnwood site.

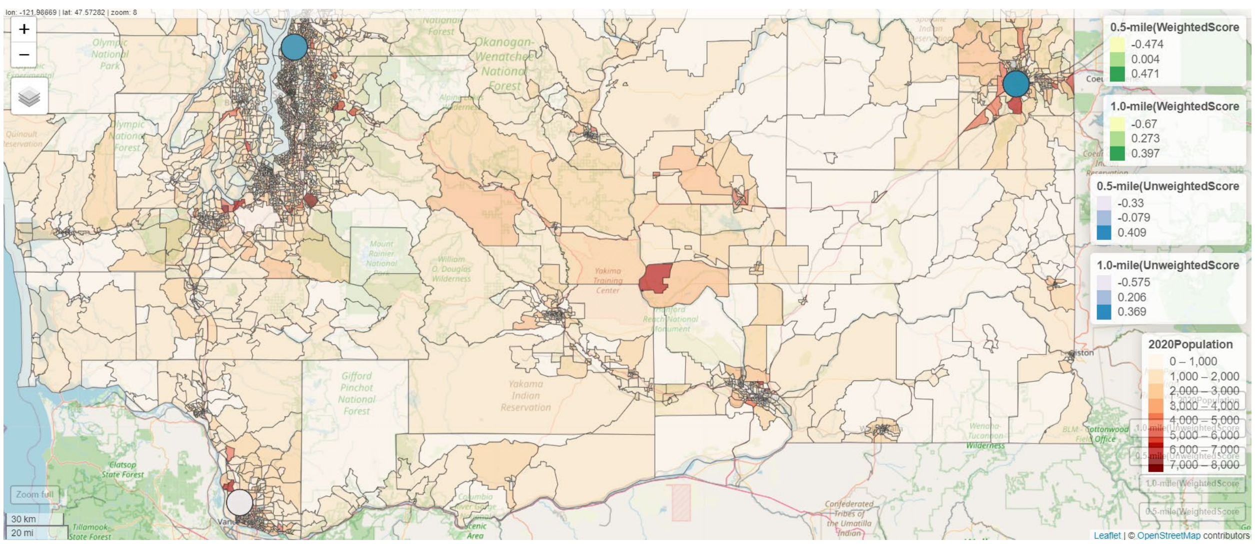
In comparison to the weighted results, the TOD suitability scores for the three sites calculated with the unweighted sum showed some differences (Figure 6). The TOD suitability of the Clark site became higher, although it was still the lowest of the three pilot sites. The TOD suitability of the Lynnwood site became lower. As for the Spokane site, its TOD suitability remained high in Scenario (1), which emphasized affordable housing. This implies that the Spokane site may be particularly suitable for TOD projects aimed at promoting affordable housing. Note that the order of priorities among these three pilot sites remained the same for all three scenarios.

Visualizing the Potential for TOD

To visualize the results of applying the TOD prioritization tool, the researchers used the R package Mapview to create interactive maps and display the measured TOD suitability of the P&R sites. As shown in Figure 6, the interactive map allowed users to zoom in on the scale of the three P&R sites. Clicking on a point displayed all of its information. This information included the value of each TOD indicator listed and the TOD suitability scores obtained from the prioritization tool. The results of the weighted and unweighted TOD suitability scores were also shown on the right.



(a) Zoom out to present the entire Washington state



(b) Zoom in on the scale of the P&R sites

Figure 7 Interactive maps of the tool’s application outcomes

Discussion and Conclusions

This research developed a multi-criteria TOD prioritization tool and used it to measure the suitability of TOD at publicly owned P&R sites. The tool consisted of a total of 14 indicators in five domains: public transportation services and demand, land-use mix and walkability, sociodemographic characteristics, real estate market conditions, and planning context. We also designed three TOD scenarios emphasizing affordable housing, market-rate housing, and mixed-use development, respectively, for a more focused application of this tool. Different TOD indicators were selected and applied to prioritize potential TOD sites under these scenarios.

A Delphi process was used to select the most relevant TOD indicators and assign weights to them based on the experts' ratings and rankings. These weights represented the relative importance of the indicators for measuring TOD suitability. The results, shown in Table 4, indicated that the importance of most TOD indicators did not vary much across the scenarios. If a scenario for future development cannot be decided because of uncertainty in practical projects, then the average weights of the indicators of the scenarios can be applied.

All TOD indicators in the list were enumerated, normalized, and weighted to measure the TOD suitability of publicly owned P&R sites. The results of this research indicated that the weighted scores differed for some locations and for different TOD scenarios. This TOD prioritization tool can be customized and applied to measure the development priorities of other public lands in the future. For a sensitivity analysis, these TOD indicators were also unweighted to obtain the TOD suitability scores of the selected sites and compare them with the weighted results.

This TOD prioritization tool can be applied to measure the suitability of a broader set of P&R sites in Washington state and elsewhere in the future. First, the datasets used to measure the

TOD indicators in the tool are public and available to regions nationwide. This makes the indicator measurement feasible for other locations. Second, the tool takes into account a comprehensive list of TOD indicators, both common TOD characteristics (i.e., public transportation, land use, sociodemographic characteristics, and real estate market domains) and local characteristics that support TOD (i.e., planning context domain). To contextualize and evaluate a public land for TOD suitability, various dimensions related to TOD can be included by applying this TOD prioritization tool. In addition, this tool uses the standardized values of the TOD indicators to compare the TOD potential of the public lands assessed. It can help agencies understand the relative competitiveness or readiness of different locations for TOD, as well as the changing TOD potential at these locations.

It is worth acknowledging that the small number of experts who participated in the Delphi process probably limited the number of disciplines and the range of professional experience represented in the process of rating and ranking TOD indicators. On the other hand, the small number of experts made it possible for the research team to organize the online discussion session for the experts to exchange different opinions and build consensus on the relative importance of the indicators.

This study had a limitation in that we selected only three P&R sites for evaluation and comparison of their potential for TOD. In light of this limitation, this multi-criteria TOD prioritization tool can be more widely applied to TOD planning and implementation in future research. In the next phase, additional P&R sites or other public lands owned by WSDOT will be included in the analysis. The tool can be further developed through improving the measurements of the identified TOD indicators by using new datasets.

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Appendix

Table 1 Worksheet for collecting the experts' opinions on the importance of TOD indicators in the final round of evaluation

Variable name	Rating of each indicator (5-level ratings: 1=most important, ..., 5=least important) (You can choose the intermediate values between two adjacent ratings, e.g., 2.5 between 2 and 3)									Ranking among all indicators (n=16)	
	Most important (1)	Intermediate importance between the 1 and 2 (1.5)	More important (2)	Intermediate importance between the 2 and 3 (2.5)	Moderate (3)	Intermediate importance between the 3 and 4 (3.5)	Less important (4)	Intermediate importance between the 4 and 5 (4.5)	Least important (5)	Your rankings for the second round	Your *suggested* ranking for the final round
Transit supportive land use zoning											
Job accessibility in proximity to P&R site and adjacent transit services											
Population in proximity to P&R site and adjacent transit services											
Transit supportive policies											

Variable name	Rating of each indicator (5-level ratings: 1=most important, ..., 5=least important) (You can choose the intermediate values between two adjacent ratings, e.g., 2.5 between 2 and 3)									Ranking among all indicators (n=16)	
	Most important (1)	Intermediate importance between the 1 and 2 (1.5)	More important (2)	Intermediate importance between the 2 and 3 (2.5)	Moderate (3)	Intermediate importance between the 3 and 4 (3.5)	Less important (4)	Intermediate importance between the 4 and 5 (4.5)	Least important (5)	Your rankings for the second round	Your *suggested* ranking for the final round
Land price/value											
Land use mix											
Presence of special generators of transit demand (universities or colleges, hospitals, et al.)											
Walkscore											
Future upzoning potential											
Household income											

Variable name	Rating of each indicator (5-level ratings: 1=most important, ..., 5=least important) (You can choose the intermediate values between two adjacent ratings, e.g., 2.5 between 2 and 3)									Ranking among all indicators (n=16)	
	Most important (1)	Intermediate importance between the 1 and 2 (1.5)	More important (2)	Intermediate importance between the 2 and 3 (2.5)	Moderate (3)	Intermediate importance between the 3 and 4 (3.5)	Less important (4)	Intermediate importance between the 4 and 5 (4.5)	Least important (5)	Your rankings for the <u>second round</u>	Your *suggested* ranking for the <u>final round</u>
Transit network connectivity (stop's/station's nodal value)											
Housing unit rent											
Home value											
Employment											
Racial diversity											
Neighborhood safety regarding crime											

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