**Abstract**

Public Lands in Washington State appeal to a diverse spectrum of recreational users with considerable interest in the accessibility of these lands. As a visual medium, maps have a uniquely informative capacity to represent the complexities of accessibility to a broad audience. Public lands in Washington have therefore been mapped extensively by public and private interests, making the resulting products widely available to recreational users. However, while these products may provide information on areal extent and elevation, they neglect a crucial dimension of the accessibility of public lands: Time. This study consolidates temporal data associated with the accessibility of public lands in Washington State, hourly to seasonal. The resulting interactive cartographic representation demonstrates land accessibility relative to a discrete point in time, defined by the viewer. The binary distinction between accessible and inaccessible is shown to be superseded by a nuanced spectrum of accessibility dependent upon temporal factors. Accessibility shifts subtly as access points and the pathways allowing egress to those points change over time.

**Introduction**

Washington State encompasses nearly 30,000 square miles of diverse public land, ranging from high mountain summits to rugged, wave-carved coasts. This complex system of public holdings represents more than 41% of the state’s total area, much of it open to a variety of recreational uses (Dunford & Zander, 1983). Washington’s public lands are therefore a subject of keen interest among residents and visitors alike, all of them searching for the next opportunity to explore the most beautiful environments the state has to offer. The accessibility of these lands therefore remains a major concern among stakeholders (Brown et al., 2015). However, not all public lands are created equal, and accessing a public parcel can be as simple as walking down the street or as difficult as hiking for several days through unforgiving mountainous terrain, weighed down by a host of specialized equipment. Therefore, many park users desire accurate, in-depth information on their local parks when planning a visit and indeed, when deciding which park among many is worthy of visiting.

Of course, many of the recreational opportunities associated with Washington’s park system have existed for more than a century, with some of the state’s most iconic public properties established soon after its admission to the union in 1889 (Ingraham, 1895). As geographic information systems have developed and garnered wider recognition, recreational lands have been among the first to receive analytical attention. However, while the extent of these lands is well known, researchers often overlook one of the most influential factors in their accessibility. That factor is time, and the many changes that accompany the passage of one season to another, or indeed, one hour to the next. Time dictates whether a park will be closed, a bus route to a hiking destination suspended, or a trail buried under several feet of snow. The first question on many recreational users’ minds is, “when should I go?” But this information is often not easily gleaned from a traditional map.

The purpose of this project, therefore, is to unite time with cartography to produce an interactive web map that accurately depicts continuing changes in the accessibility of Washington’s public lands. There exists a wealth of research on the topic of time geography and on the connections between time and accessibility. All that remains is to connect this understanding to a practical application situated in a specific geographic context, Washington State. This application will serve an audience of recreational users searching for accessible local parks and seeking to choose one among many that is worthy of visiting at a particular time. Through the implementation of interactive controls, users will dictate their needs to the application and receive accurate planning information based on these needs. In addition to answering the question “when should I go?”, the application will serve as an important foundation for collecting information on user interaction with parks in Washington State. The selections made by this diverse group of users will provide insight into the effectiveness of local greenspaces and will illustrate differences in the temporal accessibility of many parks that would otherwise appear comparable.

**Literature Review**

The relationship between time and geography, first described in research in the early 1970s, has since become a subject of considerable relevance to current GIS research. Given the tremendous influence of time on an individual’s ability to access important features of their environment, time is now mentioned frequently in conjunction with geographic accessibility. It shares this distinction with a multitude of relevant political and climatological factors, including the traditional measure of physical proximity. Studies that attempt to describe an individual’s access to surrounding features will therefore supplement route analysis with temporal closures, transportation changes, and climatological variations.

In 1970, Torsten Hägerstrand, writing for the Regional Science Association, critiqued the treatment of people as identical, perfectly divisible, and interchangeable within the social sciences. While he viewed aggregation as necessary to the efficient production of large-scale analysis, Hägerstrand argued that the spatial experience of single individuals was poorly understood. He wrote that an individual could not be separated from their experience of time and existed always on a continuum. Certain locations could only be visited at particular times, and every individual, due to travel time and bodily constraints, was bound within a limited geographical “island”, despite what the map may display. Hägerstrand concluded by lamenting the inability of technology to account for the experience of the individual.

However, aided by the availability of modern GIS tools, researchers have made significant progress in the analysis of an individual’s temporal path through the spatial environment. For instance, in a 2019 study, Allen examined the impact of time and transportation availability on access to public libraries. The results showed substantial differences between the accessibility of libraries at different times of day or week, which the author attributed to library hours and public transportation routes. As a result, individuals without access to a personal vehicle experienced smaller windows of time with access to local libraries. Neutens et al. (2012) conducted a similar study of government offices, adding gender and employment status. These factors, when considered in the context of individual accessibility, played an important role in individuals’ access to government buildings. For example, the overlap between a person’s working hours and the open hours of government facilities significantly restricted access for the working individual. Kwan expanded knowledge of personal accessibility in a study of Franklin County Ohio. Using personal travel diaries, Kwan compared personal accessibility to more conventional measures of physical proximity, finding that there were obvious differences along gender lines, even between individuals in the same household. Importantly, women’s experience of personal accessibility was not as strongly correlated with conventional accessibility. Kwan hypothesized that differences could be attributed to gender roles that reduce the feasibility of visiting certain locations, regardless of travel time (2010).

Alongside the growing body of temporal and personal accessibility research, academic attention has increasingly been paid to the incorporation of time into GIS technologies and research. This is evidenced in models like the one developed by Shaw & Xin that describes a format for practical research design that planners may use when attempting to answer geographic questions (Shaw & Xin, 2003). While this is merely one of many such models, the authors’ careful consideration of the placement of time in experimental design is evidence of the growing need to effectively communicate the passage of time in geographic representations. In extending spatiotemporal theory to modern planning, additional research by Romero et al. provides insight into the cultural conception of time and the interaction between time and visual representation. The authors demonstrated that visual conventions such as placing temporal information on a left-to-right continuum had a marked impact on viewer perception of the passage of time (Romero et al., 2019). Additional projects such as the historical progression of Kyoto produced by Yano et al. demonstrate the application of these conventions to a GIS project, communicating the passage of time to an uninitiated audience using spatial representation. Using GIS in conjunction with VR and archival media, the authors demonstrate how recent technological developments can be applied together to strengthen the connections between cartography, spatial analysis, and time (Yano et al., 2008).

While temporal and personal accessibility represent new and blossoming fields of scientific inquiry, conventional research of site-based accessibility has also been advanced by the development of new knowledge, GIS technologies, and modeling frameworks. Increasingly, measures of conventional, destination accessibility are viewed in conjunction with the nuanced personal characteristics involved in individual, temporal accessibility. Such is the case in both the Morey et al. and Apollo et al. studies of site-based accessibility. Morey et al. created several hypothetical recreation environments, asking mountain bikers to evaluate the accessibility of these environments. Bikers had obvious preferences for lower access fees and the availability of single-track trails. However, the accessibility of a site was also influenced by individual circumstances, such as ownership of a bike with a strong suspension system. Importantly, the study demonstrated that site-based characteristics are not only those naturally found in the environment but those imposed on it by human managers (Morey et al., 2002). The Apollo et al. study included similarly diverse characteristics, but within a physical research area, the high Himalayas. Features specific to the Himalayan environment, i.e. snowpack, vegetation, topography, road access, and other development were shown to play a substantial role in a mountaineer’s ability to access climbing opportunities in the region. However, a single individual factor, such as the inability to obtain a permit, could completely nullify accessibility factors dependent on the destination (Apollo, 2017). That is not to say that destination-based accessibility factors are unimportant. Snowpack, vegetation, topography, and road access are all popular areas of continuing study. Taking snowpack for example, technological advancements in the assessment of snow accumulation are well documented by Nolin. The increasing accuracy of remote multispectral analysis allows not only for the prediction of snow cover extent and depth, but also snow-water equivalent and the onset of snowmelt in spring (Nolin, 2010), which plays a significant role in the accessibility of alpine regions over time. In addition to accurately mapping present snow extent, research attention has also been paid to predicting snow accumulation and extent well into the future. Rasmus & Lehring demonstrate this possibility using newly generated atmospheric and weather predictions for the late 21st century (2004). Their model, validated by measurement at field sites, represents one of many additions to the increasing library of spatiotemporal data with accessibility implications. Another is the model developed by Hewer et al. in their evaluation of the impact of weather on visitation to Pinery Provincial Park, Canada. Evaluating tourism in response to daily temperature and precipitation, the authors found that visitation was associated with a particular temperature range, above or below which visitation would begin to decline. Precipitation also had a significant negative relationship with visitation. Using these relationships as a starting point, Hewer et al. were able to project impacts on future park visitation using climate projections for the region (2016).

Lastly, in addition to personal, site-based, and temporal characteristics, physical proximity is an important contributor to “real accessibility”. Network analysis is therefore a topic of considerable importance to researchers involved with GIS. Contemporary network analysis studies, in response to related personal and temporal accessibility findings, often seek to incorporate these factors into the research design. Yigitcanlar et al. approach this intersection by diverging from the traditional assumption of automobile travel as the default. Instead, the researchers develop a GIS-based network analysis on the Gold Coast composed entirely of public transportation and walking routes. The resulting accessibility index illuminates potentially overlooked areas that are difficult to access for those without a personal vehicle (Yigitcanlar et al., 2007). In a similar study, Comber et al. sought to map access to greenspaces in Leicester, England, using roads and paths as the foundation of the network. However, in addition to mapping the distance to the nearest greenspace from any given point in the city, the authors incorporated census data to identify disparities. Identifying concentrations of ethnic groups around the city, Comber et al. found that Indians, Hindus, and Sikhs had lesser access to greenspaces than the general population (2008). Incorporating temporal, rather than personal accessibility factors, Schielein et al. developed a network analysis in the Brazilian Amazon that accounted for changes in road quality over time by recording travel time to locations within the forest across the wet and dry seasons. Poorer road quality in the wet season was evidenced by longer travel times in the forest, revealing a continuing temporal pattern (Schielein et al., 2003).

Accessibility has always been a popular research topic, but one that is deceptively complex. Simple accessibility measures that aggregate entire populations across all time have explanatory value but are less relevant to any individual user (Miller & Wu, 2000). Fortunately, in addition to an advanced understanding of the factors that influence accessibility, contemporary researchers are also adept at incorporating both time and individual characteristics into spatial models. This is obviously the case in the context of network analysis. Nuanced individual temporal concerns also played a role in several of the site-oriented accessibility studies described here. The relevance of these concerns to the sprawling field of accessibility will surely spur further study on the topics.

**Intervention**

To unite individual accessibility concerns with public lands in Washington, it was necessary to develop an application that responds to both the temporal accessibility of public lands and any Washington resident’s individual circumstances. Therefore, the intervention developed in conjunction with this report is a web application that accepts several user inputs (starting location, date and time, travel method, and desired travel time) to filter parks by their temporal proximity to the user, excluding those that are closed at the specified time. The filtered parks are then placed into 1 of 5 categories depending on the assumed travel time from the user’s location. The user may then tab between these parks, view details such as the regular hours and managing agency and create a route that dictates a path from their location to the selected park using the travel method of their choice. The user may select an option to account for traffic, which will alter the accessibility of parks within their immediate area depending on average traffic patterns over the course of the day.

Although the primary function of this application is routing from a user location, it also responds immediately to any changes made to the date and time. Therefore, without inputting a location, a user may still plan their park visit by selecting a date and time and panning over the map to see which parks remain open at that time. The application accounts for seasonal light level changes to accurately reflect the status of parks that open at sunrise or dawn.

**Methods**

To gauge the accessibility of Washington’s public lands, it was first necessary to develop a comprehensive map of these lands, isolating those that are open to recreational use. In service of this goal, OpenStreetMap proved to be the most comprehensive resource for obtaining park boundaries. However, it excluded most of the land held by the Washington State Department of Natural Resources. To fill this gap, additional features were therefore acquired from the DNR’s open data portal and merged with the existing OSM park dataset in ArcGIS Pro.

Although the OSM data download was restricted to Washington State, some features nevertheless extended beyond state boundaries. To remedy this, the park dataset had to be clipped to the extent of Washington State using a boundary shapefile downloaded from the DNR. After completing this operation, several fields were added to the data table, including the managing agency, open time, close time, open date, and close date. DNR features were supplied in the form of parcels rather than comprehensive park units, so to transform them, named features were dissolved and unnamed features were merged if they clearly represented pieces of a continuous unit. In the process of examining the dataset and performing background research, many park features were removed if they were closed to public use or open only to a small subset of users in a particular club or community. Some examples include the watersheds that supply drinking water to Tacoma and Seattle, McNeil Island, military installations, gated community parks, land trust properties managed for conservation, and conservation easements on private property, among others.

To answer the question of how park accessibility changes over time, it was initially hoped that park open times and dates could be obtained via the Google Maps API. However, this data quickly proved to be inaccurate, with many parks within the same management unit displaying vastly different opening times. Additional research often revealed that these times did not correspond to the managing agency’s listed policy. A more in-depth analysis of the parks and managing agencies yielded a level of accuracy that would not have been possible otherwise, and revealed many parks that were restricted to a particular club or community yet appeared as part of the larger OSM dataset without additional comment. The dates and times in the park data table were therefore populated with information supplied largely by individual government websites and sometimes supplemented by an inspection of park signage in Google Street View or photos attached to the online park listings.

Because the goal of this project was to account for individual differences in temporal accessibility, the park dataset needed to respond to parameters set by a user who may or may not be trained in cartography. To this end, the dataset was exported from ArcGIS Pro as a geojson to be used in an interactive webpage created using HTML5. The website was designed to include an interactive date and time selector. Using the date and time fields populated in ArcGIS Pro, parks could be filtered out if the user-selected date and time fell outside the listed open times. Because some parks open not at a specific hour, but at a relative time like dawn, the SunCalc library was used to account for sunrise and sunset times throughout the year so that these times could be used in the park filter.

With administrative hours accounted for, the application would still need to respond to an individual user’s location and transportation requirements to properly answer the question of changing accessibility. Therefore, the application was improved to allow a user to drop a pin, or, for the cartographically untrained, search for an address using the Nominatim geocoder, to supply a starting point for the route analysis. The foundation of this analysis was the Mapbox API’s Isochrone generator, which accepts a location and several additional parameters and returns an isochrone polygon representing the area around that location accessible within a given amount of time. To ensure the adaptability of the web application, controls were added to allow any user to communicate their individual needs to the API. These controls included the method of transportation, starting time, and desired travel radius, formatted as 4 successively longer travel times to allow for comparison between local parks. The returned isochrones, instead of being displayed on the map, were instead used in a turf.js intersection to identify the parks that intersected a particular isochrone, i.e. those within 10 minutes, 20 minutes, etc. of the user. The symbology of each group of parks was then edited to easily communicate the travel time to the user, and the park’s information added to a sidebar. The application would exclude any park from the filter if it was closed at the user-specified time.

This web application was finally hosted on the web and made available to the general public to allow any individual in Washington to set the parameters and examine differences in the accessibility of their local parks over time.

**Discussion**

The temporal accessibility application, in addition to serving as a planning aid for park goers in Washington State, has revealed several patterns of changing park accessibility throughout the state. Firstly, seasonal administrative closures of Washington parks are incredibly rare, with only 52 of the 6,837 parks, or 0.76% of park features experiencing a regular seasonal closure. Of these, 22 are managed by the Washington State Parks and Recreation Commission. However, it is worth noting that some parks, particularly in mountainous regions, may experience road closures that effectively prevent the greater public from accessing them in the winter and spring seasons, while others experience internal road and trail closures that impact only a small portion of the park (King County, 2021). Environmental factors may likewise limit access at irregular times (Jenkins et al., 2023); however, these are more nuanced than the administrative closures that form the basis of the present research. The project could reasonably be expanded in the future by incorporating factors such as stream flows, snowpack, road closures, and temporary administrative closures for individual parks.

Unlike seasonal closures, nightly closures are quite common, with 4,025 parks (58.87%) experiencing a regular nightly closure. There is not a single park in the dataset closed between the hours of 12pm and 3pm, and only one park (the Tổ Đình Việt Nam;Vietnamese Cultural Center) closed anytime between 10am and 4pm. However, given Neutens et al. (2012) findings about the restrictive impact of employment status on access to public facilities, these hours are likely to coincide with regular work hours, limiting accessibility for the employed. Closures are often tied to the sun, rather than a standard time, with 2,083 parks opening at sunrise or dawn and 2,567 closing at sunset or dusk. Of those parks that close nightly, the earliest to reopen do so at 4am in Seattle. The last to close do so at 12am, though this is not the official city, county, or statewide ordinance of any managing agency. Rather, it is a special allowance for several individual parks in various jurisdictions, almost all of which are incredibly popular local tourist destinations. This means that 58.87% of the parks in the state are closed every night between midnight and 4am. While only about 59% of parks experience a nightly closure, many others may be effectively closed to the general public due to separations between camping and day-use areas and the inability of an average person to obtain a camping reservation at any time they would like to visit a park. Many parks allow camping only at specific times of the year (National Park Service, 2018), which is not a factor the application accounts for. Still other parks may allow nighttime visitors, but do not have established campsites and therefore couldn’t accommodate a visitor for the period that they might prefer (Washington State Parks and Recreation Commission, 1997). Likewise, permit accessibility may dramatically limit the ability of recreational users to visit a park during all hours that it is administratively open, such as in the popular Enchantments permit area in the Central Cascades, which distributes permits to only about 6% of applicants annually (Whelan, 2023). Future additions to the web application may account for the various amenities available to park users, as well as any special use permits required in an effort to expand the scope of accessibility beyond simple administrative closures.

Despite the sheer number of parks experiencing daily administrative closures, these represent only a small minority of the total public land area in the state at approximately 691 square miles. This contrasts with the total public land area in the dataset, which is approximately 29,590 square miles (41% of the state’s area). This number may be slightly less than the total public land area due to the exclusion of public land without recreational access (Dunford & Zander, 1983). Nevertheless, parks with daily administrative closures represent only about 2.34% of the public lands included in this dataset. This means that the vast majority of the state’s public land (97.66%) is administratively open to the public at all hours of the day, year-round. This figure of course neglects many other important accessibility concerns such as a user’s physical ability to reach these parks at various times of year or spend an extended period of time within them. Including road and trail coverage and composition, slope (Lepoglavec et al., 2023), snowpack, and stream flow for individual parks may be a useful future addition to the application in the service of trip planning.

It is important to note that parks with administrative closures, in addition to being relatively small (with several notable exceptions), are often confined to urban and suburban areas. Of the 4,025 parks experiencing daily closures, 2,964 of these (73.64%) are city managed, and therefore within city limits. An additional 503 (12.50%) are county managed, often in the regions immediately surrounding a city or town. Notable gaps in park coverage are particularly sizeable in rural areas, which often represent a buffer between park-dense urban centers and the sprawling federal and state park properties in remote uplands. This finding is supported by prior research regarding spatial inequalities in park access. In 2013, Wen et al. identified a similar pattern across the contiguous US, with rural residents traveling a greater distance on average to reach local parks than their urban counterparts. Additional research predicated on the quality-of-life benefits of park access has formed the basis of standards for greenspace proximity, accounting for both distances traveled and the size of the target parks (Pauleit et al., 2003). Given this guidance, and the relevance of individual accessibility to the research at hand, these parkless zones present an enticing avenue for further study.

The current project serves the individual needs of Washington residents through a user-friendly web application, but it does so without aggregating data about these individuals or their requirements. Future research may compare population density maps with park coverage and collect information on user-submitted locations to produce meaningful statistics about the number of accessible parks within the user’s radius and the overall area of parkland available to them. Storing these values in a database would allow claims to be made about the regions where park access is relatively weak and therefore allow for the identification of ideal future park sites.

**Conclusion**

Outdoor recreation is often a personal affair. Much will depend upon an individual’s circumstances; where they live, what transportation they have access to, their physical ability, and most importantly, what time it is. Maps may have a timeless quality, but when embarking on an outdoor experience, time is inescapable and plays a vital role in accessibility. Despite this, time remains a poorly mapped phenomenon, especially in the context of outdoor recreation.

The goal of this project was therefore to examine temporal changes in park accessibility and identify common patterns with a strong bearing on trip planning. Given the well-researched importance of individual differences on a user’s ability to access features in the world around them, the project sought to improve user interactivity to allow for the incorporation of those differences. Providing accurate feedback to a user’s personal circumstances would allow for a close examination of how access differs between various users, and how park accessibility looks when viewed from the perspective of an aggregated group of park users.

The web application successfully incorporated administrative closures of nearly 7000 distinct tracts of parkland in the state, and in doing so revealed several interesting patterns with the potential to serve as vital planning aids. Among these were the strong prevalence of nightly closures, scarcity of seasonal closures, restricted geographic extent of administratively closed parks to urban areas, and lack of parkland in transitional land between suburban and unpopulated uplands. The application also successfully incorporated user controls for location, departure time, transportation type, and desired transportation range, allowing for informative comparisons between these variables. Unsurprisingly, travel by car was the most effective means of reaching the greatest number of local parks, but also experienced greater hourly fluctuation due to traffic in urban centers. Users located in these urban centers typically had access to the greatest number of parks across transportation types and travel radii. However, these urban parks were typically among the smallest in the state, and users living in remote uplands would therefore enjoy access to a greater total area of park land, limited to far fewer administrative units. These remote units, in contrast to urban parks, were also much more likely to remain open at all hours of the day for the entire year.

However, while this project represents an informative intersection between personal and temporal accessibility, it nevertheless illustrates pathways for additional research and development that will more fully answer the question of changing personal and temporal access to park lands. Most importantly, while the application serves as a strong framework for providing informative feedback to park users in Washington State, it has yet to be used by the broader public, and its research value is therefore limited to what can be derived by a single user making multiple hypothetical inputs for the sake of comparison. To examine personal accessibility more accurately, the application will need to be used by a larger public audience, making a wider variety of selections. It will also need to be capable of recording these selections and aggregating them into meaningful statistics about where park users are located, the size and quantity of the park units they have access to, their transportation needs and typical departure times, as well as their desired travel distance.

Administrative closures represent the simplest version of changing temporal accessibility. As time passes, a park enters one of two binary states, open or closed. Because administrative closures fundamentally block public access completely, they are one of the most important accessibility factors for park goers seeking to plan a trip with a temporal dimension. However, administrative closures are not the only factor that links to both time and accessibility. Among numerous additional temporal accessibility factors are road closures, snowpack, stream flow, campsite availability, and reservoir water levels, all of which have the potential to dramatically impact accessibility, but in a manner that is not binary between no access and complete access. In service of providing more complete accessibility information to recreational users, these would all be valuable inclusions in the temporal park application, in addition to many accessibility factors that may have no temporal dimension. Among these factors are park amenities, road and trail availability and quality, slope, and terrain type, among others.

At this moment, the application dictates accessibility in terms of the travel time from a user defined location. This is a convenient measure, but ideally the routing engine would be capable of evaluating all of the additional accessibility concerns to more accurately gauge travel time not only to each tract of park land, but also between points within the park. By incorporating these values, a user would be able to ask not only “when should I travel to this park?”, but also “where should I go within the park once I arrive, and at what time should I go there?”

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