

Calibrating the Huff Model for Outdoor Recreation Market Share Prediction *Ski Industry in Washington State*



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By Chelsey Aiton and Brenden Mclane

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ii. List of Acronyms

- EE - Earth Economics
- OFM - Washington State Office of Financial Management.
- PNSAA - Pacific Northwest Ski Areas Association
- RCO - Recreation and Conservation Office
- RFP - Request for Proposal
- SCORP - 2013 Washington State Comprehensive Outdoor Recreation Plan
- SES - Social-Ecological System
- SWE - Snow-Water Equivalent

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v. Recommended Course of Action

In this study, we tested and calibrated the GIS-based Huff Model market analysis tool to predict market shares of 12 ski resorts within Washington State. The results of this testing indicate a high degree of accuracy in the Huff Model’s ability to predict each resort’s market share based on a number of intrinsic and extrinsic variables. Our market share predictions came within 1 percentage point of reality for 10 of 12 resorts, and within 5 percentage points of reality for 2 of 12 resorts. With these results, we recommend the use of the Huff Model to our sponsors, Earth Economics, for further predictions of other outdoor recreation activities’ market shares, when actual market share data are unobtainable. Furthermore, our testing of two other market share prediction methods, network service areas and Thiessen polygons, yielded less accurate results than the Huff Model. However, our testing also indicates that the accuracy of the Huff Model estimates depends on a high degree of accurate information about the locations where each outdoor activity is performed. Without such information, the Huff model predictions could be less accurate. Furthermore, the Huff Model inputs used in

this analysis require further geoprocessing to be used on other outdoor recreational activities in Washington State. Finally, the Huff Model Python script must be modified to prevent the exclusion of certain inputs.

1.0 Introduction

1.1 Washington State Request for Proposal

This project began with a Request for Proposal (hereafter RFP) from the Washington State Recreation and Conservation Office (hereafter RCO), and Earth Economics' successful bid in Spring of 2014 to conduct the analysis required by the RFP. The stated purpose of this RFP is to “quantif[y] the economic contribution of outdoor recreation to Washington State's economy” (RCO 2014, 3). The RFP includes 5 modules which introduce various levels of analysis. For a complete listing of the modules, refer to **Appendix B**. Module I is concerned with valuing the economic contribution of all outdoor recreation in Washington State. Specifically, the analysis must “quantify the total annual economic contribution (direct, indirect and induced, and resulting number of jobs) of all expenditures related to outdoor recreation in Washington State” (RCO 2014, 3). While this sort of analysis has been done before, this current RFP additionally requests that the granularity of the analysis be reduced to the level of the legislative district, most preferably, or to the county level, less preferably. This is to allow for the creation of county or legislative district recreation profiles which can be delivered to office holders, giving them a better understanding of the role that outdoor recreation plays in the economy of their jurisdiction. It is in this aspect that our work with Earth Economics has been concentrated. Specifically, the GIS-based Huff Model market analysis tool, the use of which is our main focus in this study, can be used to help disaggregate activity-based spending from the state level to that of the constituent locations where the activities are performed. Subsequently, this spending can then be allocated to the legislative districts and counties in which it took place, contributing to a larger total economic contribution for each area.

1.2 Justification and Goals

1.2.1 Earth Economics-specific Goals and Justification

While the Huff Model is traditionally applied to the analysis of retail store placement in relatively confined geographic areas, we elected to focus on its application in the ski industry at the scale of Washington State. Our focus on the ski industry came spontaneously midway through our larger focus on Module I of the RFP. Our sponsor, Greg Schundler of Earth Economics, was experiencing difficulty receiving visitation statistics for Washington ski resorts. We had previously been testing the Huff Model's ability to predict absolute visitation (as opposed to relative market share) of local public parks. For more on this, please refer to **Appendix F**. We were asked if the Huff Model could be used to estimate each ski resort's share of the ski market, to help disaggregate state-level ski spending data. The Huff Model had, up until now, delivered disappointing results for the purposes to which we had been putting it. However, we elected to pursue its application in the ski industry nonetheless. When, shortly after our initial testing, Greg informed us that he had succeeded in obtaining resort-specific visitation data for the last 10 years, we saw a unique opportunity to test and calibrate the Huff Model.

By comparing our Huff Model results to the actual market shares, we could see how accurate the tool is. Furthermore, we could calibrate the inputs required to make accurate estimates. This will be explained in greater depth in section **2.0 Design and Methods**. With the knowledge of not only the sensitivity of the model inputs, but the kinds of inputs required to get the most accurate market share estimates, the Huff Model could assist in disaggregating further location-based recreational activity spending or participation totals. Examples of this include allocating state-level fishing permit data to individual fishing locations, or shell-fishing permits to beaches where recreational harvesting takes place. In these two cases, with the numbers of permits allocated to individual locations statewide, Earth Economics can multiply the number of permits issued by the average spending associated with each activity, and then sum these numbers to the legislative district or county level. Furthermore, if Earth Economics takes on a similar RFP in another region of the country, and experiences

difficulty in receiving ski resort-specific visitor or spending data, the Huff Model could be similarly used given a knowledge of how to most successfully set it up.

To further validate our recommendation of the Huff Model for market share prediction, we also tested two other prediction methods. These were Thiessen polygons and 125-mile street network service areas, both of which create a service area around a resort.

To state again our goals in the form of a question, we asked:

- What variables (characteristics of a ski resort) are required to accurately estimate a resort's market share?
- How sensitive is the Huff Model to changes in variables?
- How accurate are the Huff Model's estimates?
- How does the Huff Model compare to other market share prediction methods?
- Could the Huff Model be used to predict location "market shares" in other recreational activities?

If our testing and calibration indicated that the answer to the final question is "Yes", our goal would be to create the following:

- Best practices documentation, including a step-by-step Huff Model set-up and run guide in the form of a "Standard Operating Procedures" document. See **Appendix C**.
- A Geodatabase containing general Huff Model GIS inputs.
- Python scripts which streamline the analysis process, allowing for quick and easy review of results. See **Appendix D**.

1.2.2 Additional Goals

As a corollary to our calibration of the Huff Model for present ski resort market share prediction, we decided to additionally focus on future trends of ski resorts in Washington State. The idea was given to us by John Gifford, the president of the Pacific Northwest Ski Areas Association (PNSAA) and Ski Washington, from whom the actual ski resort visitation data were received. John had asked us, after we presented to him some initial Huff Model results, if our market share estimates were for the present time

or some point in the future. Until that point, we had been using data specific to 2010-2014. Although not a specific part of the RCO's RFP, we decided nonetheless to use future population and climate projections for Washington State to see how ski resort market share might change by the year 2040. Therefore, we also asked:

- Can the Huff Model be used to predict future market share of ski resorts?
- How will market share change, according to our model, by the year 2040?

Addressing the question of future market share would allow us to answer questions about the resilience of the ski industry in Washington State to social, economic, and ecological trends outside of their control. This could create the foundations of a methodology for the use of the Huff Model in sustainability management.

1.3 Washington State Recreation Social-Ecological System

1.3.1 General Recreation in Washington State

The purpose of a Social-Ecological Systems table (SES) is to assist in defining the state space of a particular dimension and scale. Defining the scales above and below the project focal scale helps to understand the state of being for each individual cell. In this instance, the three dimensions are biophysical, economic, and social. Understanding the dynamics of each space individually combined with understanding of the relationships between each cell allows one to develop analyses, applications, and management for a state space. Often times the nature of a system is so complex, it is difficult to understand the problem in its entirety without breaking it down, allowing one to focus on the relationships within a specific dimension and scale. The goal is to be able to manage or make decisions based on the system as a whole given that one understands the complexity of each cell and its relation to the surrounding cells (Aguirre 2014).

Figure 1.1 contains the social, economic, and biophysical dimension for the focal scale of outdoor recreation activities in Washington. The above scale, the United States, demonstrates the complexity of outdoor recreation as a country. Inherently, there are direct, indirect, and induced benefits from outdoor recreation such as boosting of the tourism industry, creating jobs, and increasing tax revenues; while playing a large role in economic development and growth. Alongside the economic benefits, the biophysical

dimension provides opportunity and context for outdoor recreation (Conservation Economics Study 2010, 4). The diversity of the US population greatly influences the trends that draw people to different types of outdoor activities. These trends include activity level and age, family structure, technology, urban setting, health, etc. (RCO 2014, 7).

Outdoor recreation stimulates WA economy, enhances property values, supports communities, educational context, and reduces healthcare costs (Conservation Economics Study 2010, 4). It also contributes to Washington's high quality of life, drawing in business advantages and allowing for opportunities to be outdoors (Conservation Economics Study 2010, 6). Through the fostering of Washington environmental stewardship, outdoor recreation leads the public to have a better understanding of the needs and management challenges that forests, beaches, and urban open space require.

The below scale of King County is an example of the types of relationships and states where many counties will find themselves similarly in. Each county has its own individual needs, stipulations, facets, etc. that create a unique set of problems and obstacles making up a complex account of that county. Many Washington counties provide recreation in the form of waterbodies, receive economic value through property taxes, and different levels of services for their parks.

Figure 1.1 General Social-Ecological System (next page)

Washington State Outdoor Recreation Social - Ecological System

Social-Ecological System Table

Scale Dimension	Biophysical	Economic	Social
Above Scale: Western Region or USA?	Biophysical dimension provides ecosystem services to US population. Provisional services include timber, wildlife fisheries, disease regulation, climate regulation, storm and flood damage attenuation, wild pollinators, etc. (Lovanna and Griffiths 11 in RCO 2014, 40)	Outdoor recreation contributes \$646 billion and 6.1 million jobs to the U.S. economy annually (OIA 2012, 2).	Percentage of US population ethnically Caucasian from 67% in 2005 to 47% in 2050. 29% of Americans of Latino origin by 2050 (Fox 2014, 2). Outdoor recreation rates highest among Caucasians and lowest among Latinos and African-Americans (Walker 2010, 5). Youth survey showed 62% and 61% of youths cited lack of transportation and no natural areas in proximity as in top 3 of reasons not to participate in outdoor recreation (The Nature Conservancy 2011 in RCO 2014, 32).
Focal Scale: Washington State	Recreationalists are more connected to natural resources and tend to have more care and concern for the environment. This leads to the public influencing better guidelines and criteria for the management of open spaces and the provision of outdoor opportunities in WA (SCORP 2013, 9). Public lands in WA total 17.5 million acres; about half are used for recreation (SCORP 2013, 26).	Outdoor recreation contributes \$22.5 billion and 227,200 jobs to WA economy (OIA 2012, 2). Hikers viewed their time outdoors worth \$20 more per hour than their actual wage earnings (Frantz 2007, 6).	20% of Washingtonians over age 65 by 2030. 8 million residents by 2028 (Fox 2014, 1). Obesity rates lower than national average at 27% (United Health Foundation 2014, in RCO 2014, 22). Changing family structure impacts ability to make outdoor trips, leading to loss of recreation skills and a loss of generational desire to be good stewards of the land (Fox 2014, 8).
Below Scale: Park District Ex. King- Seattle Park District (King County)	King County is a steward of 200 parks, 175 miles of regional trails, and 26,000 acres of open space that experience heavy public use (OSP 2010, 7). King County's shoreline provides recreational value in the form of marine beaches, lakes, and rivers. It supports industries such as shipping, fishing, and tourism (King County Comprehensive Plan 2013, 5-15). King County's aquatic systems provide beneficial functions, including wildlife habitat, food supplies, water supply, commercial, domestic, and industrial uses, also, transportation, recreation, and aesthetics. (King County Comprehensive Plan 2013,, 4-56).	In 2009, King County contributed \$13 million to 40 implementation, completed, or developing projects and \$64 million to new recreation facilities (OSP 2010, 63.) Establish property tax of 6.25 cents per \$1000 of assessed value solely for the financing of acquisition of open space, agriculture, and timber lands. ⁶⁹ Median household income: \$67,806 (OSP 2010, 13) According to the King County Comprehensive Plan, they recognize the value of recreation for its economic, natural, and educational contribution (King County Comprehensive Plan 2013, 9-19)	Percentages based off of Level of service calculations. 34% unmet demand for the number of parks and recreation facilities. 47% facilities support active recreation 83% of facilities are fully functional 66% are satisfied with park facilities and condition. 73% of residents within service area can access recreation areas safely via foot, bicycle, or public transportation 64% satisfaction with park rec. facilities conditions, quantity, and distribution (SCORP 2013, 167).

1.3.2 Ski Industry in Washington State

Specifically for identifying the relationships within the ski industry of Washington State, an additional SES table was created, see **Figure 1.2**. Here, the same dimensions of biophysical, economic, and social and the above and focal scales remain the same while the below scale is now defined as Individual Ski Resorts. The industry of ski resorts and the surrounding supporting businesses provide a large social benefit as one of the United States valued pastimes, and also as an economic contribution to the country. Skiing provides \$727 million in economic contributions to the state of Washington alone (Herbert and Hou 2008, 4). This figure is comprised of direct, indirect, and induced calculations.

In an industry that relies heavily on weather and snow patterns, defining the state spaces of this system can be quite complex. According to the article “Additional Analysis of the Potential Economic Costs to the State of Washington of a business As Usual Approach to Climate Change Lost Snowpack water Storage and Bark Beetle Impacts,” over the past century snowpack across the Pacific Northwest has declined due to rising temperatures, this is especially true in lower elevation areas (Adams et al 2010). Additional literature reiterates this in the fact that most climate change scenarios predict annual warming as well as later start dates and earlier end dates for the ski resorts (Meijer su Schlochtern et al 2014, 589). More precipitation will be falling as rain rather than snow affecting the average snowpack of a resort. A snowpack standard of measurement is the snow water equivalent (SWE). It is defined as the amount of water that is in a given volume of snow would theoretically yield if it were melted. Expectations for the April 1 SWE will decrease over the coming decades (Adams et al 2010, 2). For the state of Washington the SWE will decrease by 28%-30% by the 2020s, 38-46% by the 2040s and 56%-70% by the 2080s. Snowpack is considered an ecosystem service, as it proves economic benefits in the form of natural water storage. The water is then released throughout the spring and summer, replenishing the groundwater. The amount of water released then has significant impacts on the amount available for human consumption, as well as the surrounding landscape (Adams et al 2010, 2). However, the changing snow patterns depend largely upon altitude; higher elevations may receive higher than average snowfall due to a predicted increase in precipitation,

while the lower altitudes will experience a decrease in snowpack due to warmer temperatures (Meijer su Schlochtern et al 2014, 589).

Climate warming impacts the SWE reducing the quality of snow cover and duration. Therefore, reducing the number of available ski days, and increasing the need for machine made snow (Meijer su Schlochtern et al 2014, 583). The costs to produce this type of snow reduce the economic value of an individual resort, as costs go up for acquiring water, maintaining pipes, use of snow guns, water pumps, and system engineering. Making snow to elongate the ski season in this manner has limits, snow can only be made below 3 degrees Celsius (38 degrees Fahrenheit), limiting the ability to make snow in November, April, and May (the tail ends of the season). Humidity also plays a large factor in the ability to make snow. As the temperature and humidity drop, the conditions for making snow go up per hour (Gifford, 2014).

Additionally, ski resort management practices, such as machine made snow and grooming have the potential to negatively impact the vegetation and soil characteristics. The process of managing a ski resort involves physical disturbances from removal of original vegetation, compaction from machine grading, grooming which compacts the snow, etc. Changing snow characteristics in turn, changes the soil and vegetation characteristics. The process of creating snow involves the use of chemical compounds, such as salt, which change the chemical makeup of the soil (Meijer su Schlochtern et al 2014, 586). Often, the water required for this process is taken from a lake, reservoirs, or groundwater in very large amounts. These water sources have different chemical attributes than normal snow. This may then lead to changes in soil pH, nitrogen retention, carbon storage, and changed microbial activity. The soil erosivity and plant processes rely heavily on the current conditions (Meijer su Schlochtern et al 2014, 586). For example, if the chemical composition of the area changed, conditions could be primed for an increase in invasive plant species, and loss of vegetated ground. Reduced infiltration rates could also be a side effect of physical disturbance, combined with compacted snow, water runoff will be enhanced due to the inability of the water to be absorbed in the soil (Meijer su Schlochtern et al 2014, 588). Ski resort management

practices combined with reduced snow pack has the potential to drastically change the native landscape of the resort (Meijer su Schlochtern et al 2014, 583).

Figure 1.3, the Threshold Matrix reflects the characteristic states of specific dimensions and scales from the SES table. These state spaces are those in which we chose to focus on with testing and analysis. It strives to identify controlling variables' threshold level, which when reached moves that state space from the characteristic state to an alternative state. This alternative state is often, but not always, an undesirable state.

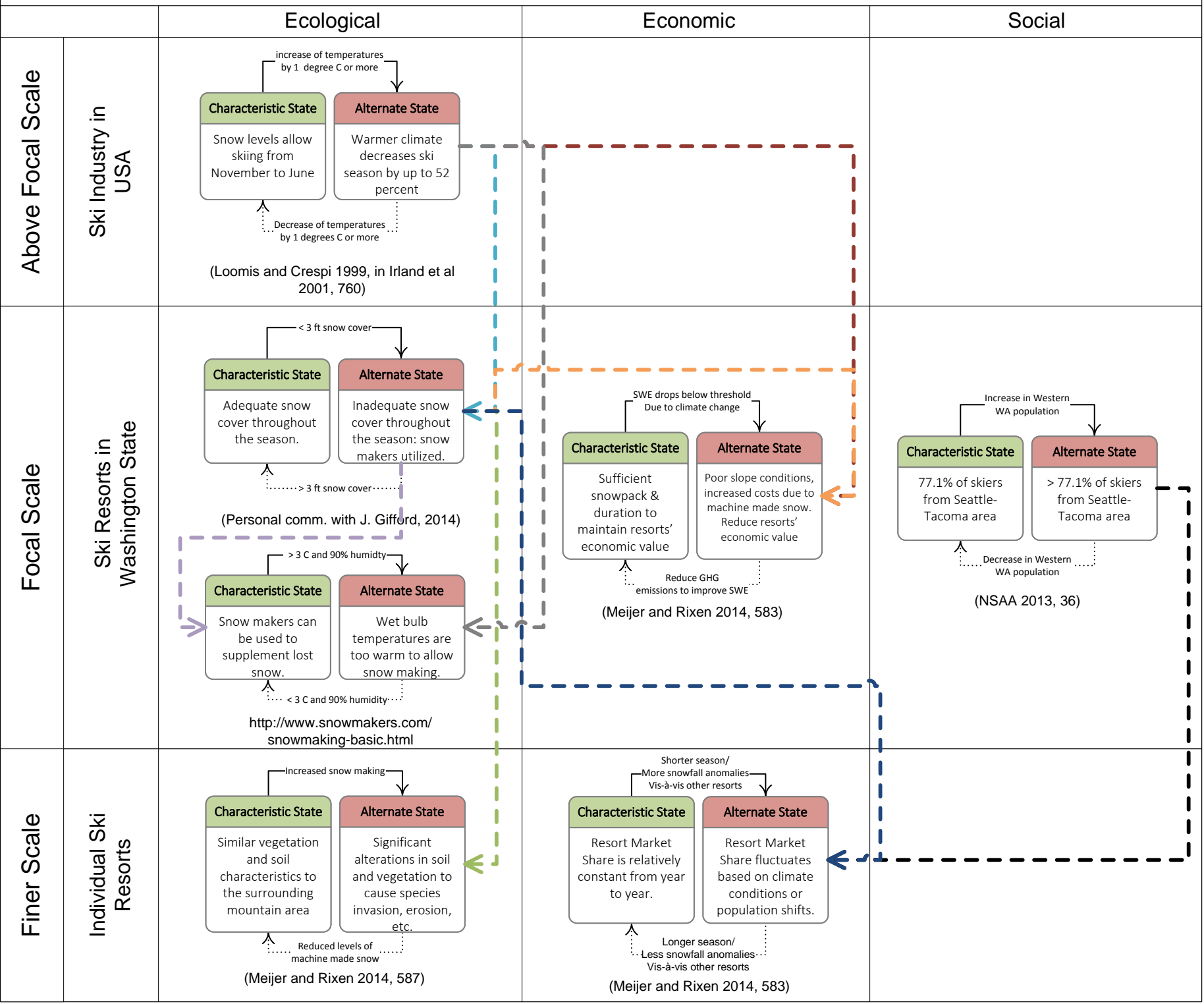
Figure 1.2 Ski Industry Social-Ecological System (next page)

Figure 1.3 Ski Industry Thresholds Matrix (page after next)

Social-Ecological Systems Table | *Ski Resort Industry*

Map		Biophysical	Economic	Social
Above Focal Scale	Ski Industry in United States of America	<p>Snowpack provides an ecosystem service in the form of storage for winter precipitation that will affect spring and summer stream flow</p> <p>(Adams et al 2010, 2)</p>	<p>Outdoor recreation participants spend \$53,047,209,901 on snow sports. Snow sport direct provides \$3.7 billion annually and indirectly provides \$9 billion annually to the economy</p> <p>(OIA 2012, 17)</p>	<p>There are 471 ski resorts operating in the US compared to 735 in 1984. Since 1979 the number of US skiers has hovered around 50 to 60 million. Therefore there are less choices for destinations for the same number of visitors. This has caused degradation to the landscape.</p> <p>(Ziegler 2012, 2)</p>
Focal Scale	Ski Resorts in Washington State	<p>SWE (snowpack) will decrease by 28%-30% by the 2020s, 38-46% by the 2040s and 56%-70% by the 2080s.</p> <p>(Adams et al 2010, 2)</p>	<p>\$727 million economic contribution to the state of Washington. \$282.8 million from direct spending, \$167.1 million from indirect spending, and \$277.1 million from induced spending</p> <p>(Herbert and Hou 2008, 4)</p>	<p>91.6% of skiers are from Washington State</p> <p>(NSAA 2013, 33)</p>
Finer Scale	Individual Ski Resort	<p>Individual ski resort management practices have the potential to significantly impact the landscape. Ex. erosion, noxious weeds, slope stability, prolonged soil frost, soil infiltration rates.</p> <p>(Meijer su Schlochtern et al 2014, 589)</p>	<p>The average WA cost for a ski trip is \$120.00, multiplied by an individual resorts visitation rate contributes to the annual economic value of the resort.</p> <p>(Herbert and Hou 2008, 4)</p>	<p>Average skier visits based on survey of individual WA resorts:</p> <ul style="list-style-type: none"> Median Group – 3 Average num of days in trip - 1.3 Average miles traveled on way to ski area - 82.6 Average annual visits per visitor - 10.1 <p>(Herbert and Hou 2008, 8)</p>

Thresholds Matrix | *Ski Industry in Washington State*



2.0 Design and Methods

2.1 Huff Model Overview

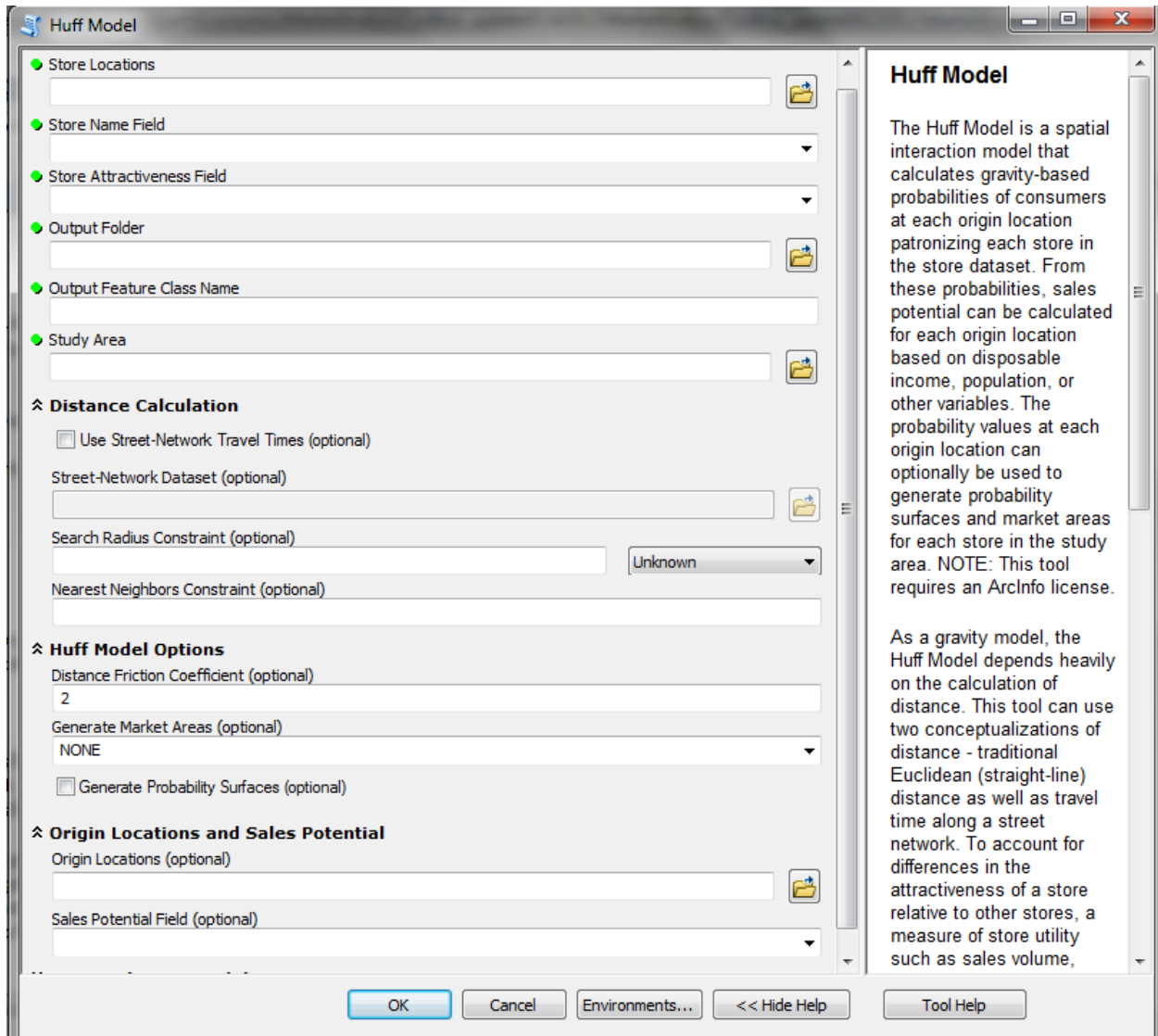
The Huff Model is a series of market analysis equations originally developed by Dr. David Huff in the 1960's (Huff and McCallum 2008, 1). With the invention of commercial GIS applications such as ArcGIS, the Huff Model has been programmed with the Python language into an ArcGIS script tool. This tool is available for free from <http://www.arcgis.com/home/item.html?id=f4769668fc3f486a992955ce55caca18> and requires at least an ArcGIS for Desktop license. As a script tool, users must run the Huff Model with ArcCatalog or ArcMap and can input data in the Huff Model dialogue box. In our analysis, we used the Huff Model script located in the MarketAnalysisTools.tbx toolbox (i.e. not *MarketAnalysisTools10.tbx*).

The Huff Model documentation describes the tool as “...a spatial interaction model that calculates gravity-based probabilities of consumers at each origin location patronizing each store in the store dataset. From these probabilities, sales potential can be calculated for each origin location based on disposable income, population, or other variables.” Essentially, the Huff Model has two main outputs: the probability that consumers at a given point will visit a location, and the potential sales from those consumers. It is from the potential sales that “market share” can be calculated. This will be discussed in greater detail in section **2.3 Huff Model Calibration**.

Since the model relies in large part on the spatial interaction of consumers at multiple points and the locations of multiple stores, distance is a key factor in determining probability and potential sales. The model measures distance in two ways: using straight-line (or Euclidean) distance, or by distance along a street network. As we will show in our results, which form of distance measure one chooses has a great effect on the accuracy of the predictions.

2.1.1 Huff Model Inputs and General Setup

Figure 2.1 Huff Model Script Dialogue



Attractiveness Measure

To run the Huff Model, one must have at the absolute minimum the point locations of the “stores” (i.e., ski resorts, beach access points, fishing grounds, etc.) that are under analysis. In order for the Huff Model to run, there must be at least 2 point locations in the feature class. These point locations must have two fields: a text field with the name of each location (or a designation), and a numeric field with an “attractiveness” value. This value is an equally important input after the choice of distance measure. The attractiveness measure essentially acts as a weight. Higher attractiveness scores increase

the probability of patronage and sales for a given location, while lower attractiveness scores result in lower patronage and sales. The attractiveness measure can be a simple input such as the size of a store (or recreational location), or can be a measure comprised of multiple ranked variables that are more comprehensive in their quantitative description of a location.

Consumer Locations

Optionally, the user can choose to include the origin locations of consumers. Typically, these can be points or polygons and include census tracts, cities, counties, or some other set of origins. As an additional option for the origin locations, a “sales potential” field can be specified, from which the sales potential is calculated. This is done by multiplying the output probabilities by the “sales potential” field. This field can be any attribute that affects the potential sales (i.e. patronage) of the location. Typically, population or median family income are good measures, but other origin-specific demographic attributes can be used as well, or ranked combinations of attributes similar to the attractiveness measure described above.

Network Dataset

If the user desires to use distance along a network instead of the default Euclidean distance, a Network Analyst license must be active. Furthermore, a functioning network dataset must be constructed that reaches the entirety of the analysis study area. This network must have at least one cost attribute, such as distance or time. In the currently model coding, we believe that a store location must be within 1000 meters of a road to be included in the analysis.

Study Area

The study area is a polygon feature class that encompasses the entire area of interest. Generally, this area should include all consumer origin locations and store locations.

Figure 2.2 Huff Model Inputs – General (next page)

Parameter Name	Parameter Description
Store Locations	Point feature class containing the centroids of each park. Must contain at least 2 features
Store Name Field	The attribute field from the store (park) locations containing a unique name for each park
Store Attractiveness Field	Attribute field containing the measure of attractiveness. Must be a numeric number
Output Folder	Folder where a file geodatabase containing the outputs will be created
Output Feature Class Name	Name of the output feature class that will be contained in the geodatabase
Study Area	Analysis area of interest. Utilized for calculation of lag distance when generating probabilities using Kriging
Distance Calculations	
Use Street - Network Travel Times (Optional)	Determines conceptualization of distance. Travel time is more accurate when using street networks
Street - Network Dataset (Optional)	Street-Network dataset for calculating travel times. Must contain cost attribute.
Search Radius Constraint (Optional)	Maximum distance between point and origin for probability consideration. 0% outside radius. May set units. ex feet, miles, kilometers
Nearest Neighbors Constraint (Optional)	Number of Nearest store locations that will be considered.
Huff Model Options	
Distance Friction Coefficient (Optional)	Determines strength of inverse relationship of distance and probability of visiting store
Generate Market Areas (Optional)	Determines market areas that will generated. (NONE, TRUE, ORIGINS)
Generate Probability Surfaces (Optional)	Generates probability surfaces using Kriging
Origin Locations and Sales Potential	
Origin Locations (Optional)	Consumer locations to be used as origins. If not specified random points in study area will be used.
Sales Potential Field (Optional)	Measure of sales potential, or visitation. Ex. population or disposable income

2.2 Geodatabases

2.2.1 Data Collection and Sources

Data used in the Huff Model analysis of ski resorts were collected from a variety of locations. All data were in vector or tabular format. Ski resort point locations were exported from KML files downloaded from Google Earth. Attribute fields were manually added and populated based on resort-specific data obtained at <http://www.liftopia.com/ski-resort-info/statemap/WA/Washington> . Census tracts were obtained from Washington State OFM, as were future population projections at the county level. Median Family Income data at the tract level were obtained from the Census Factfinder service. Streets (Census TIGER/Lines) were downloaded from the USGS National Map Viewer. Historic and future climate projections were obtained from the National Center for Atmospheric Research. See the **Table 2.1** below for a complete list of data inputs and sources. The derivation of feature classes and tables represented in the geodatabase schema below will be described in section **2.3 Huff Model Calibration**.

Table 2.1 Data Inputs and Sources

Data Input	Type	Source URL
Census Tracts	Polygon	http://www.ofm.wa.gov/POP/geographic/tiger.asp
Cities	Point	http://geography.wa.gov/geospatialportal/dataDownload.shtml
Climate projections 2040	Point	https://gisclimatechange.ucar.edu/gis-data
Counties	Polygon	http://www.ofm.wa.gov/POP/geographic/tiger.asp
Median Family Income (Select Economic Characteristics)	Table	http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml
Ski Resorts	Point	Google Earth, http://www.liftopia.com/ski-resort-info/statemap/WA/Washington
Ski Resort Market Shares	Table	John Gifford, President PNSAA, derived.

State Highways and Interstates	Line	http://www.wsdot.wa.gov/mapsdata/geo/datacatalog/
Street Network	Line, Network Dataset	http://viewer.nationalmap.gov/viewer/ , derived.
Washington State	Polygon	http://geography.wa.gov/geospatialportal/dataDownload.shtml
Washington State 2040 population projections	Table	http://www.ofm.wa.gov/pop/gma/projects12/projections12.asp

2.2.2 Geodatabase Schema

Figure 2.3 Geodatabase Schema

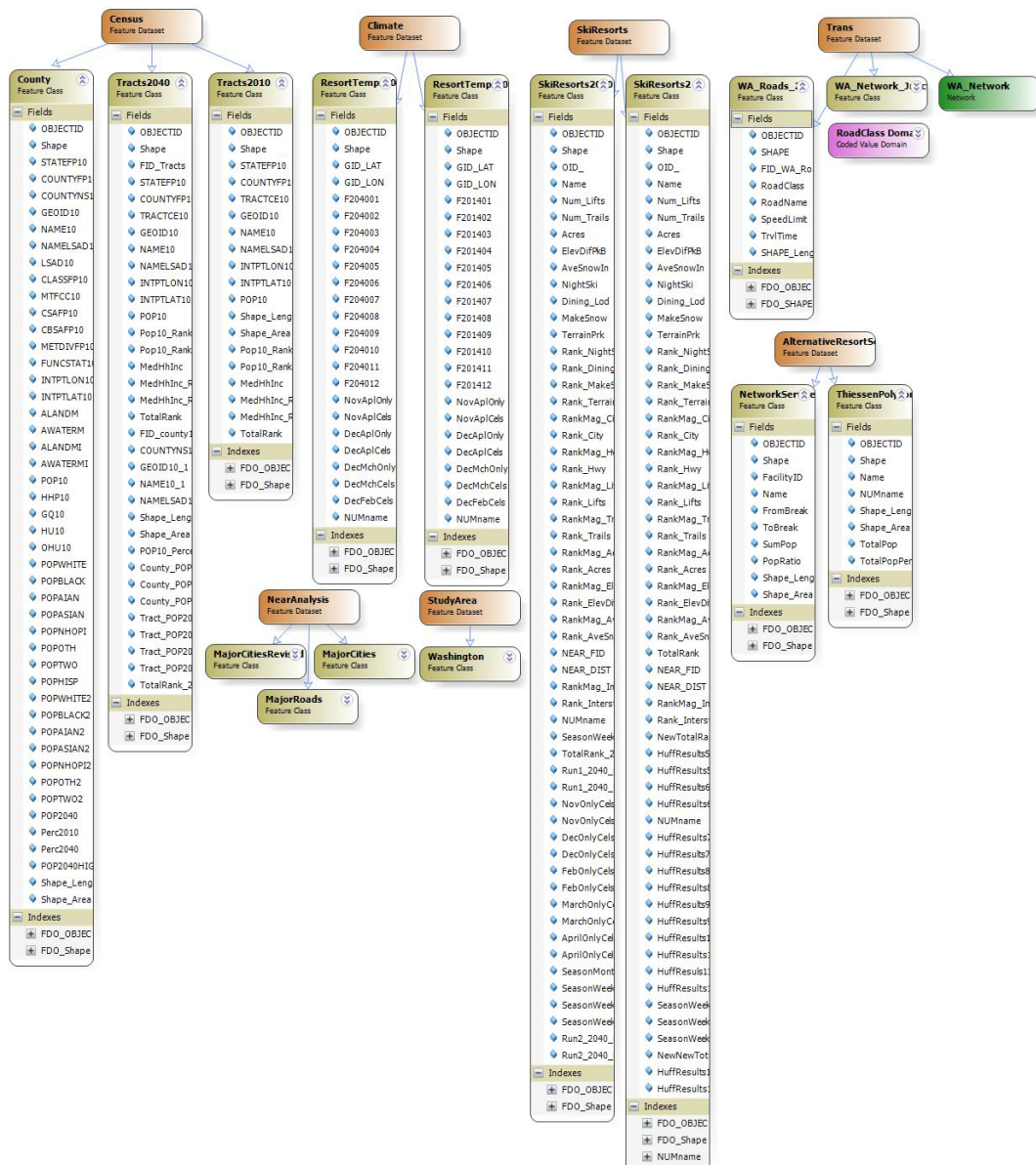
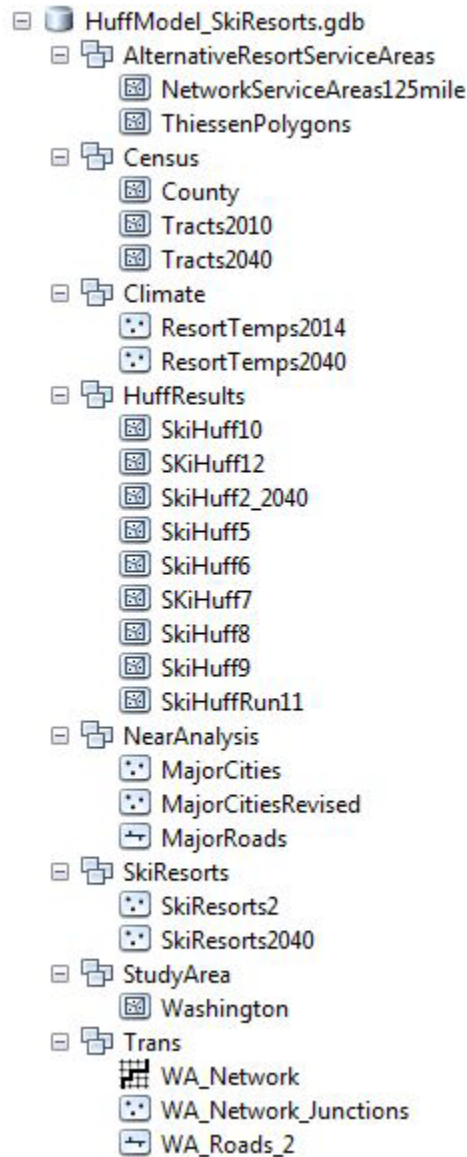


Figure 2.4 Geodatabase



2.3 Huff Model Calibration

2.3.1 Data Preparation

Ski Resorts

Ski resort points were downloaded from Google Earth as a KML file. Originally, there were 15 points in the feature class. Upon receiving the ski resort visitation data from John Giffords, we eliminated two resorts, Badger Mountain and Kahler Glen, because these resorts were not included in the total visits. A third resort, the Stevens Pass

extension, was combined with Stevens Pass proper. The multiple resorts at Snoqualmie Pass were counted as a single resort.

The ski resort attributes were manually attributed using information from www.liftopia.com. Due to the small number of resorts and less than 11 resort-specific attributes that were common to all resorts, this was a fairly quick process. The final ski resort attribute table can be seen below in **Table 2.2**. These attributes were ranked to form the custom “attractiveness” measure for use in the Huff Model. This is described in detail in section **2.3.2 Calculating the Attractiveness Measure**.

Finally, a new string field called “NUMname” was added and calculated as “OBJECTID + 1”. As will be evident later, this unique ID field will allow for faster processing of the Huff Model results.

Table 2.2 Ski Resort Feature Class Attributes

Name	Num_Lifts	Num_Trails	Acres	ElevDifPkB	AveSnowIn
49 Degrees North Mountain Resort	7	82	2325	1851	301
Crystal Mountain Resort	11	57	2600	3100	350
Hurricane Ridge Area	3	10	200	800	400
Leavenworth Ski Hill	2	4	15	300	150
Loup Loup Ski Bowl	3	10	550	1240	150
Mission Ridge Ski & Board Resort	6	36	2100	2250	170
Mt Baker Ski Area	8	38	1000	1500	647
Mt Spokane Ski & Snowboard Park	5	45	1250	2000	300
Ski Bluewood	3	24	355	1125	300
Stevens Pass	10	53	1151	1800	450
The Summit at Snoqualmie	24	112	1916	2280	400
White Pass	6	36	1000	2250	200

Table 2.2 continued

Name	NightSki	Dining_Lod	MakeSnow	TerrainPrk	SeasonWeeks
49 Degrees North Mountain Resort	1	1	1	1	16
Crystal Mountain Resort	0	1	1	1	23
Hurricane Ridge Area	0	1	0	1	14
Leavenworth Ski Hill	1	0	0	1	12
Loup Loup Ski Bowl	0	0	0	0	12
Mission Ridge Ski & Board Resort	1	1	1	1	18
Mt Baker Ski Area	0	0	0	1	24
Mt Spokane Ski & Snowboard Park	1	1	1	1	16
Ski Bluewood	0	0	1	0	16
Stevens Pass	1	1	0	1	20
The Summit at Snoqualmie	1	1	1	1	20
White Pass	1	1	1	1	21

* 1: Yes/Presence; 0: No/Absence

Season Length is in weeks and was not added until later in the analysis. Season lengths vary by year, so we used the reported season start and end months for 2013-2014 based on each resort's website calendar to estimate the average season length. We could not however find the season length for 49 Degrees North, so this was estimated based on the length of nearby Spokane Mountain's average season. Furthermore, White Pass's start month could not be found and was similarly estimated. We were conservative in our estimation of these two resorts, and tended toward shorter seasons.

Three further variables were introduced at various points in the analysis that were derived by running the "Near" tool in ArcGIS. The variables are distance to a city, distance to a major road (highway or interstate), and distance to an interstate only.

We also received tabular ski resort visitation data courtesy of John Gifford, president of Ski Washington and the PNSAA. These data were delivered as absolute visitation numbers. However, as a stipulation of their use, we agreed to only report these data as

percentages of the total. Therefore, we had to manually calculate these “market shares” for 3 sets of years: 2010-2011, 2012-2013, and a 3 year average for 2010 - 2013.

Census Tracts

The census tracts feature class from OFM has selected demographic attributes already, including population in 2010. Because we were also interested in median family income, the select economic characteristics table from the U.S. Census was linked to the census tracts through the key field “GEOID2”. The median family income field (HC01_VC85) was then populated from the linked table and the join was severed.

Cities

Cities points were converted from Washington State city polygons. The initial city point feature class includes the following cities: Bellevue, Bellingham, Everett, Federal Way, Kennewick, Kent, Olympia, Pasco, Renton, Seattle, Spokane, Spokane Valley, Tacoma, Vancouver, Yakima. The revised city point feature class includes only Bellingham, Everett, Olympia, Seattle, Spokane, Tacoma, Vancouver, the largest cities in Washington (with the exception of Bellevue).

Network Dataset

A network dataset was created to allow network routing in the Huff Model. A custom data model was created containing the following fields: RoadClass (short), Name (string), TrvlTime (double; minutes), and ShapeLength (double; feet). All paved road classes (local, secondary, primary) were selected from the Census TIGER/lines street dataset for Washington State using a SQL statement, and were loaded into an empty feature class (WA_Roads) with the aforementioned schema. Unpaved roads were excluded. The new feature class was then input into the “feature to line” tool in ArcGIS. After running for 7 hours, the resulting feature class (WA_Roads_2) was created. This tool ensured that nodes were placed at all street segment intersections, or else network routing would not function.

Next, the road classes were attributed, and from this speed limits were assigned. To calculate travel time, the formula

$$([\text{Shape_Length}] * 60) / ([\text{SpeedLim}] * 5280)$$

was used, calculating the time in minutes. The road classes and speed limits are in the **Table 2.3** below. Speed limit is in miles per hour.

Table 2.3 Street Network Hierarchy and Speed Limits

Type	Road Class	Speed Limit
Interstate	1	60
Highway	2	55
Local Road	3	35

Area of Interest

Huff Model documentation suggests that defining the study area is one of the most important considerations for model use. This is due to the fact that the study area can be thought of as an “island,” where the conclusions to be drawn may be impacted by this parameter. The model thus assumes that business originates from inside the area of interest boundary with very little crossover from outside this area. Therefore, it is best to identify an area of interest that best fits the elements of the system being modeled (Huff and McCallum 2008, 9). In this case, the State of Washington was set as the delimited area of interest. This makes sense as we are attempting to estimate the market shares of Washington only. Additionally, according to NSAA 91.6% of Washington skiers originate from within Washington (NSAA 2013, 33). This we felt was sufficient evidence for making the assumptions required to continue forward with the study of the Huff Model.

2.3.2 Calculating the Attractiveness Measure

As previously mentioned, the attractiveness measure is an important Huff Model input, and is calculated within the ski resort feature class attribute table. In our running of the Huff Model on ski resorts, we in fact used multiple simple and complex attractiveness measures. A simple attractiveness measure is a single, unadulterated attribute field that is correlated with more or less attractiveness. For example, “acres” is a simple attractiveness measure. The more acres, the more attractive the resort is. However, if one wants to include multiple variables in the attractiveness measure, these variables

can be given standardized ranks and summed together to create a single total rank. When calculated, the individual variable ranks will be between 0-100, regardless of the original unit of the variable. For variables that are defined by the presence or absence of something (the first four columns of **Table 2.2 continued**), we arbitrarily assigned ranks between 0 and 100; 0 if absent, 100 if present. The method described below was performed on the variables listed in **Table 2.2**. Furthermore, the ranks for 3 variables based on a distance from each resort were calculated. For these 3 variables (distance to major cities, distance to major roads, and distance to interstates), lower distances were ranked higher. For all other variables, higher amounts (acres, # of lifts, inches of snow, etc.) were ranked higher.

Within the Ski Resorts feature class attribute table:

Step 1: Add field (*double*) called VARIABLE_RankMag, replacing “VARIABLE” with the name of the variable (e.g. “Acres_RankMag”), for each variable to be included in the attractiveness measure.

Step 2: Record the *Maximum* and *Minimum* values of a variable and input them into the following equation in the Field Calculator:

$$(Maximum - Minimum) / 100$$

Repeat for each variable.

Step 3: Add field (*double*) called VARIABLE_Rank for each variable.

Step 4a: For higher values to have higher ranks, input the following equation into the Field Calculator:

$$100 - ((Maximum - VARIABLE) / VARIABLE_rankmag)$$

Step 4b: For lower values to have higher ranks, input the following equation into the Field Calculator:

$$(Maximum - VARIABLE) / VARIABLE_rankmag$$

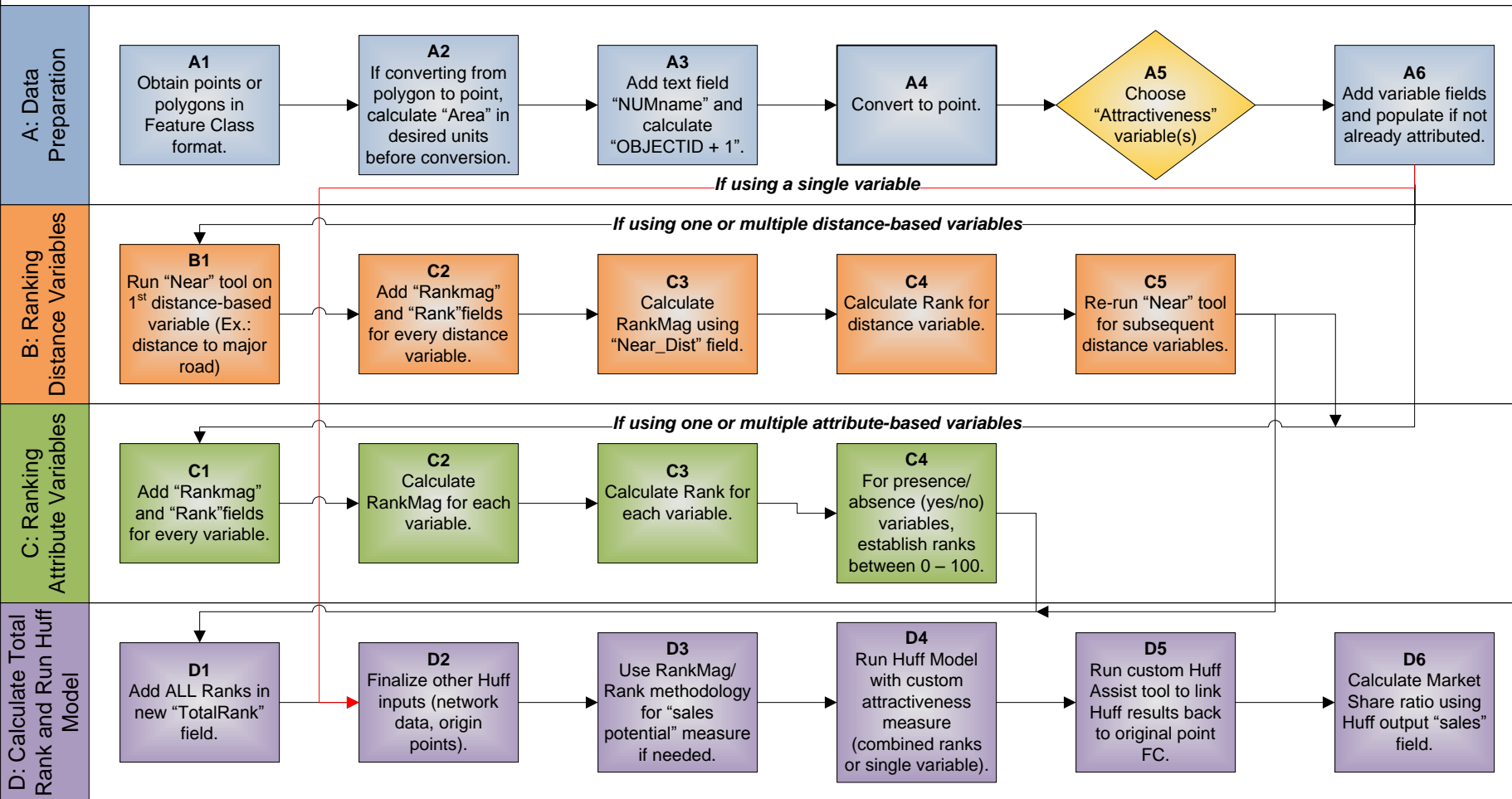
Repeat for each variable.

Step 5: Add field (*double*) called “TotalRank”. In the Field Calculator, add all variables’ “_Rank” fields together.

At various points throughout our running of the Huff Model, different combinations of ranks were calculated to form total ranks (attractiveness measures). These combinations are described in greater detail in **Tables 2.4** and **2.5** in section **2.3.5 Model Run Variations**. For a graphic depiction of the attractiveness measure calculation process, see **Figure 2.5**.

Figure 2.5 Calculating the Attractiveness Measure and Running the Huff Model (next page)

Calculating the Huff Model Attractiveness Measure | *General Application*



2.3.3 Calculating the Sales Potential Measure

The sales potential is an attribute of the origin location feature class. The Huff Model documentation suggests using factors such as population, income, or other social/economic data. We decided to test out two sales potentials of our origin location (U.S. census tracts). The basic sales potential was population. The second sales potential measure consisted of a ranked combination of median family income and total population for the year 2010. These were ranked in the same fashion as the attractiveness measure variables and summed together. For both median family income and total population, higher value received higher ranks. We choose to combine median family income and population because both are positively correlated with skiing. Areas with higher populations, we assumed, can give more business to their nearest ski resort than can areas with lower populations. Similarly, because skiing or snowboarding can be very costly recreational activities, we assumed that areas with higher median family incomes could also contribute more business to a ski resort than areas with lower incomes.

The Huff Model calculates the output sales potential by multiplying the probability of a census tract's patronage to a given ski resort (which is calculated using distance and the attractiveness measure) by the sales potential measure. When using a ranked and summed sales potential measure, the output sales potential is essentially meaningless. However, it is the relationships between each resort's total sales potential that matters. From this, we can calculate the individual market share of each resort resulting from a given model run. To see which model runs used which sales potential measure, refer to **Table 2.4** in section **2.3.5 Model Run Variations**. In this table, the sales potential measures for our main Huff Model runs are called "Pop/income" and "Pop". The "incorrect pop/income" was a sales potential measure that was used in our initial model runs. We realized later that we had falsely calculated the population and income ranks, so that lower values were receiving higher ranks. This was corrected, but we elected to keep the model run results for comparison.

2.3.4 Huff Assist Python Script Tool Development

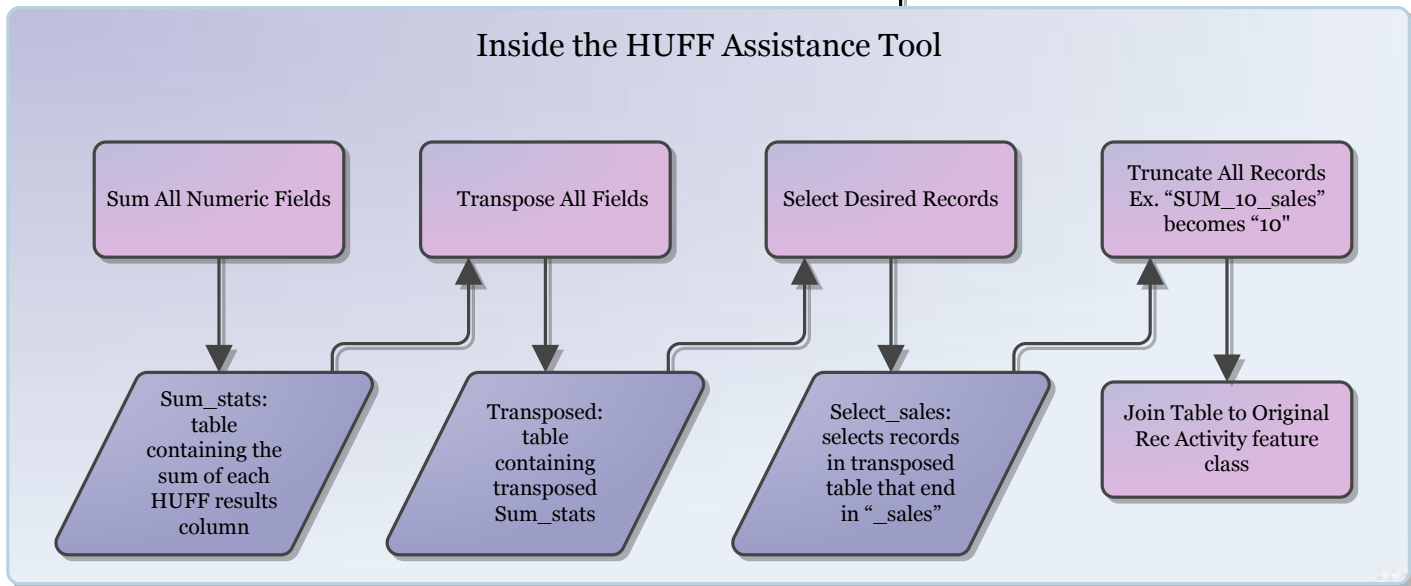
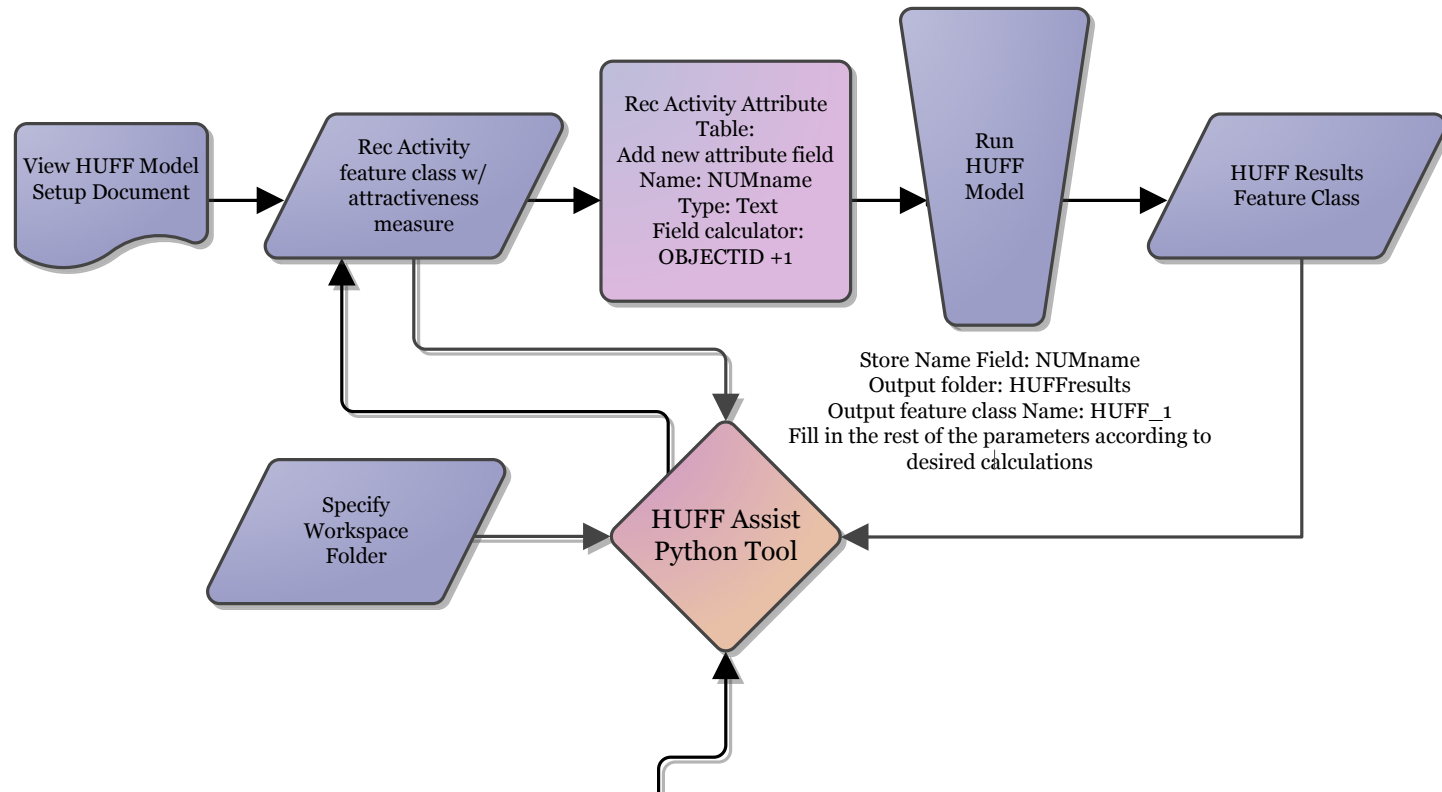
This Huff Assist Script Tool was developed in order to aid in processing the output from the HUFF model, so that results may be used to calculate market share of a particular recreational activity. Before running the HUFF model, it is suggested that one add a *Text* field called “NUMname”. Calculate this field with the following expression: OBJECTID + 1 . Use this field as the “Name” input in the Huff model if you will be using the “HUFF Assist” script tool. This allows a key to be made to link the Huff output with the point FC input

The HUFF model creates a field in the attribute table of the origin locations (census tracts) for every recreational activity point, naming the field according to the unique field value you specify as the “Name” input in the HUFF model. The tool then takes this output and sums all the numeric fields and exports them to a table. It then transposes the summary statistics table and outputs the table as “transposed.” The tool then proceeds to select only the desired records ending in “_sales” (the output sales potential), truncates the names by removing the suffix and prefixes that were added from previous steps, essentially renaming the selected fields. The fields now resemble the original “NUMname” and the Huff Assist tool joins this information to the original recreation feature class input, in our case ski resorts.

Finally, due to the large size of field names, we recommend using only geodatabase feature classes, not shapefiles.

Figure 2.6 Huff Assist Script Tool Diagram (next page)

Entity-Relationship Diagram: HUFF Model Assistance Python Script Tool



Python Script

```

    # Description: Script that runs the Summary Statistic tool to calculate the
    # Sum statistic for every numeric field
    # Set local variables
    inTable = arcpy.GetParameterAsText(0) # Huff results in output.gdb
    outTable = "HUFFtool_output.gdb/Sum_stats"
    stats = {}
    # Loop through all fields in the Input Table
    for field in arcpy.ListFields(inTable):
        # Just find the fields that have a numeric type
        if field.type in ("Double", "Integer", "Single", "SmallInteger"):
            # Add the field name and Sum statistic type
            # to the list of fields to summarize
            stats.append([field.name, "Sum"])
    # Run the Summary Statistics tool with the stats list
    arcpy.Statistics_analysis(inTable, outTable, stats)
    # Description: Script that runs the transpose tool to move the sum from a row t
    inTable2 = "HUFFtool_output.gdb/Sum_stats"
  
```

2.3.5 Model Run Variations

As part of our calibration of the Huff Model, we tested different combinations of inputs. One reason for the variation of model runs is due to our own learning process: generally after run 5, we realized that we had incorrectly calculated many of our ranks, especially in the sales potential measure. These had to be recalculated and the model runs were continued. This is why Runs 1-4 are not included in our results: not only had we been using incorrectly calculated attractiveness measures (namely valuing higher values lower), but the number of resorts and variables had differed. Pre-run 5, we had 15 ski resorts, instead of 12. Furthermore, we discovered that a number of our variables were incorrect. For example, we did not have the correct number of lifts for Crystal Mountain, and thus had to update this variable and recalculate the ranks. Additionally, certain inputs were incomplete until later model runs. For example, our network dataset was not completed until model run 7. Until then, we had used Euclidean distance. The season length was not discovered until run 12. Distance to interstates was added after run 9, as we thought it would significantly increase the market shares for resorts such as Snoqualmie, because these resorts are easier to access than isolated resorts on treacherous highways. Starting with run 8, we recalculated “distance to major city” using a new selection of the largest cities in Washington. Until then, the city point feature class, from which the distance was being calculated, included smaller cities in the east such as Yakima and Pasco, which increased the predicted market shares of smaller resorts in eastern Washington well above the actual market share. Finally, after run 11 a change was made to the network dataset. We discovered that SR 123 near White Pass resort closes in winter. Thus, we deleted this road from our network dataset.

Two of our model run variations were designed to test the sensitivity of the distance calculation. As a reminder, the Huff Model uses either Euclidean, or straight-line, distance; or distance along a street network. Runs 9 and 11 used the same attractiveness and sales potential measures, but run 9 used network distance while 11 used Euclidean distance. The difference between the results can be seen in Table XXX in section **3.0 Results**.

Table 2.4 Huff Run Input Variations

Run #	5	6	7	8	9	10	11	12	2 (2040)
Euclidean Distance	X	X					X		
Network Dataset			X	X	X	X		X	X
Attractiveness Measure 1a*	X	X	X						
Attractiveness Measure 1b*				X					
Attractiveness Measure 2*					X		X		
Attractiveness Measure 3*						X			
Attractiveness Measure 4*								X	
Attractiveness Measure 5*									X
Incorrect Pop/Income	X	X	X	X					
Correct Pop/Income					X		X	X	
2040 Pop / Income									X
Pop only						X			
Distance Constraint (100 mi)		X							

Table 2.5 Attractiveness Measure Variable Inputs

Variable	Attractiveness Measure 1a	Attractiveness Measure 1b	Attractiveness Measure 2	Attractiveness Measure 3	Attractiveness Measure 4	Attractiveness Measure 5
# of Lifts	X	X	X		X	X
# of Trails	X	X	X		X	X
Acres	X	X	X	X	X	X
Elevation Difference	X	X	X		X	X
Average Snowfall (Inches)	X	X	X		X	X
Night Skiing	X	X	X		X	X

Snowmaker	X	X	X		X	X
Food/lodging	X	X	X		X	X
Terrain Park	X	X	X		X	X
Distance to Major City 1*	X					
Distance to Major City 2*		X	X		X	X
Distance to Major Road	X	X	X		X	X
Distance to Interstate only			X		X	X
Season length weeks					X	
Season length weeks 2040						X

2.4 Huff Model Future Projections

The goal of using the Huff Model to make future market share projections is to assess the resilience of Washington’s ski resorts to changes in population and climate. It is also to analyze the Huff Model’s suitability for making future predictions. The logic is this: if one can accurately predict current market share, what stops one from predicting future market share based on changes in the attractiveness and sales measures? To this end, we chose the year 2040 for our analysis due its distance from the present time and the accessibility of climate and population data for this year. We assumed that 25 years is enough time for conditions to change, and thus an analysis of market share of ski resorts at this year is acceptable.

2.4.1 Climate Scenarios

The National Center for Atmospheric Research produces future climate projections based on different economic growth scenarios. In particular, GIS data for three scenarios are available at <https://gisclimatechange.ucar.edu/> : A1B, B1, and A2. We chose scenario A2 for our Huff Model testing because it exhibits the highest increase in

annual average temperatures in Washington State. A description provided by NCAR is available below.

“**A2 scenario** includes: *high* population growth, *medium* GDP growth, *high* energy use, *medium-high* land use changes, *low* resource (mainly oil and gas) availability, *slow* pace and direction of technological change favoring regional economic development.”

<https://gisclimatechange.ucar.edu/>

From the website listed above, one can download a grid of annual or monthly average temperature points by drawing a bounding box on an interactive map. One also specifies the range of years that are of interest. For our purposes, we downloaded a grid covering Washington State that included monthly average temperatures for 2014 and 2040 under the A2 scenario. The grid points are spaced about 5 km apart. A select by location tool was run to select the closest temperature grid points to each resort, and these points were extracted out and included in our Huff Model ski geodatabase. Each temperature point came to within at least 2 km of a resort, so the temperature predictions can be reasonably attributed to the resorts themselves.

From here, the temperatures were converted from Kelvin to Celsius using the formula $C = K - 273.15$. Then, a new resorts feature class was created (SkiResorts2040) and the average temperatures for November, December, February, March, and April for both 2014 and 2040 were attributed to each ski resort. These months were chosen because they represent the range of start months (Nov/Dec) and end months (Feb/March/April) for Washington ski resorts. May was excluded because of its intermittent nature. The differences in temperatures for each 2014/2040 month pair were taken to see if average monthly temperatures for each resort are expected to increase or decrease.

Generally, our approach used a mix of quantitative and qualitative methods, and is not perfect by far. We first looked to see if predicted monthly average temperatures in the season start and end months will be higher for each resort in 2040 than in 2014. We have seen that for all resorts, end month average temperatures (March or April for all but one resort) in 2040 are predicted to be colder than in 2014. However, for about 50%

of the resorts, especially resorts which begin the season in November, start months are expected to be significantly warmer (by a few degrees Celsius at most). For any resorts expecting to see warmer start or end months, we then looked to see if the average temperature is above or below 0 C, and more importantly, above or below 3 degrees Celsius (or 38 Fahrenheit, the maximum temperature (given correct humidity) for making snow). If the average temperatures in 2040 are above or very near 3 C, we then subtracted the number of weeks the resort is open in that month from the total season length. Resorts generally are not open for the full start or end month. In all, about half of the resorts saw shorter seasons, by anywhere from 1-4 weeks. However, due to the qualitative nature of our correlation between higher average monthly temperatures and loss in length of season in weeks (due to reduced snow or inability to make snow), we realize that this method is very limited. Furthermore, we assumed that all resorts would be able to and would choose to make snow by 2040, and that the humidity was always correct to allow snowmaking up to the maximum of 38 degrees Fahrenheit. In any future analysis, these methods must be vastly improved upon. The 2014 and 2040 season lengths can be seen in **Table 2.6** below.

Table 2.6 Temperature and Ski Season Changes in 2040

Name	Season	Start Month Near or > 3 C?	End Month Near or > 3 C?	Season 2014	Season 2040
49 Degrees North Mountain Resort	Dec-Apl	NO	NO	16	16
Crystal Mountain Resort	Nov-Apl	YES	NO	23	20
Hurricane Ridge Area	Dec-Mch	YES	NO	14	12
Leavenworth Ski Hill	Dec-Feb	NO	NO	12	12
Loup Loup Ski Bowl	Dec-Mch	NO	NO	12	12
Mission Ridge Ski & Board Resort	Nov-Apl	YES	NO	18	16
Mt Baker Ski Area	Nov-Apl	YES	NO	24	20

Mt Spokane Ski & Snowboard Park	Dec-Mch	NO	NO	16	16
Ski Bluewood	Dec-Apl	NO	NO	16	16
Stevens Pass	Nov-Apl	YES	NO	20	18
The Summit at Snoqualmie	Dec-Apl	YES	NO	20	19
White Pass	Nov-Apl	YES	NO	21	19

The 2040 season length projections were included in the new 2040 total rank calculation (Attractiveness Measure 5). All other variables were held constant, because we cannot predict changes each resort will make to their facilities, such as adding lifts and trails, or providing snowmaking capabilities. Furthermore, we elected to hold average snowfall in inches constant. We decided that we could not revise average snowfall for the resorts because we do not know enough about the correlation between temperatures and precipitation to accurately predict such changes. Furthermore, because many of the resorts would indeed see colder deep winter temperatures, we were unsure what effect colder temperatures would have on snowfall. This is a further limitation that should be addressed in any further ski resort market share prediction methodologies.

2.4.2 Population Projections

Population projections for Washington State at the census tract level currently do not exist. However, the OFM does produce predictions at 5 year intervals at the county level. In order to assign each census tract in the state a population for 2040, we took each census tract's proportion of the current (2010) county population, in which the tract is located. We then used this ratio to divvy up the projected 2040 populations. The projections we used were for the year 2040 under the highest growth scenario. From here, the population rank was re-calculated and summed anew with the median family income rank to form a 2040 "sales potential" field in the origin location points attribute table. We elected to leave median family income the same because we do not know enough to predict future changes in the distribution of income across the state. The

results of the 2040 ski resort market share predictions are in **Table 3.1** in section **3.0 Results**.

2.5 Alternative Market Share Prediction Methods

As an experiment to verify that the Huff Model was indeed the more accurate and best tool to predict the percent market share of each individual ski resort, network analysis services areas and Thiessen polygon methods were employed. The results of these two additional methods for calculating the market shares of Washington ski resorts will be presented in section **3.0 Results**. However, a brief description of each method will be described in this section.

2.5.1 Network Analyst Service Areas

The calculation of service areas based off of a network requires the use of ArcGIS Network Analyst extension. This method identifies the service area around any of the points based on a road network system. This also requires that the road network is complete and working properly. A network service area is that area which encompasses all accessible streets within a specified distance (ESRI 2014). In this case the distance of 125 miles was set for this parameter. This value is based on a study suggesting that that is the maximum number of miles a person would be willing to travel in a day, one way, to visit a ski resort (Raleigh et al 2007, 3). This type of analysis helps to identify accessibility; one is able to vary the distance parameter to show variances in accessibility (ESRI 2014). In this case 125 miles one way was the only impedance chosen. The tracts which had centroids contained within each service area polygon were then summed by population, multiplied by 100 and divided by the total population of all the resort service areas to achieve a percentage of the total market share. Total population of Washington State is not used because the service areas do not cover the entirety of the state. This method of analysis assumes that the population contained within each service area have the potential to visit any ski resort that is within 125 miles traveling along a road network. It does not take into consideration any other values that might draw an avid skier to that destination. Furthermore, service areas generated this way do not overlap each other.

2.5.2 Thiessen Polygons

The creation of Thiessen Polygons is done by using a point feature class, where a polygon is created that contains only one point input feature. Any location within that polygon is closer to that one point than any of the other points in the input feature. This tool then divides the area of Washington into many polygons. These represent the area of service for each individual ski resort (ESRI 2014). The tracts with centroids contained within each Thiessen polygon were then summed by population, multiplied by 100 and divided by the total population of Washington State to achieve a percentage of the total market share. This method does not take into account any time of variable that may draw them to the ski resort other than simply living in a tract that is closer to that resort than any other by Euclidean distance. This method makes estimations based on an assumption that the majority of the population visits the ski area closest to them only. Additionally, it does not take into consideration any type of network time to get to that resort. For the market share predictions of both 125-mile service areas and Thiessen polygons, refer to **Table 3.1** in section **3.0 Results**.

3.0 Results

3.1 Results Tables

The results of the present and future Huff Model runs, alternative market share prediction runs, and actual ski resort market shares are depicted in **Table 3.1** below. The actual market shares for the past 3 years are highlighted in light gray. The Huff Model run with the most accurate predictions, run 12, is highlighted in light green.

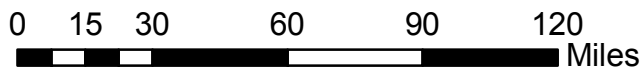
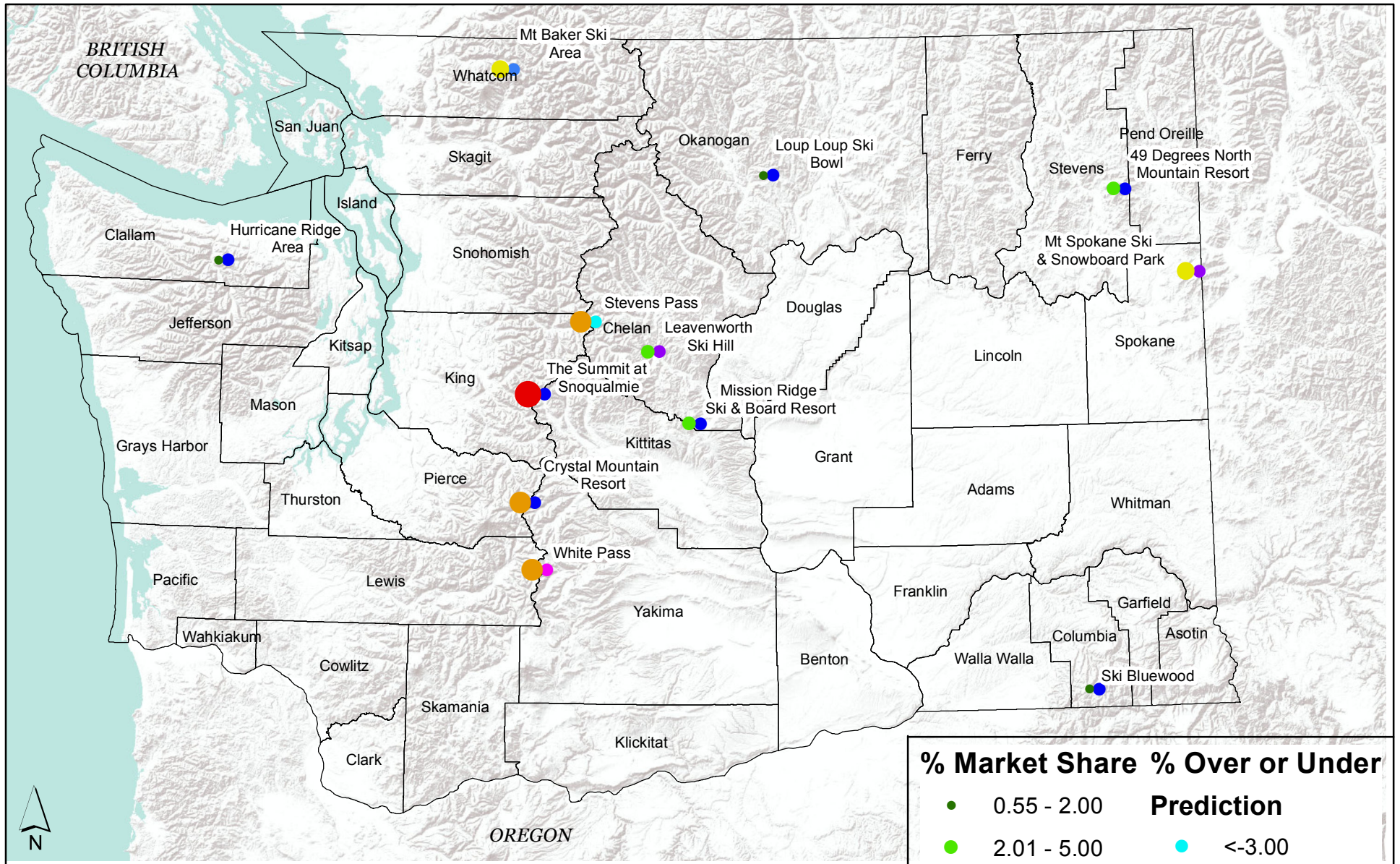
Table 3.1 Actual and Predicted Market Share %

Resort	2010-2011	2012-2013	3 year avg	Run 5	Run 6	Run 7	Run 8
49 Degrees North	4.1	4	4	3.7	2.9	4.1	4.4
Crystal Mountain	20.5	14.5	18.5	12.8	13.1	16	17.5
Hurricane Ridge	0.1	0.2	0.2	11.5	13.2	1	1
Leavenworth	1.4	3.2	1.9	7.2	5.8	7	3.6
Loup Loup	0.7	0.7	0.6	3.9	1	3.5	0.9
Mission Ridge	4.8	4.9	4.8	7.3	6.2	4.7	4.6
Mt. Baker	7.6	7.3	7.5	6.5	5.7	7.4	5.7
Mt. Spokane	4.3	5	4.3	7.1	7	7.8	8.2
Ski Bluewood	1.4	1.4	1.3	3.7	4.1	3.2	1.5
Stevens Pass	17.6	19.7	18.7	10.1	9.4	11.7	11.4
Summit at Snoqualmie	30.2	32.6	31.5	16	15.7	21.9	28.7
White Pass	7.3	6.5	6.8	10	15.9	11.8	12.3

Table 3.1 Continued

Resort	Run 9	Run 10	Run 11	Run 12	Thiessen Polygons	125 mile Service Area	2040 Run 2
49 Degrees North	3.4	5.2	3.5	3.55	0.9	0.6	3.54
Crystal Mountain	17.6	27.7	15.1	18.33	12.4	21.5	18.15
Hurricane Ridge	0.6	0.5	7	0.55	9.5	0.3	0.5
Leavenworth	3.7	0.1	4.2	3.7	0.3	0.6	3.68
Loup Loup	0.8	1.4	0.9	0.81	0.8	1.1	0.78
Mission Ridge	4.5	6.8	7.7	4.9	3.7	1	4.86
Mt. Baker	5.7	5.3	5.8	6.76	5.5	6.5	6.69
Mt. Spokane	6.9	6.1	6.7	7.01	7.4	8.8	6.97
Ski Bluewood	1.5	1.4	1.5	1.95	5.4	5.8	2.1
Stevens Pass	12	9.1	11.7	13.28	2.4	5.1	13.31
Summit at Snoqualmie	31.2	27.9	25.5	33.8	39.8	40.9	33.88
White Pass	12.1	8.6	10.5	5.33	12	7.8	5.51

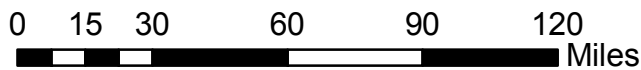
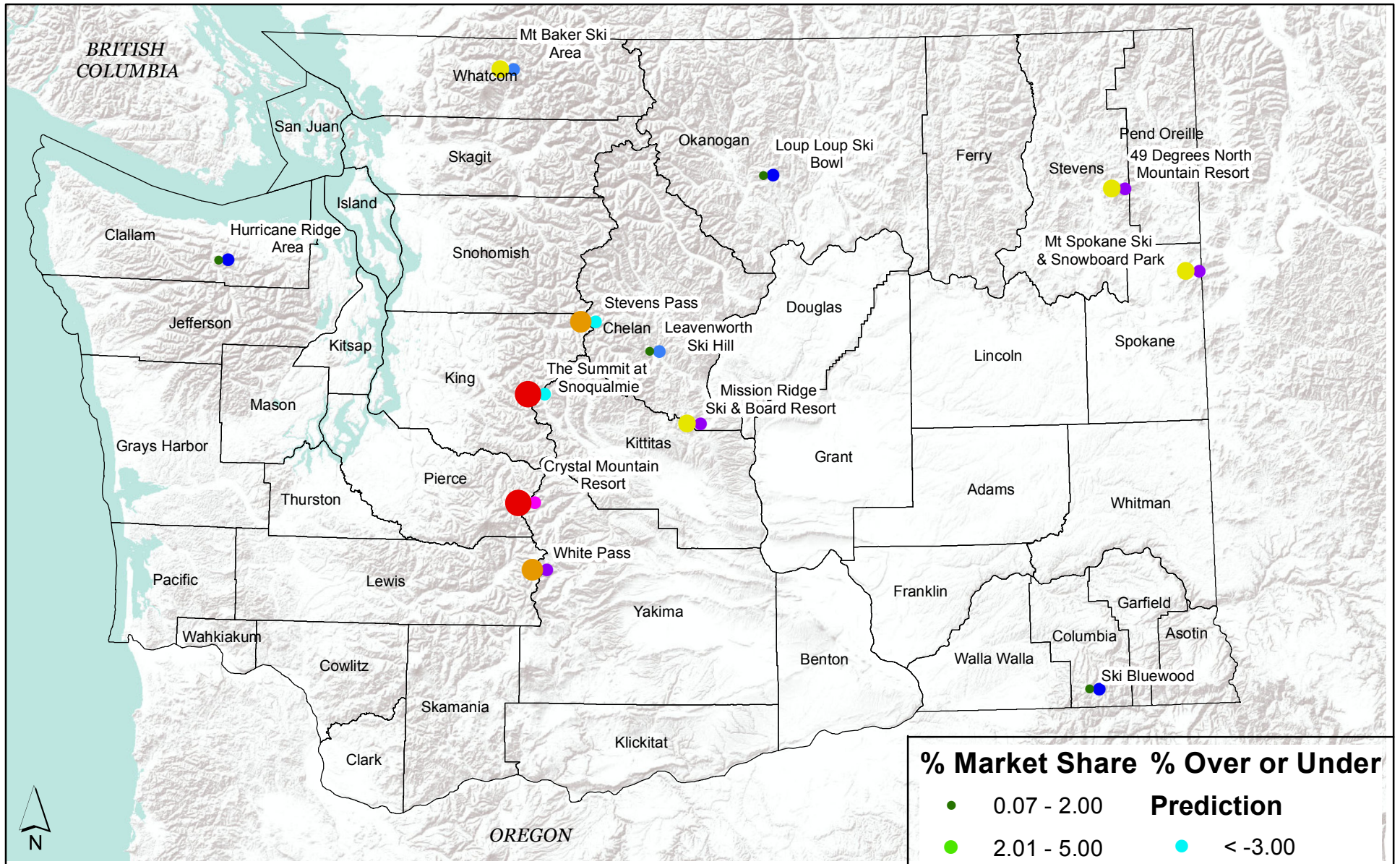
Figures 3.1 – 3.7 Results Maps (pages 43 – 49)



Source: Manually placed and attributed. Data from:
<http://www.liftopia.com/ski-resort-info/statemap/WA/Washington>
 Market shares calculated with Huff Model

Market Share of Ski Resorts – Run #9 Using Huff Model

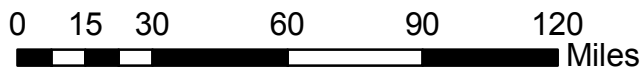
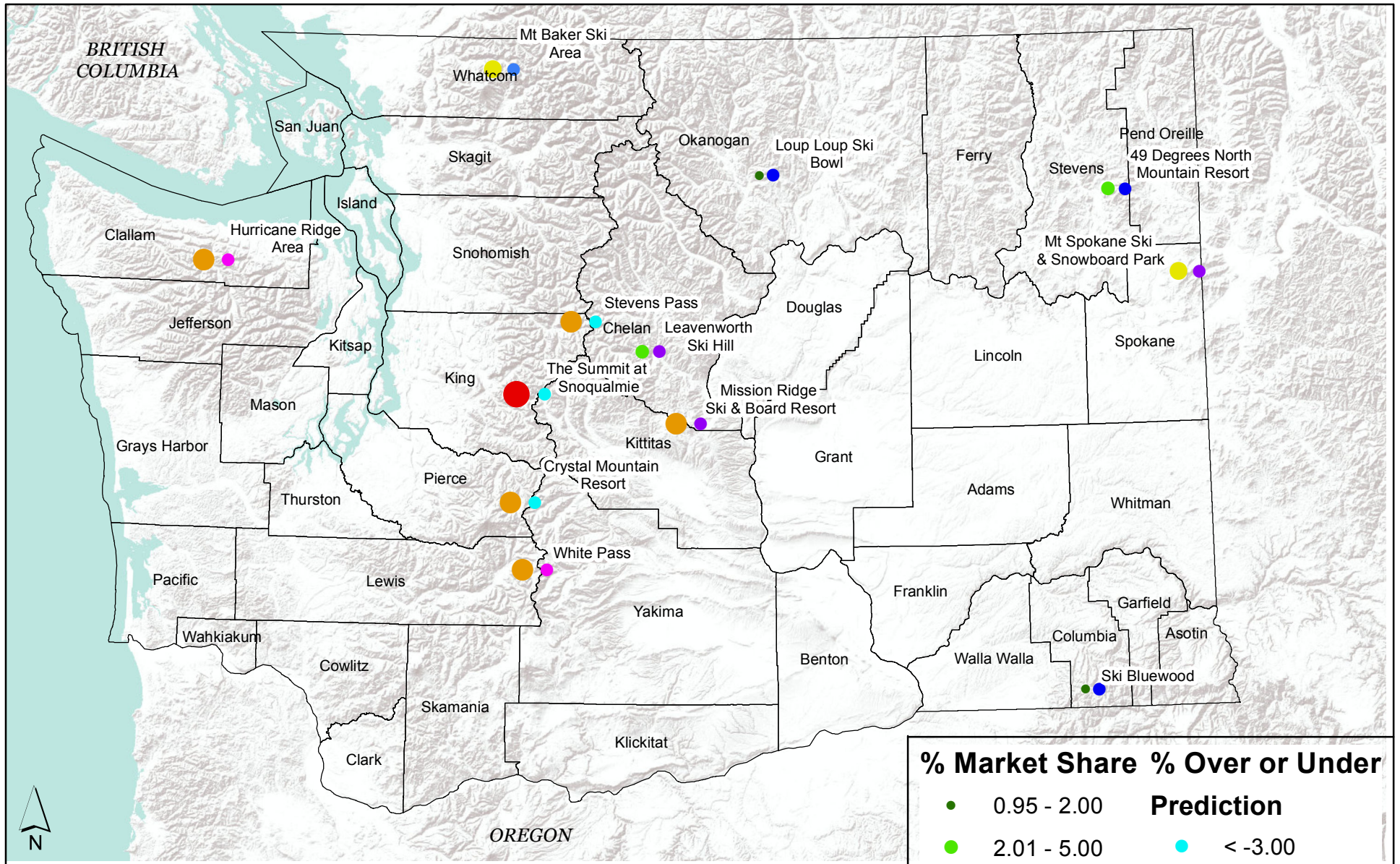
% Market Share		% Over or Under Prediction	
●	0.55 - 2.00	●	<-3.00
●	2.01 - 5.00	●	-2.99 - -1.00
●	5.01 - 7.00	●	-0.99 - 1.00
●	7.01 - 19.00	●	1.01 - 3.00
●	19.01 - 31.23	●	>3.01



Source: Manually placed and attributed. Data from:
<http://www.liftopia.com/ski-resort-info/statemap/WA/Washington>
 Market shares calculated with Huff Model

Market Share of Ski Resorts – Run #10 Using Huff Model

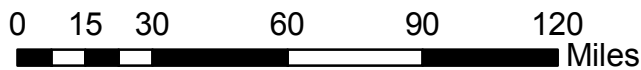
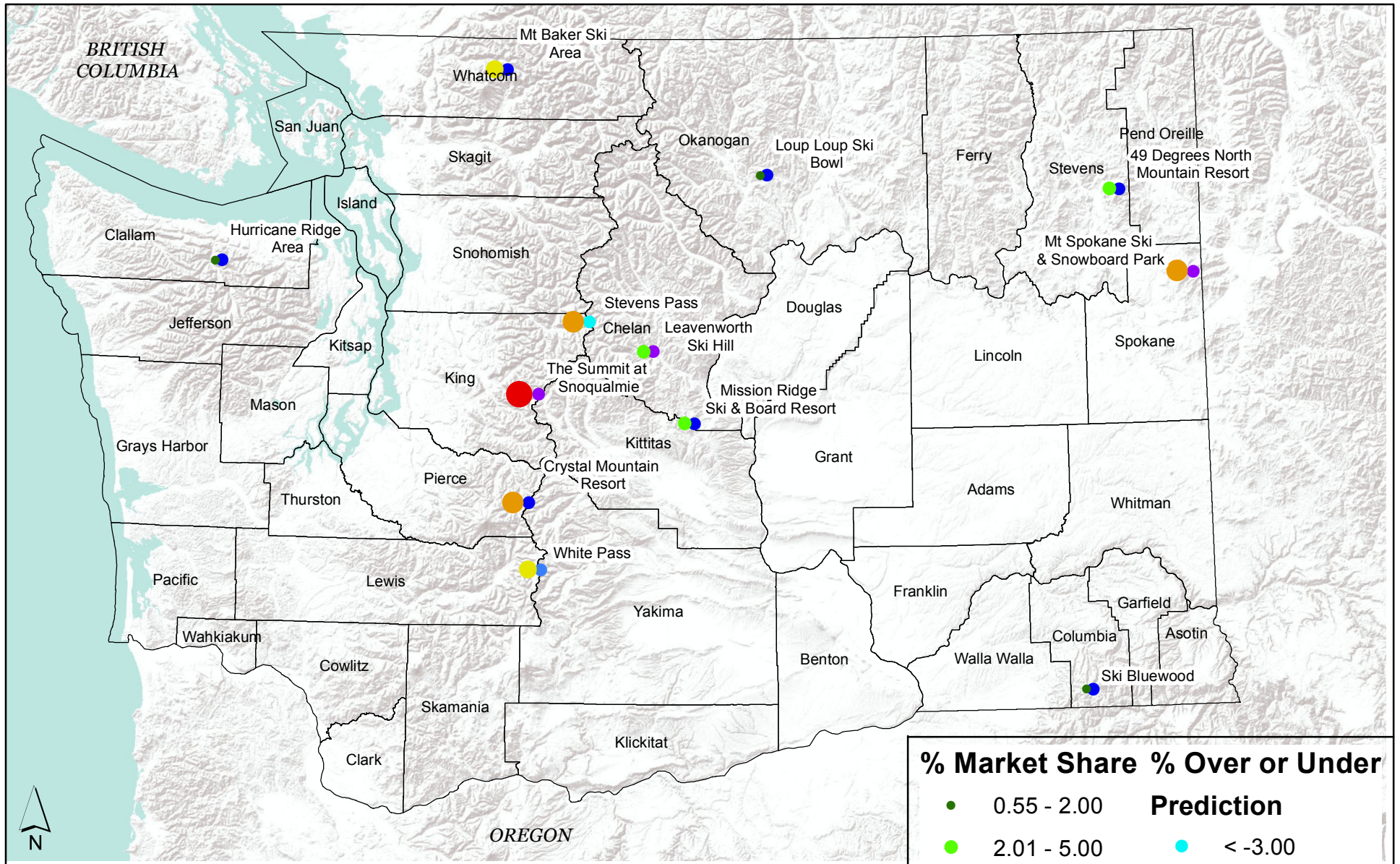
% Market Share		% Over or Under Prediction	
●	0.07 - 2.00	●	< -3.00
●	2.01 - 5.00	●	-2.99 - -1.00
●	5.01 - 7.00	●	-0.99 - 1.00
●	7.01 - 19.00	●	1.01 - 3.00
●	19.01 - 27.89	●	>3.01



Source: Manually placed and attributed. Data from:
<http://www.liftopia.com/ski-resort-info/statemap/WA/Washington>
 Market shares calculated with Huff Model

Market Share of Ski Resorts – Run #11 Using Huff Model

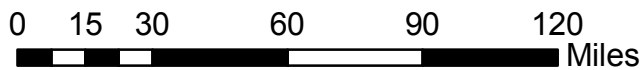
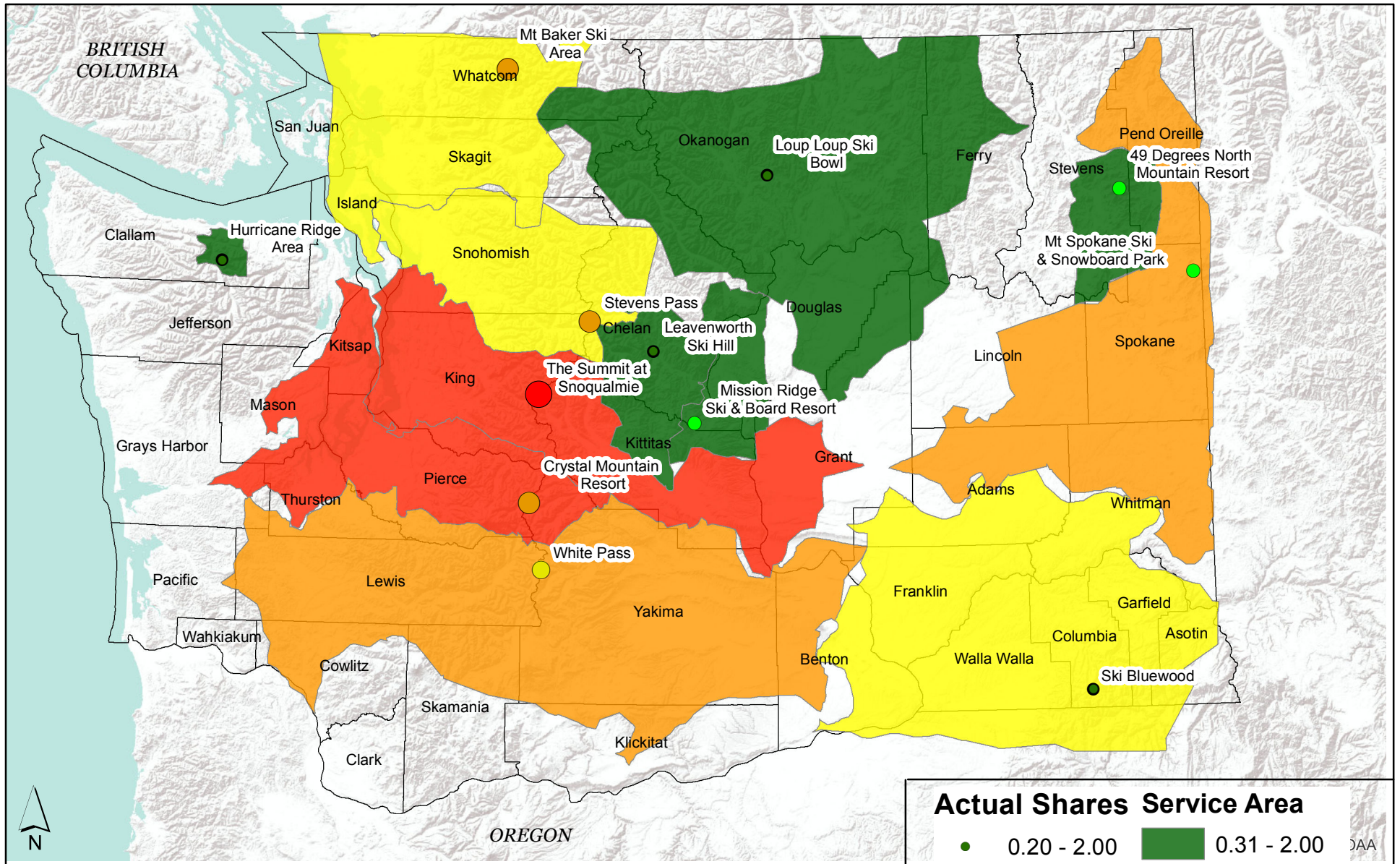
% Market Share		% Over or Under Prediction	
●	0.95 - 2.00	●	< -3.00
●	2.01 - 5.00	●	-2.99 - -1.00
●	5.01 - 7.00	●	-0.99 - 1.00
●	7.01 - 19.00	●	1.01 - 3.00
●	19.01 - 25.49	●	>3.01



Source: Manually placed and attributed. Data from:
<http://www.liftopia.com/ski-resort-info/statemap/WA/Washington>
 Market shares calculated with Huff Model

Market Share of Ski Resorts – Run #12 Using Huff Model

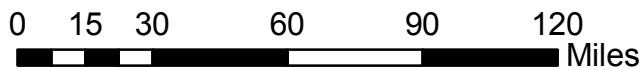
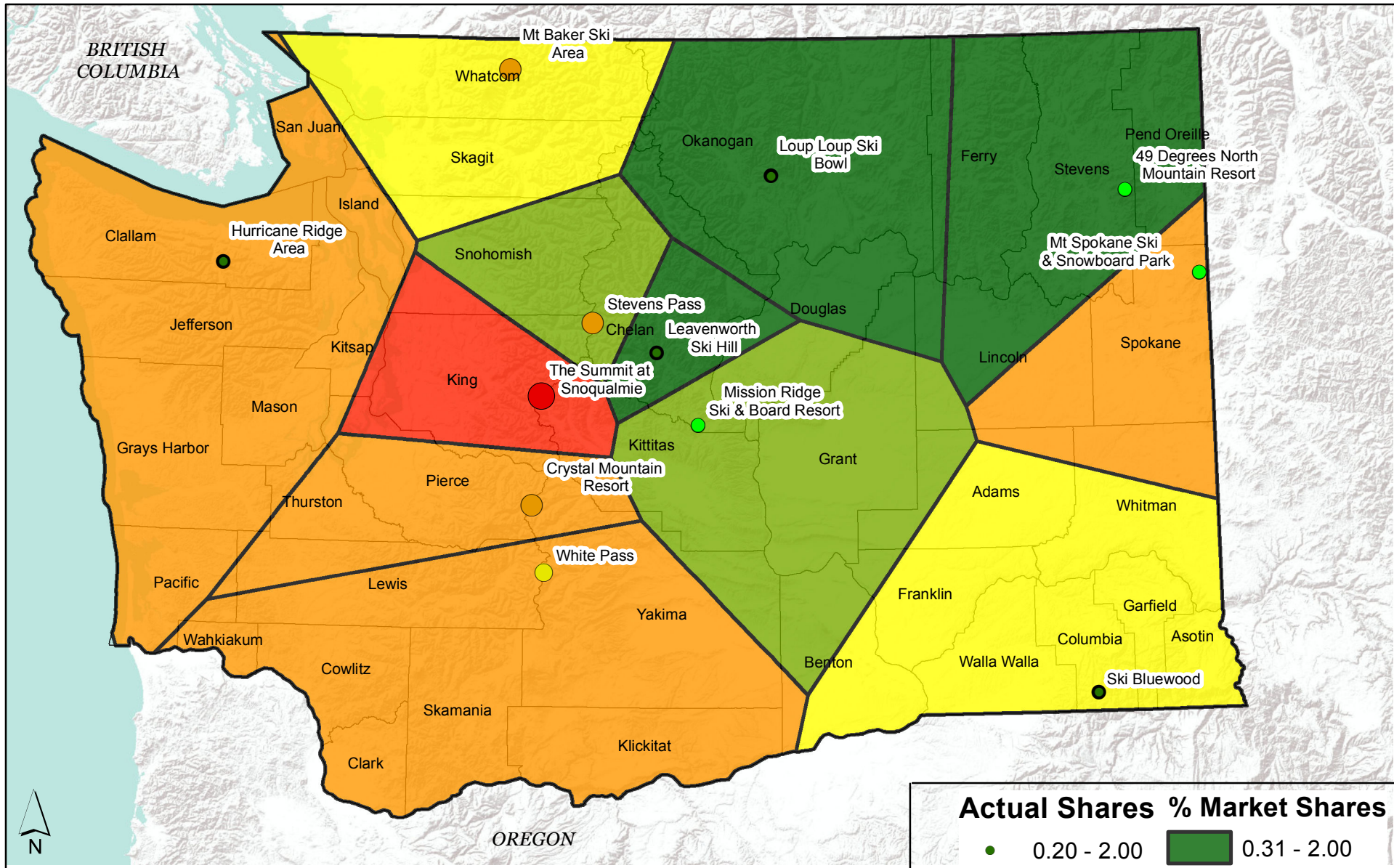
% Market Share		% Over or Under Prediction	
●	0.55 - 2.00	●	< -3.00
●	2.01 - 5.00	●	-2.99 - -1.00
●	5.01 - 7.00	●	-0.99 - 1.00
●	7.01 - 19.00	●	1.01 - 2.71
●	19.01 - 33.80	●	>3.00



Source: Manually placed and attributed. Data from: <http://www.liftopia.com/ski-resort-info/statemap/WA/Washington>

Market Share of Ski Resorts – Network Service Area, 125 Miles

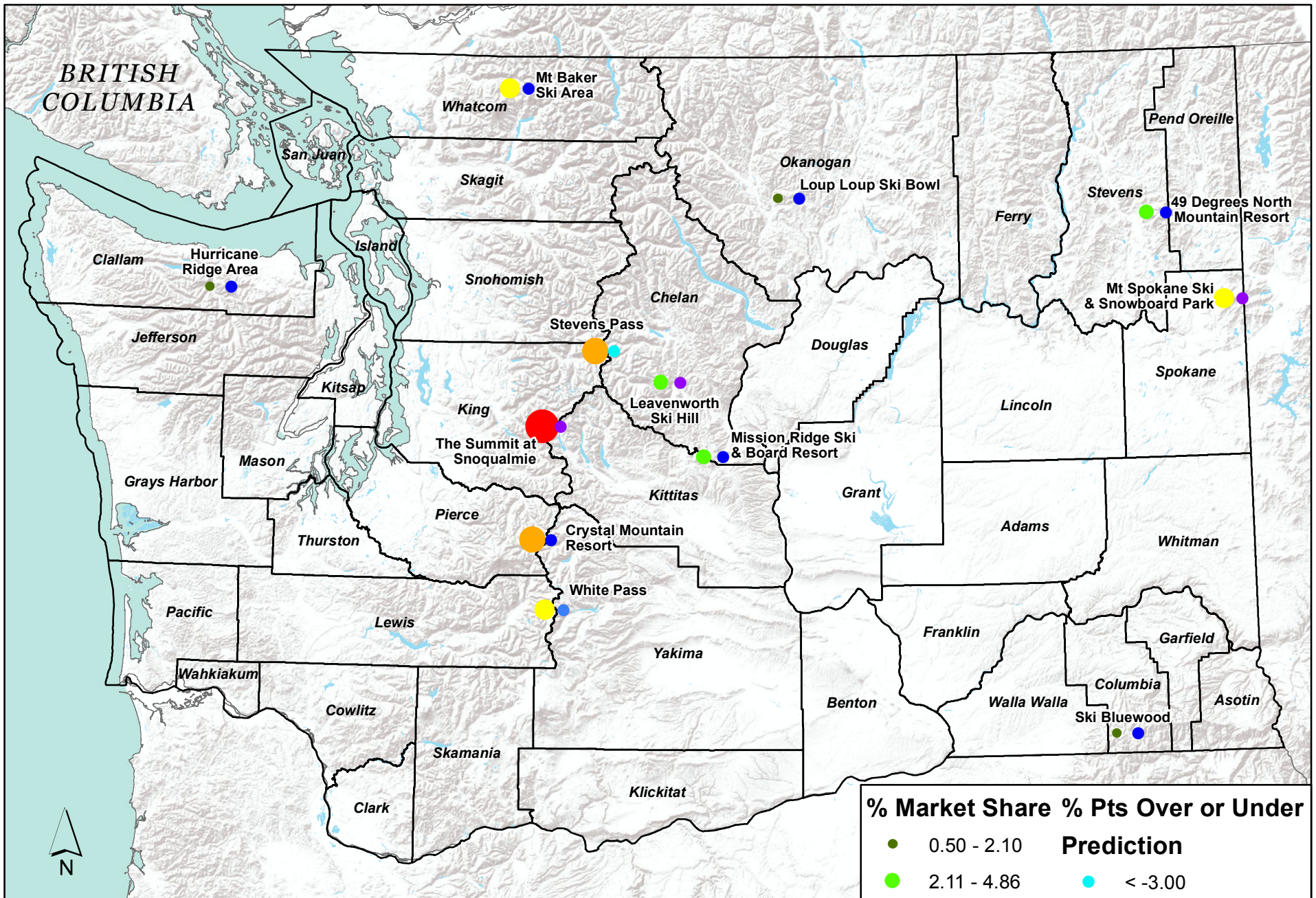
Actual Shares		Service Area	
●	0.20 - 2.00	■	0.31 - 2.00
●	2.01 - 5.00	■	2.01 - 5.00
●	5.01 - 7.00	■	5.01 - 7.00
●	7.01 - 19.00	■	7.01 - 19.00
●	31.50	■	19.01 - 40.95



Source: Manually placed and attributed. Data from:
<http://www.liftopia.com/ski-resort-info/statemap/WA/Washington>

Market Share of Ski Resorts – Thiessen Polygons

Actual Shares		% Market Shares	
●	0.20 - 2.00	■	0.31 - 2.00
●	2.01 - 5.00	■	2.01 - 5.00
●	5.01 - 7.00	■	5.01 - 7.00
●	7.01 - 19.00	■	7.01 - 19.00
●	31.50	■	19.01 - 39.81



0 25 50 100 Miles

Source: Manually placed and attributed. Data from:
<http://www.liftopia.com/ski-resort-info/statemap/WA/>
 Washington
 Market shares calculated with Huff Model

Future Market Share for Year 2040 Using the Huff Model

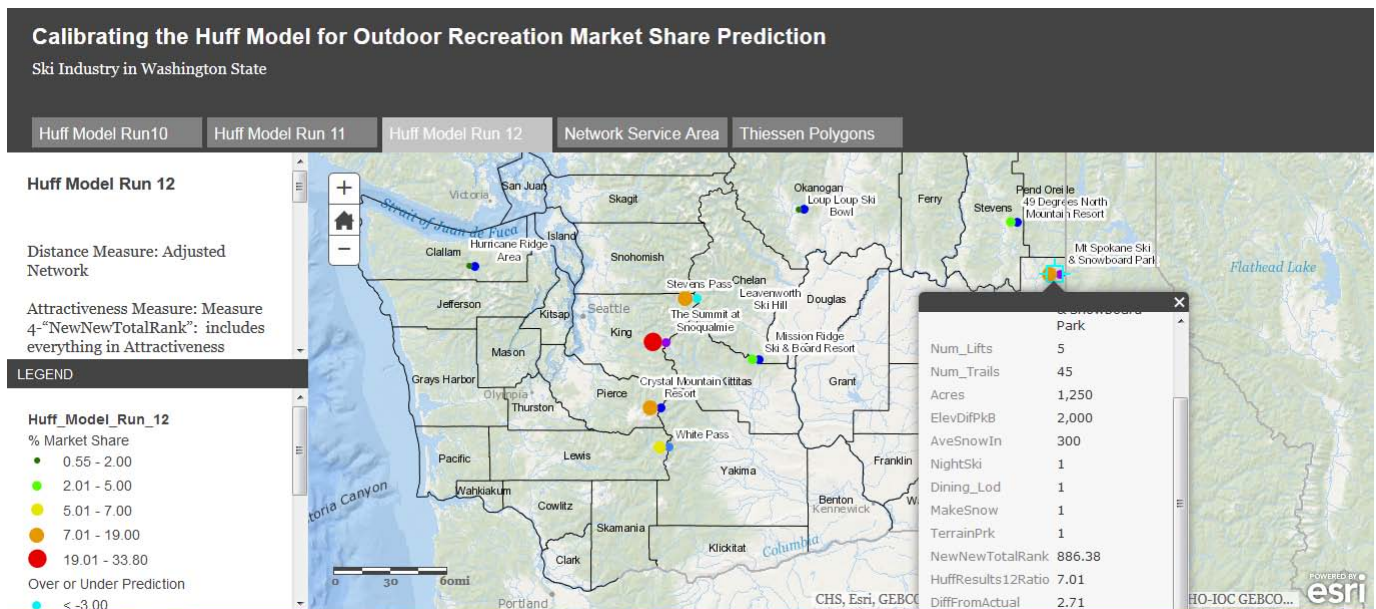
% Market Share		% Pts Over or Under Prediction	
●	0.50 - 2.10	●	< -3.00
●	2.11 - 4.86	●	-2.99 - -1.00
●	4.87 - 6.97	●	-0.99 - 1.00
●	6.98 - 18.15	●	1.01 - 2.69
●	33.88	●	> 2.70

3.2 ArcGIS Online Web Mapping Application

To allow for the easy spatial comparison of results by our sponsors, we have also created an online web map utilizing ArcGIS Online Story Maps. The map displays results for Huff Model runs 10-12, Thiessen Polygons, and Network Service Areas. It also displays the difference in percentage points (over or under predictions) for each Huff Model run. On the side tab for each map, the user can read about the specific inputs for each run. By clicking on any resort point, one can see the variables that were used to calculate the attractiveness measure, as well as each resort's total rank (attractiveness measure).

This web map can be accessed at: <http://uw-geog.maps.arcgis.com/apps/StorytellingTextLegend/index.html?appid=3585292578b74517ae53c82ac5e8fd2f>

Figure 3.8 ArcGIS Online Story Map - Results



4.0 Discussion

4.1 Market Share Prediction Results

4.1.1 Huff Model Runs

Our testing and calibration of the Huff Model for ski resort market share prediction clearly indicate that the Huff Model, given the right mix of inputs, can accurately predict

a ski resort's share of the total ski and snowboard market in Washington State. The Huff Model run 12 results are the best example. Run 12 is the most accurate set of results of all model runs, including the alternative prediction methods. All resort predictions came within 1-2 percentage points of the 3 year average, except for two: Mount Spokane (predicted 7%; actual 4.3 %); and Stevens Pass (predicted 13.28%; actual 18.7%). For the other 10 resorts, the accuracy of the run 12 results is astounding. Leavenworth Ski Area came within 2 percentage points (predicted 3.7%; actual 1.9%), as did The Summit at Snoqualmie Pass (predicted 33.8%; actual 31.5%). However, Leavenworth's 2012-2013 market share was 3.2%, which is much closer to the run 12 prediction, while Snoqualmie's was 32.6%. Other resorts' market shares were predicted to within less than 0.5%, such as Mission Ridge (predicted 4.9%; actual 4.8%), or Crystal Mountain (predicted 18.33%; actual 18.5%).

Run 12 is set apart by its inclusion in the attractiveness measure of the most variables of all runs. Including all the original base variables such as # of lifts, presence/absence of a terrain park, distance to a major city, etc. (see **Table 2.5** for the complete list) run 12 was the only run to include the season length in weeks. Furthermore, it was the first and only present scenario that used the revised network dataset (which did not include SR 123), which brought many predictions, such as those for White Pass, much closer to the actual market shares.

4.1.2 Sensitivity of Huff Model Result and Inputs

In this section, we discuss the sensitivity of the model results to changes in inputs, such as the network dataset and the attractiveness measure. By sensitivity we mean this: how much will the results change when the inputs change? If the results change little, they are not sensitive. If they change greatly, they are sensitive.

One trend that sheds light on the sensitivity of the Huff model is the case of Stevens Pass's large underprediction of market share in all model runs. We can only surmise as to why Stevens Pass's prediction in particular was never closer than 4 percentage points from the actual market share using the Huff Model. It may be that we are not including the right variable that sets Stevens Pass apart from other nearby resorts. However,

looking at the results, we see that in all Huff Model runs, Leavenworth is consistently overpredicted while Stevens Pass is consistently underpredicted. Leavenworth Ski Area is the closest resort to Stevens Pass, and therefore is consuming part of the market share in the model that goes to Stevens Pass in real life. It is likely to do with the relative weakness of the season length attribute, as well as other attributes. Leavenworth sees the shortest ski season of all resorts (less than 3 months), while Stevens Pass sees one of the longest (5-6 months). This variable, in real life, has a large impact on visitation. The longer a resort is open, the logic goes, the more chances people have to visit it. Thus, there are twice as many opportunities to visit Stevens Pass than to visit Leavenworth Ski Area. However, in all attractiveness measures, we include at least 10 and up to 13 variables. Since we are only ranking these attributes, without applying an additional weighting scheme, each variable has just as much weight in determining attractiveness as the next. By that reasoning, the presence / absence of a snow maker has just as much effect on the attractiveness, and thus the market share, as the season length in weeks. This is obviously false. Therefore we can say that as the number of variables in the attractiveness measure increases, the results become less sensitive to changes in them.

However, we do not wish to indicate that the Huff Model results are not sensitive to the attractiveness measure in general. Huff run 10 demonstrates this. It used the network dataset, but used only “acres” as the attractiveness measure and “population” as the sales potential measure. The results were very inaccurate, having the greatest effect on the largest of resorts such as Crystal Mountain and the Summit at Snoqualmie. It predicted the former at 27.9% (actual 18.5%) and the latter at 27.7% (actual 31.5%). Thus we can say definitively that the size of a resort alone is not the best predictor of visitation. Furthermore, the use of population alone in the sales potential measure is weaker than using a combination population and income.

Finally, the model results are extremely sensitive to the use of a network dataset compared to Euclidean distance. The results for model runs 9 and 11 clearly show this. Run 9 and 11 differed only in the calculation of distance; run 9 used a network dataset while 11 used Euclidean distance. They both used the same measures of attractiveness and sales potential. The differences between the two runs’ results are significant. The

predictions for Hurricane Ridge's market share differed by 6.4 percentage points between the two runs, with run 9's results being much more accurate. Similarly, The Summit at Snoqualmie's results differed by 5.7 percentage points, with run 9 also being more accurate. Other results differed only slightly between the two runs, but run 9 overall had a higher degree of accuracy. Therefore, we suggest that the use of a network dataset over Euclidean distance is absolutely critical in obtaining accurate market share predictions.

The accuracy of the street network itself is also important. Run 12 demonstrates this effectively. In run 12, a revised network dataset was utilized which eliminated State Route 123 near White Pass, due to this highway's frequent closure in winter. In previous runs, the market share for White Pass had been overpredicted by up to twice its actual percentage (6.8%), usually around 12%. After we deleted SR 123 from the network and ran the Huff Model for run 12, the market share for White Pass dropped to 5.5%, much closer to reality. Other resorts which had been underpredicted, such as Stevens Pass, also increased, if only slightly, towards their actual market shares. We suggest that the user of the network dataset possess a full understanding of the seasonality of the recreational activity under scrutiny and make appropriate adjustments to the network if roads are closed.

4.1.3 Alternative Prediction Methods

The results of the alternative market share prediction methods, namely network service areas and Thiessen polygons, clearly suggest that these methods, despite being quick and straightforward, are not nearly as accurate as the Huff Model. Between the two, it is additionally evident that network service areas are much more effective than Thiessen polygons at predicting the market share of ski resorts, given ski resorts' wide geographic dispersion.

Thiessen polygons' effectiveness varied widely. While they were able to come within a few percentage points of reality for a few resorts, namely Loup Loup (predicted 0.8%; actual 0.6%) or Mission Ridge (predicted 3.7%; actual 4.8%), they were extremely inaccurate in predicting others such as Hurricane Ridge (predicted 9.5%; actual 0.2%)

or Stevens Pass (predicted 2.4%; actual 18.7%). This method cannot be recommended in any way.

125 mile service areas, on the other hand, were much more effective than their lesser alternative. Hurricane Ridge was predicted with considerable accuracy (predicted 0.3%; actual 0.2%), while Mount Baker came within 1 percentage point (predicted 6.5%; actual 7.5%). However, most resorts saw dramatic over- or under-predictions of market share, with Stevens Pass faring the worst (predicted 5.4%; actual 18.7%). While we could recommend this method for a “quick and dirty” analysis, due to its requirement of a network analyst, which is one of the most time-consuming inputs in the Huff Model, we would suggest going one more step and developing an attractiveness measure. After all, the network analyst service areas prediction method is basically the Huff Model without the gravity based calculations involving the attractiveness measure. Furthermore, this method requires a literature review to discover the greatest distance that consumers are willing to travel to visit a location, which can require additional time and resources to accomplish. Therefore we suggest the use of the Huff Model over both service areas or Thiessen polygons as the method which results in the greatest payoff for the time requirements.

4.1.4 Huff Model Future Predictions

The Huff Model future market share predictions, using the current inputs, do not show a great amount of market share change for Washington State ski resorts by the year 2040. In fact, the results barely differ from the Huff Model run 12. The greatest change in market share is at White Pass, which changed by about 0.2 percentage points, from 5.33% in run 12 to 5.51% in the 2040 run. All other resorts changed by less than 0.05 percentage points.

The reason for the small variation in present and future model predictions is due to the large number of variables in the attractiveness measure, as discussed in section

4.1.2 Sensitivity of Huff Model Results and Inputs.

Between run 12 and the 2040 run, the only changes were to the season length in weeks and the population at the origin consumer locations. Because there are 12 other variables in the attractiveness measure (and one other variable besides population in the sales potential measure), the change in season weeks will have relatively little effect. If we could reduce the number of total variables, or introduce a weighting scheme which values the season length higher, then the changes in future market share would likely be greater. However, that is now beyond the scope of this study.

4.2 Resilience/Sustainability of Ski Industry in Washington State

As a condition of our use of PNSAA's and Ski Washington's ski resort visitor data, we agreed not to analyze the vulnerabilities of individual ski resorts in Washington State. The comments here apply to the ski industry in Washington State generally.

The authors of the text *Resilience Practice* define resilience as “the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks - to have to same identity” (Walker and Salt 2012, 3). They distinguish general versus specified resilience, and point out that building resilience often comes at a cost to either general or specified resilience. Furthermore, transformability is a key component of resilience, meaning that sometimes, a self-organizing system must change in order to preserve its fundamental identity (Walker and Salt 2012, 3).

Applying these points to the ski industry in Washington State is a straightforward task. The specified threat to the ski industry is a warming climate due to greenhouse gas emissions, which could potentially decrease snowfall and thus shorten ski seasons. General threats include unexpected avalanches and low snowfall anomalies, as well as demographic changes which could affect the relative market shares for certain resorts (such as incomes decreasing in parts of the state, resulting in fewer visitors to the local resort). While the literature in part suggests that the ski industry in the USA could see drastic declines in season length in the coming decades (see **Figure 1.3 Thresholds Matrix**), our examination of future winter temperatures for recalculating ski resorts'

season lengths indicates that the ski industry in Washington State is resilient against specified threats such as a warming global climate. Specifically, under the A2 climate scenario, no resorts saw warmer season end month temperatures in 2040, while all resorts saw higher start month temperatures. Despite this, only 5 resorts saw season start month temperatures that were higher than 3 degrees Celsius, and thus wouldn't be able to make snow for large parts of their traditional start months. By our mixed qualitative/quantitative season length prediction method for 2040, only half of resorts will see shorter seasons, and then only by 4 weeks at maximum. Additionally, while building resilience against lower snowfall at the tail ends of the season can come at a high cost in dollars due to the massive expense of snow making, resorts have the unique opportunity to take advantage of lower summer snowpack by offering summer recreational activities such as hiking or mountain biking. Furthermore, due to the lower overall deep winter temperatures (December through March), snowfall is unlikely to decrease during the core of the Washington State ski season (and may even increase due to higher precipitation). Therefore, Washington's ski industry is expected to retain its identity for decades to come.

4.3 Huff Model Simplifying Assumptions

We have discussed the Huff Model's and our own simplifying assumptions throughout this text. Below is a summarized list of various assumptions that were made by us or are inherent to the model.

1. The "attractiveness" measure accurately represents those entities that attract people to the destination.
 - a. Does not take into consideration people's perception of a resort, such as nostalgia, crowds, special occasions, personal preference for types of runs, etc.
 - b. Does not take into consideration quality of lifts, terrain parks, dining, availability of first aid, rentals, difficulty level of lifts, classes, differences between lift ticket costs, etc.
2. Does not take into consideration origin locations outside the area of interest boundary.

3. Road network dataset does not contain non-paved roads and ferry routes.
4. Future Scenario: Unknowable variables remain constant.
5. Future Scenario: Future population projections were distributed to census tracts based on their 2010 ratio to total county population
6. Future Scenario: Income remained constant
7. Future Scenario: An average monthly temperature higher than or near 3 degrees Celsius meant that snow could not be made for at least part of the month, and thus a resort must shed one or more weeks off its season depending on how much higher than 3 degrees Celsius its predicted temperature is.
8. Future Scenario: All resorts would choose to make snow as long as they could rather than close early.

4.4 Huff Model Limitations

Though the model documentation suggests that the Huff model may be used for calculating a specific number of people visiting a store, and even calculates the visitation rate from each census tract, we strongly encourage users to avoid this type of use for predicting absolute numbers as a means of calculating economic impact of a specific activity, especially at the state level.

One reason that the Huff Model is a poor predictor of absolute visits, as opposed to a potential *market share*, is the fact that the model assumes that the entire population within a tract will visit a resort, when in fact there are often some people who do not ski, and others who have multiple visits. The model makes the simplifying assumption that these two factors balance each other out. Furthermore, when using the Huff Model for this purpose, the total number of visitors to all locations will inevitably equal the total population of all consumer locations. So if one wants to predict the total visitation of all ski resorts in Washington State based on the population in 2010, the result must equal 6.7 million. Therefore, the Huff Model is more effective when predicting relationships between resorts, i.e. market shares. *How much* the model predicts for a given resort matters less than how much is predicted *in relation to all other resorts*.

5.0 Business Case for Future Implementation

5.1 Recommendation for Successful Model Use

It is recommended that the Huff Model is valuable for predicting market share, but with the stipulation that one considers the full range of possible variables for calculating the “attractiveness” measure. While it is possible to run the model with minimal inputs, the analysis in this report has shown that the results more closely resemble reality when more, but not too many, aspects of the recreation activity are present in the analysis. This also has the potential to impact the results and the conclusions made about those results.

5.2 Further Steps & Projected Costs

Our recommended course of action is that the Huff Model is indeed appropriate for usage in estimating market shares for various recreation activity points when the state total is known. Estimating the cost to run the Huff Model for the entirety of one type of recreation activity, from collecting the data to deciding on ‘attractiveness’ measures, proved to be difficult due to the high variability between different types of recreation activities. Therefore, we have decided to portray an estimate of cost for what it would take to complete those tasks that would demand additional time from an Earth Economics GIS Analyst to complete before the Huff Model could be used in the desired fashion. What has been discovered from our sponsor attempting to run the model on other types of recreation, such as fishing grounds, is that the Huff Model script itself must be adjusted. This is due to requirement that a recreation location point be within a minimum distance of 1000 meters from a road network to be included in the analysis. Some work would need to be accomplished before one would be able to set the distance to network as 5000 meters, or 10000 meters, or any chosen distance.

An additional expense before the Huff Model could be run as desired is that the road network dataset must be adjusted to include non-paved roads, as well as ferry routes. The current network dataset does not presently contain those elements as this was a simplification that we made for this project. The statewide scale and easy accessibility of ski resorts allowed us to use a simplified network dataset.

In order to save additional time in running the Huff Model there are some improvements that could be added to the python script for running the Huff Assist tool. Currently, the tool is set to label the attribute field in the intermediate tables containing the total sum of each ski report's participation from each origin location (census tracts) as "SUM_sales." This poses an inconvenience when running the Huff Model multiple times because each run joins a table with a field called "SUM_sales" to the original recreation field class. It then becomes necessary to change the field name after each run in order to keep track of the results from multiple runs. Therefore, it is suggested that additional time be spent in adjusting the script so that this field name may be specified according to the user for each run of the Huff Model.

An additional process that would save time completing calculations after the script tool finished would be to add additional script to the tool to do these calculations for the user. This would basically have the tool go one more step and sum the, now called, "SUM_sales" that has been joined to the original recreation activities feature class. Then, create a new field and populate this field for each record with the following equation: $([SUM_sales] * 100) / \text{Total sum of the "SUM_sales."}$ This equation fills in the table with each individual resorts percent market share rather than manually calculating the value using the Field Calculator.

Table 5.1 lists who will do what, with what expected outcomes, and at what cost for the additional tasks. As you can see, the estimates for conducting the additional steps previously described are split into two categories: the cost for if an Earth Economics GIS Analyst were to do the work or if an independent contractor were hired to complete the tasks.

Table 5.1 Future Implementation Tasks and Projected Costs

Additional Tasks Description	Estimated hours to complete *	Expected outcome	EE GIS Analyst \$16/hr	GIS Contractor \$100/hr
Adjust & manipulate Huff Model python script to allow different minimum distances from point to road network	5	The Huff Model will now include points at a user defined distance to road network	\$80	\$500
Complete & adjust road network dataset to include non-paved roads and ferry routes	10	Complete functioning road network dataset	\$160	\$1000
Addition of script to Huff Assist tool to allow user to input unique name instead of "SUM_sales".	4	Huff Assist tool for a more streamlined workflow	\$128	\$800
Also write script to calculate percent market share at the end of the tool script.	4			
Total Cost Estimation	23		\$368.00	\$2300.00

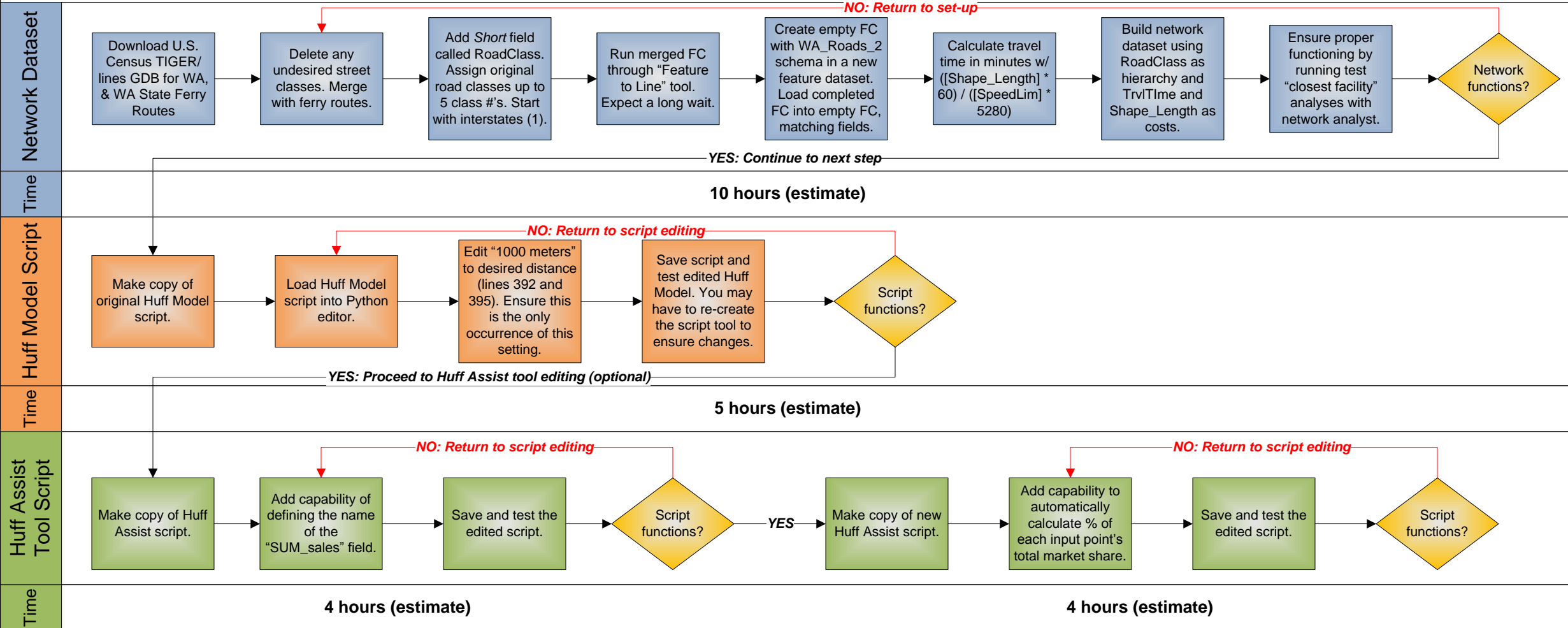
*Estimates are high to leave room for solving problems

*It is expected that a GIS Contractor would require less time to complete the work, however that person would need time to familiarize themselves with the material. Therefore, due to lack of knowledge about the requirements of a contractor, the hourly estimates remain the same for simplicity. Hourly estimates, of course, vary from person-to-person.

Figure 5.1 Future Implementation Workflow

Huff Model for Recreation Activity Market Share Prediction | *Earth Economics*

Work to be completed by EE GIS Analyst



6.0 References

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7.0 Appendices

Appendix A: Glossary

Calibration: to adjust a set of parameters associated with a computational science and engineering code so that the model agreement is maximized with respect to a set of experimental data (Trucano et al 2006, 1).

Data Model: Extensible Markup Language (XML) workspace document that contain different structures that can be applied to a database for the type of data one wants to create or work with (ESRI 2014).

Direct economic impact: expenditures associated with activity

Euclidean Distance: distance in a straight line between two objects.

Feature class: a collection of common features having the same spatial representation: lines, points, polygons.

Geodatabase: a collection of geographic datasets of different types: feature classes, raster datasets, tables, feature datasets, topologies, networks, relationships, etc.

Indirect economic: expenditures associated with suppliers.

Induced economic impact: expenditures associated with employees.

Market share: the percentage of revenue accounted for by an entity from the total.

Network dataset: dataset for the purpose of modeling networks, created from source features. It can include simple features such as lines and points, and store the connectivity of the source features (ESRI 2014).

Resilience: the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks - to have the same identity (Walker and Salt 2012, 3).

Appendix B: Original Request for Proposal

State of Washington Recreation & Conservation Office

Request for Proposals (RFP) NO. RCO1406, response to the Governor's message to the Blue Ribbon Task Force.

Project Title: Request for proposals to provide a study that quantifies the economic contribution of outdoor recreation to Washington State's economy.

Within this request for proposals, there are five modules outlined. It specifically requests proposals for Module I and Module II with additional considerations for the remaining modules to be completed within the proposed budget. Following, each of the modules is outlined, directly quoted from the RFP:

Module I: Economic contribution of all outdoor recreation in Washington State

Quantify the total annual economic contribution (direct, indirect and induced, and resulting number of jobs) of all expenditures related to outdoor recreation in Washington State.

- i. State-wide, and
- ii. If feasible, at the regional level: most preferable, by legislative district and county; less preferable, counties only or regions composed of groups of counties.

Results should be broken into contributions from different recreational activities. Using the classifications in the 2013 Washington State Comprehensive Outdoor Recreation Plan (SCORP) is recommended but not required.

Module II. Economic contribution of outdoor recreation on Washington State public lands

Quantify the total annual economic contribution (direct, indirect and induced, and resulting number of jobs) of expenditures on outdoor recreation taking place on Washington State public lands: recreation on federally managed lands (National Park Service, U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife, Army Corps of Engineers); recreation on state-owned lands (State Parks, Department of Natural Resources, Department of Fish and Wildlife), and recreation on regional and local outdoor public recreational facilities.

- i. Total contribution state-wide and, if feasible, at the regional level: most preferable, legislative districts and counties; less preferable, counties only or regions composed of groups of counties
- ii. Total contribution state-wide on lands owned by each of the nine managing entities listed above and, if feasible, each at the regional level: most preferable, by legislative district and county; less preferable, counties only or regions composed of groups of counties.
- iii. Because a great amount of recreation in Washington State occurs on rivers, lakes and larger bodies of water, and because those waters are typically considered public, we also seek an assessment of the economic contribution of recreation activities on water.

Module III. Economic contribution of outdoor recreation on Washington State private lands

Quantify the total annual economic contribution (direct, indirect and induced, and resulting number of jobs) of expenditures on outdoor recreation taking place on Washington State private lands such as golf courses, ski areas, and timber company lands.

- i. Total contribution state-wide and,
- ii. If feasible, at the regional level: most preferable, by legislative district and county; less preferable, counties only or regions composed of groups of counties.

Module IV. Economic impact of expenditures on outdoor recreation by non-local visitors

If possible, quantify the total annual economic impact of expenditures (direct, indirect and induced, number of jobs) on all outdoor recreation by non-local visitors.

- i. Impact on Washington State by recreating visitors from outside the state, and
- ii. If feasible, impact of visitors at the regional level from outside the region: most preferable, legislative districts and counties; less preferable, counties only or regions composed of groups of counties

Module V. Economic value of recreation-related ecosystem services

Identify ecosystem services that are of value to outdoor recreation in Washington State and quantify the annual economic contribution resulting from these recreation-related ecosystem services, contrasting healthy and degraded ecosystems.

- i. State-wide, and
- ii. If feasible, at the regional level: most preferable, legislative districts and counties; less preferable, counties only or regions composed of groups of counties, and
- iii. If feasible, estimate the total annual state-wide economic benefit of recreation-related ecosystem services in Washington State, contrasting healthy and degraded ecosystems.

Sources of information for Modules I-V may be original research data, secondary data, data combined with data and/or models from other studies, and inferences based on results from other studies. For any elements that are deemed not feasible within the scope of this contract due to cost, time frame, or lack of appropriate information or applicable methodology, state the reasons that the element is not feasible.

(RCO 2014, 3-4)

Appendix C: Huff Model How-To Text

Huff Model How-To: General setup for calculating percent market share of a given recreation activity

Earth Economic and UW PMPGIS

August 2014

Application:

The suggested use of the Huff Model is for estimating market shares of a location, as opposed to absolute numbers. This method can accurately predict each input point's share of total business, but not the number of customers or the total sales. This document outlines how to calculate an "attractiveness" measure for use in the Huff Model.

I. Setup Huff Model Inputs

1. Obtain or populate point feature class (FC)
 - a. Original feature class may be in line or polygon form. In this case they will have to be converted to a point FC. This can easily be done by using the Feature to Point tool in ArcMap.
 - b. The points in this feature class represent the locations to which people are being attracted. These can be golf courses, stores, ski resorts, lakes, etc. The point can be the centroid of a polygon or the entrance to the location (if it is a very large area). At minimum, this dataset must have two fields: a "Name" field, type *Text*, and an "Attractiveness" field, which must be a numeric type (*Double* is recommended). These fields can be named in any way, as you will specify them in the Huff tool dialogue.
 - c. It is also suggested to add a *Text* field called "NUMname". Calculate this field with the following expression: `OBJECTID + 1`. Use this field as the "Name" input in the Huff Model if you will be using the "Assist" script tool. This allows a key to be made to link the Huff output with the point FC input.
2. Calculate Attractiveness Fields. See Sections III and IV for directions on how to do this.
3. Setup a workspace folder for outputs; this will be used in both Huff Model and HUFF Assist tool.

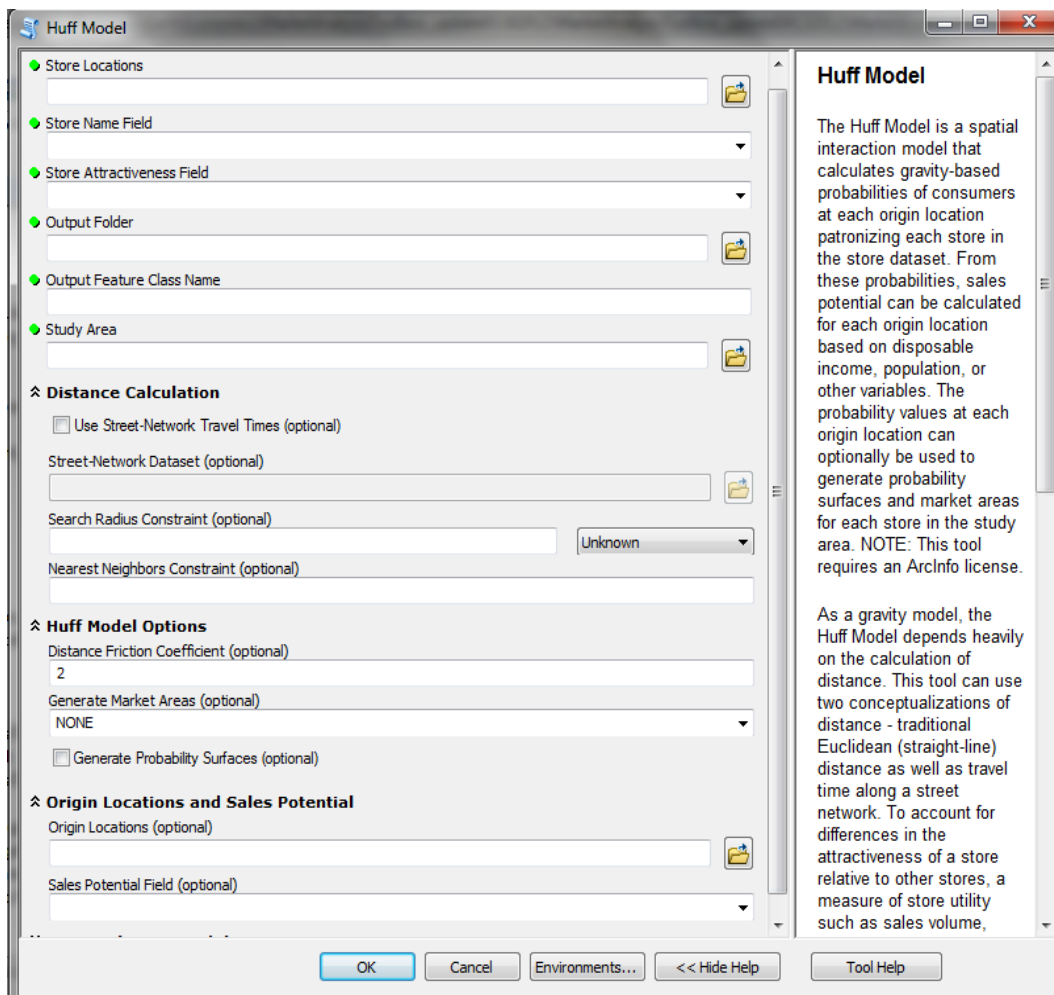
4. Obtain or create a working road network system.
 - a. Network Analyst is required for the network dataset to work
5. Obtain or create a boundary for the area of study
6. Obtain Origin locations FC for the consumer locations, to be used as origins in the model
 - a. Origin locations are often census geographies (blocks, block groups, tracts) but could also geocoded consumer locations.
 - b. If a specific dataset is not specifies random point within study area will be used
7. Populate or Specify Sales Potential Field
 - a. Field attribute with in origin location such as income, population, or other social/ economic data.
8. Verify that all FCs are in the same coordinate system, if not, convert them in ArcMap.
9. Due to the large size of field names, it is recommended to use only geodatabase feature classes, not shapefiles.

II. Populate Huff Model tool Dialog box

See image below.

1. Input Store Locations FC: Recreation activities point FC
2. Input Store Name Field: "NUMname"
3. Input Store Attractiveness Field: Field calculated in section III.
4. Input Output Folder
5. Fill in Output Feature Class Name

- a. This is the results FC, if intending to run multiple iterations of the Huff Model develop a naming convention.
6. Check the Use Street-Network Travel Times box
7. Input Street-Network Dataset
8. Input Origin Locations
9. Specify Potential Field
10. Hit Ok
11. Follow directions for result preparations and percent market share calculations in sections V and VI.



III. Calculating an Attractiveness Measure for Use in the Huff Model Methods:

1. Establish variables

Use variables that correlate with more or less attractiveness of a particular location. Total land area, presence of certain facilities, distance from a major city, etc. can all be variables that determine a location's attractiveness. Each variable will be a numeric field in your point FC. It is important to ensure that there is an entry for every location in your dataset.

10. Add variables to attribute table (if not already attributed)

If your point FC is small, this is can go quickly. If your point FC is large, choose variables (if not already attributed) that can be calculated and added using automation (such as the NEAR tool, explained below in the "Additional Methods" section).

11. Calculate standardized ranks

If you have variables using different measures, such as "acreage" or "number of boat launches", you can calculate a standardized rank which will allow you to compare different variables on the same scale (between 0 – 100). Calculating each variable's rank is a two-step process.

- a. Add a field to your point location's attribute table called "VARIABLE_rankmag", field type *Double*. Replace "VARIABLE" with your variable's name, such as "Acreage_rankmag".
- b. Add a field to your point location's attribute table called "VARIABLE_rank", field type *Double*.
- c. Right click on the variable's field and use the "Statistics" option to record the maximum and minimum values. Either copy and paste these or record them in a separate document.
- d. Open up the Field Calculator in the "VARIABLE_rankmag" field. Input the following formula, replacing the text with the values you recorded:

$$(Maximum - Minimum) / 100$$

- e. Open up the Field Calculator in the “VARIABLE_rank” field. Depending on how you want to rank your variables, you will use one of two slightly different formulas:

If you want HIGHER values to have HIGHER ranks, input
 $100 - ((\text{Maximum} - \text{VARIABLE}) / \text{VARIABLE_rankmag})$

If you want LOWER values to have HIGHER ranks, input
 $(\text{Maximum} - \text{VARIABLE}) / \text{VARIABLE_rankmag}$

- f. Repeat this process for each variable
- g. Add field, type *Double*, called “TotalRank”. In the Field Calculator, sum all the “_rank” fields (NOT “_rankmag”)
- h. This field is now ready to be used as the “attractiveness” measure.

IV. Additional Attractiveness Measure Calculation Methods

1. Calculating “Distance” Variables

- a. For those variables that involve a distance score from locations to the variables of interest (such as distance to a major road), use the “Near” tool in ArcToolbox. This tool calculates the distance of the nearest feature of interest to your point location, and adds a new field to the point location’s attribute table.
- b. When calculating the standardized ranks, replace “VARIABLE” with the “NEAR_DIST”. Remember to choose the correct formula for whether you want nearer features to have higher or lower scores. Since you will likely wish nearer features to have higher ranks in your point location attribute table, use $(\text{Maximum} - \text{VARIABLE}) / \text{VARIABLE_rankmag}$, because the smallest distance is preferred.
- c. NOTE: Every time the “Near” tool is run, it will replace the last NEAR_DIST field. Therefore, you must complete calculating the rank magnitude and rank for each distance variable in turn, before moving on to the next.

2. “Sales Potential” field in Huff Model set-up

- a. We suggest “Population” as the most effective option for this input. Use a statewide census tracts dataset with a total population field.
- b. If, however, there are other demographic factors influencing participation in the activity of interest, especially median family income, you can use the ranking methodology above to come up with a custom “sales potential” measure.

V. Prepare Huff Results For Percent Market Share Calculations

1. Utilize Tool
 - a. Open HUFF_Toolbox, Open HUFF Assist script
 - b. Define workspace: Use the same folder as the Huff Model, ex HUFF_1
 - c. Input Huff Model results FC
 - d. Input original recreation activity point FC
 - e. Hit OK
 - f. The results of the Huff Model should now be joined to the original recreation layer under the field name “SUM_sales”

VI. Calculate percent market share

1. Add a new field to the recreation activity FC, suggest naming it similar to “HUFFresultsratio_1”
2. Right click on “SUM_sales,” click on statistics, write down the sum of this field
3. In the new attribute field, calculate this field with the expression $([SUM_sales] * 100) / \text{Total sales sum}$

Appendix D: Huff Assist Python Script

'''

Chelsey Aiton and Brenden Mclane
University of Washington
GIS and Sustainability Management
Geog569 Capstone Project

This tool assists in processing the results from the HUFF model, so that they may be used to calculate market share of a particular recreational activity. The HUFF model creates a field in the attribute table for every Ski resort (in this case). The tool then takes this output and sums all the numeric fields and exports to a table, transposes the summary table, selects only the desired records, renames the selected fields, and joins this information to the original recreation layer.

'''

Import system modules

import arcpy

import os.path

import os

Set environment settings

from arcpy import env

workinfolder = arcpy.GetParameterAsText(0)

env.workspace = workinfolder

env.overwriteOutput = True

Creates geodatabase to store output tables

Set local variables

out_folder_path = workinfolder

```

out_name = "HUFFtool_outputs.gdb"

# Execute CreateFileGDB

arcpy.CreateFileGDB_management(out_folder_path, out_name)

# Description: Script that runs the Summary Statistic tool to calculate the
#Sum statistic for every numeric field

# Set local variables

intable = arcpy.GetParameterAsText(1)# Huff results in output.gdb
outtable = "HUFFtool_outputs.gdb/Sum_stats"
stats = []

# Loop through all fields in the Input Table
for field in arcpy.ListFields(intable):

    # Just find the fields that have a numeric type
    if field.type in ("Double", "Integer", "Single", "SmallInteger"):

        # Add the field name and Sum statistic type
        # to the list of fields to summarize
        stats.append([field.name, "Sum"])

# Run the Summary Statistics tool with the stats list
arcpy.Statistics_analysis(intable, outtable, stats)

# Description: Script that runs the transpose tool to move the sums from a row to a
column

```

```

inTable2 = "HUFFtool_outputs.gdb/Sum_stats"

# Set a variable to store output feature class or table
outTable2 = "HUFFtool_outputs.gdb/transposed"

# Set a variable to store time field name
transposedFieldName = "NUMname"

# Set a variable to store value field name
valueFieldName = "Sum_sales"

name = []

# List fields and loop through all of them
for field in arcpy.ListFields(inTable2):
    name.append([field.name, field.name])

# Specify fields to transpose
fieldsToTranspose = name

# Execute TransposeTimeFields
arcpy.TransposeFields_management(inTable2, fieldsToTranspose, outTable2,
transposedFieldName, valueFieldName)

# Description: Script that runs the Table Select tool to select only those records ending
in "_sales"

# Set local variables
GDB_ENVIRONMENT = "HUFFtool_outputs.gdb"

in_features = "transposed"

out_feature_class = "select_sales"

arcpy.env.workspace = GDB_ENVIRONMENT

```

```
activeExpression = arcpy.AddFieldDelimiters(in_features, "NUMname") + " LIKE '%sales%'"
```

```
# Execute Table Select tool with where clause
```

```
arcpy.TableSelect_analysis(in_features, out_feature_class, activeExpression)
```

```
# Description: Script that truncates the attribute records, removing the prefix and suffix
```

```
fc = "select_sales"
```

```
verification = arcpy.Exists (fc)
```

```
print verification
```

```
del verification
```

```
cursor = arcpy.da.UpdateCursor (fc, ["NUMname"])
```

```
for row in cursor:
```

```
    cursor.updateRow([row[0][5:-6]])
```

```
del row
```

```
del cursor
```

```
# Description: Script that runs the Join Field tool to join the new table to the original recreation table
```

```
# Set local variables
```

```
layerName = arcpy.GetParameterAsText(2) #original rec file with NUMname field
```

```
joinTable = "select_sales"
```

```
joinField = "NUMname"
```

```
# Join the feature layer to a table
```

```
arcpy.JoinField_management (layerName, joinField, joinTable, joinField)
```

Appendix E: Initial Mapping and Geoprocessing Work

To begin the project, together with Earth Economics we established a general idea of how we could help them. They needed assistance in the areas of geographic analysis, cartography, geodatabase model, and business workflow. Choosing to start with acquiring different public data sources, we were able to create new feature classes in preparation for the analysis workflow. Earth Economics has data delineating how much economic contribution each type of recreation provides in WA. Our efforts will assist Earth Economics in future economic calculations for determining what portion of economic contribution from each recreation type is allocated to each county and legislative district. In accordance with RFP Module II, this process required locating different public datasets, and extracting the different types of outdoor recreation class found within to their own feature classes.

One difficulty that Earth Economics has is that the economic impact of various classes of outdoor recreation in WA has already been calculated. However, it is aggregated at the state level. The Washington state RFP requests that it be disaggregated to the county or legislative district level. They currently have surveys that show the amount spent per trip, number of trips, and other data. The data that does not exist are visitation rates to all public and private recreation lands except National and State Parks. These rates will have to be interpolated based on proximity of a park to population centers as well as census population data and surveys.

Additionally, to assist Earth Economics with acquiring more data, we were instructed to create a series of public lands and recreation inventory of maps. These maps will assist as a reference when making decisions, and calling counties or state/ federal agencies to inquire if they can assist in providing additional data. Furthermore, a quick set of maps representing the population distribution and landuse designations to present in-house were produced. **Figures B 1-22** represent versions of the maps provided as those references.

Those datasets that were disaggregated according to recreation follow, along with the individual feature classes that were extracted. The majority of the datasets were public, with a few private datasets, as well. Thumbnails of individual maps may be seen in **Figures B1-22**. The geodatabase structure may be seen in **Figures B23a,b,c**.

Compiled and Extracted Datasets

1. Protected area database
 - a. E1 Access
 - b. E2 Owner Name
 - c. E3 Primary Local Designation
 - d. E4 Primary Designation Type
2. Washington Counties, for reference
3. Washington Legislative District, for reference
4. Washington Department of natural resources
 - a. DNR boundaries
 - b. E5 DNR parcels
5. Washington Legislative Districts, for reference
6. Other types of Washington Recreation
 - a. E6, E8 RCO Boat Facilities (Launch and Moorage)
 - b. E7 Scenic Highways
 - c. E9 Ferry Routes & Ferry Terminals Public/Private
 - d. E10 Public Shore Access
 - e. E11 Beaches
 - f. Game Management Units distribution by county
 - g. Golf Courses
 - h. Washington Ski Resorts
7. Washington Administrative Boundaries
 - a. E13 Park Districts
 - b. E14 Park Recreation Districts
 - c. Park Regions
8. Washington Public Lands Inventory

- a. DNR Aquatic
 - b. E15 DNR Land
 - c. E16 Federal Lands
 - d. E17 Local Government Lands
 - e. E18 State Fish and Wildlife
 - f. State Parks
9. Washington Landuse E19
- a. Amusements 73
 - b. Cultural Activities 71
 - c. Other Cultural Entertainment Recreational 79
 - d. Parks 76
 - e. Recreational Activities 74
 - f. Resorts Group Camps 75
 - g. Vacation Cabin 19
 - h. Water Areas 93
10. Population Distribution
- a. E20 Population By Category
 - b. E21 Population By Legislative District
 - c. E22 Population By Park Region

Figures E1-4

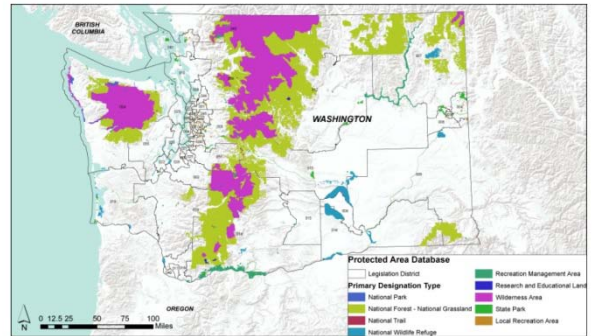
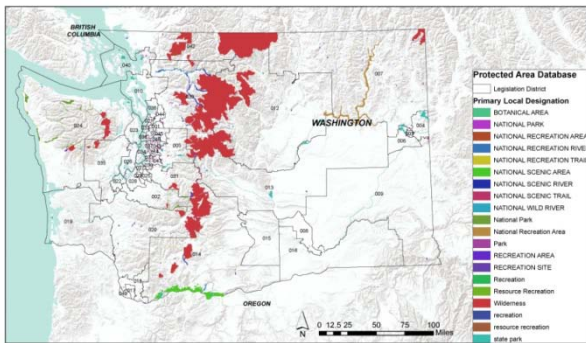
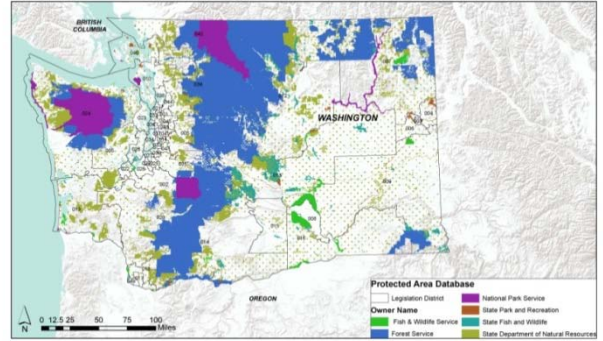
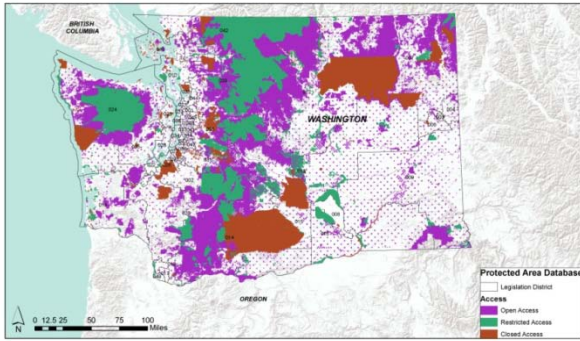
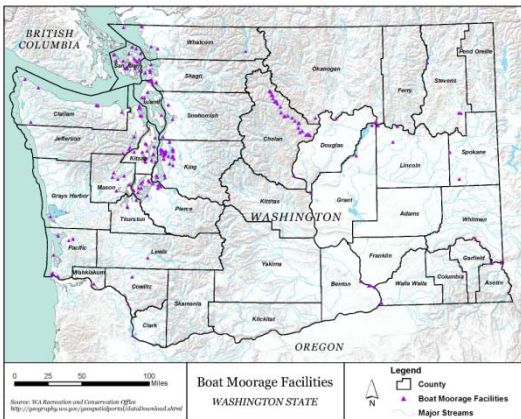
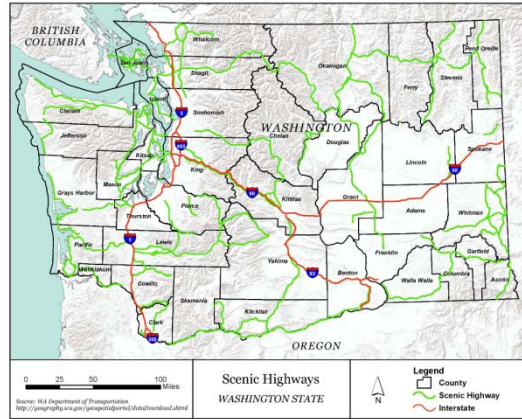
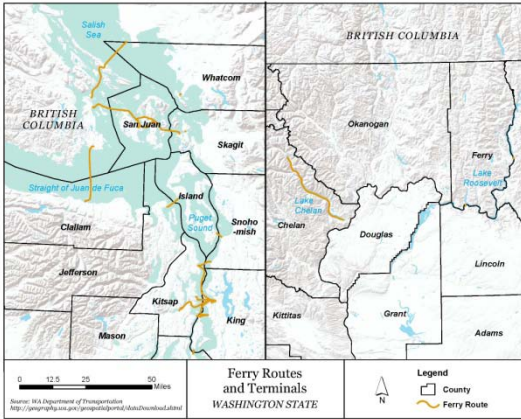
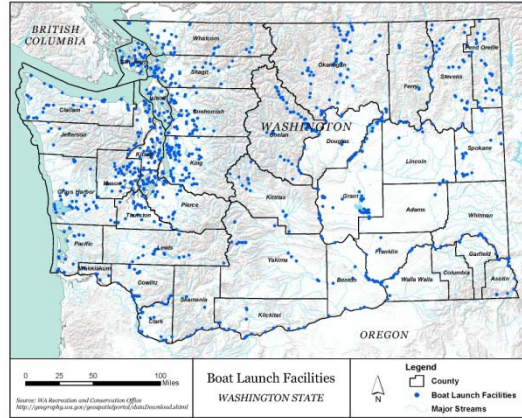
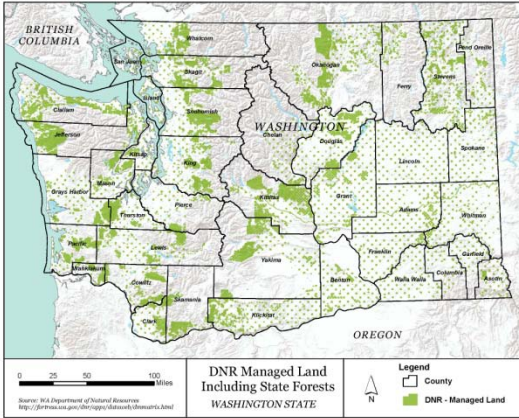
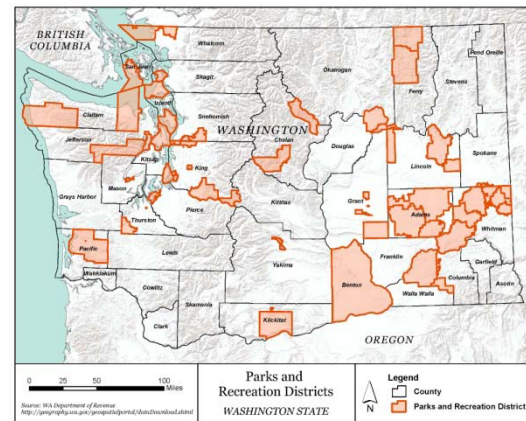
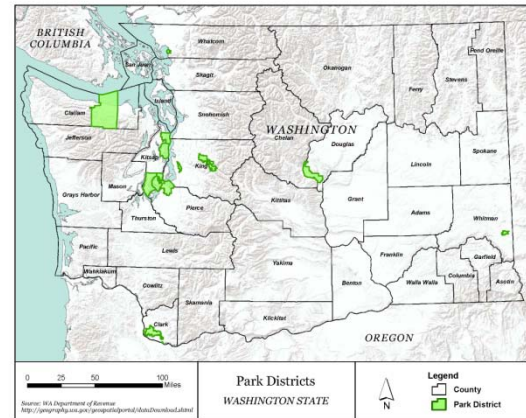
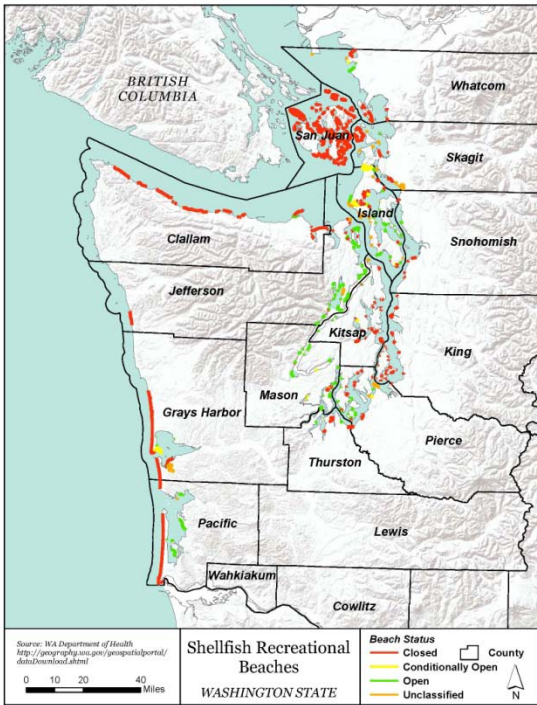


Figure E5-12: Other Types of Washington Recreation





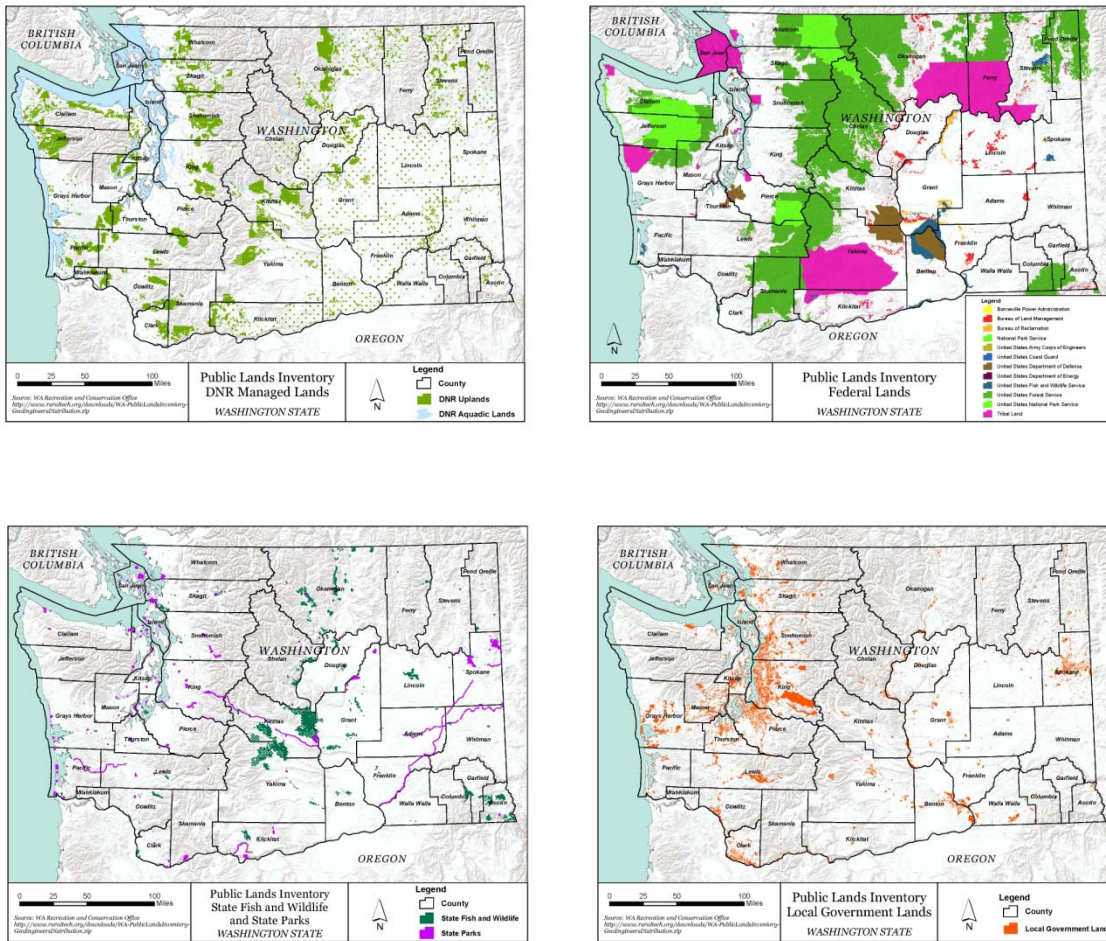


Figure E19: Washington Landuse by Recreation Category

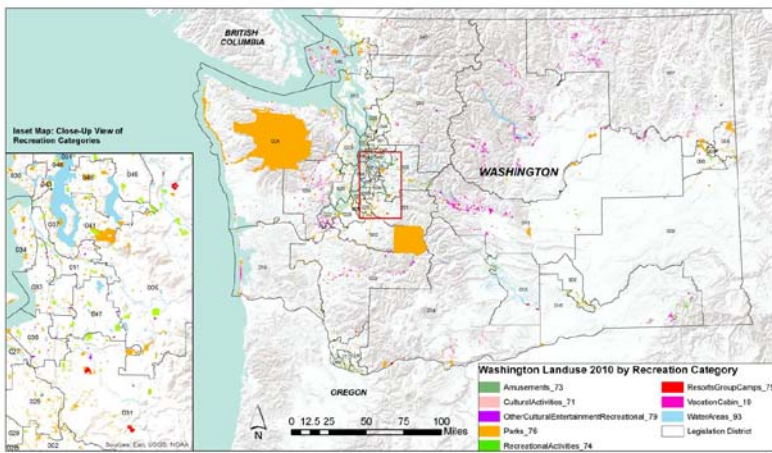
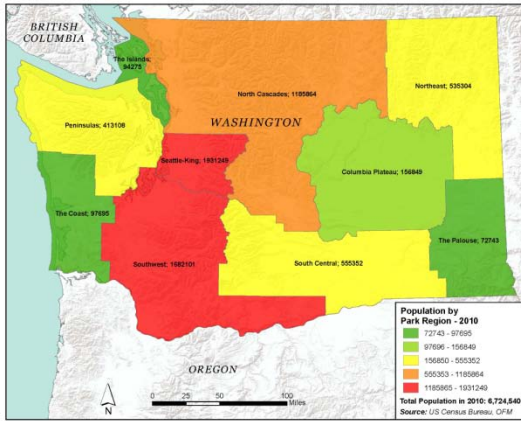
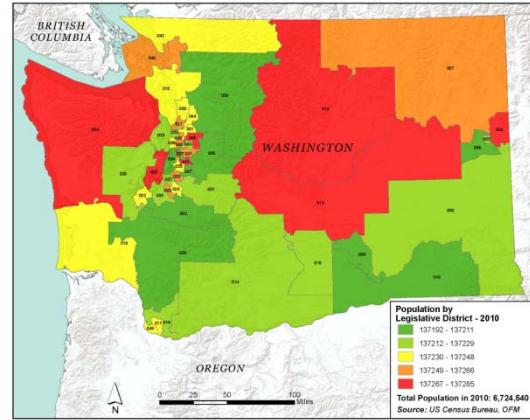
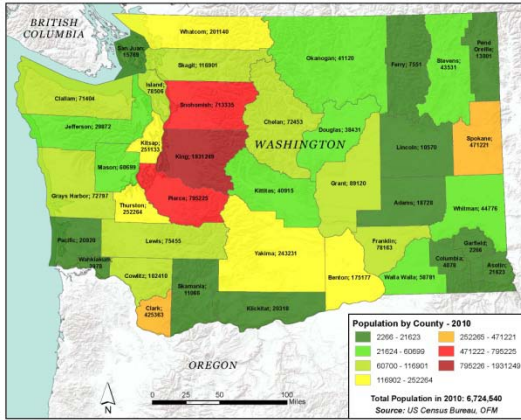


Figure E 20-22: Population Distribution



Figures E23 a, b, c

- [-] [+] WA_DNR
 - [-] [+] DNR_boundaries
 - [-] [+] DNR_Parcels
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 - [-] [+] WALANDUSE_WaterAreas93

Calculating Game Management Unit to County ratio

In addition to extracting public datasets, we were tasked with acquiring and manipulating three additional private datasets Game Management Unit to county ration, golf course locations, and ski resort locations. The methodology for follows:

1. Add new field (Double) to the GMU attribute table
2. Calculate area in acres
3. Run Union tool with county shapefile and GMU as inputs
4. In resulting GMU, delete areas “not in effect” for hunting
5. Add field (Double) to unioned GMU/County FC; calculate area in acres
6. Delete GMU areas extending beyond counties. These will have no county attributes and are very small.
7. Add field (Double). Name it “AcresPercnt” or something similar.
8. In new field using the Field Calculator, divide the new unioned acres by the total original GMU acres
9. Use “Table to Excel” tool to export the attribute table with the GMU to county ratios

Calculating County to Legislative District ratio

- Use same process as above, except replace GMUs with counties and counties with legislative districts.

Obtaining Washington Golf Data Points

1. Access: <http://www.poi-factory.com/node/29395>
2. Register to download files with POI Factory
3. Once registered, two buttons appear at the web address above .csv or .ov2. (TomTom)
4. It was useful to download both

5. The csv projects the coordinates incorrectly. However, if you have an excel file with x and y coordinates in ArcMap go to File>Add Data>Add XY Data. Choose the excel table and specify which columns are the x and the y fields. Set the coordinate system and ArcMap will project the points. One can look this subject up in ArcGIS Help window for more complete directions.
6. To convert the .ov2 file to a KML go to the following web address:
http://www.poieditor.com/poi_convert/ov2-to-kml/
7. Convert file
8. Open in ArcMap and use the tool KML to Layer
9. Clip the golf shapefile to the Washington boundary
10. Then, join Washington golf points file to the original CSV, checking the box to “only keep matching records”. The .ov2 file does not contain addresses and number of holes as the .csv file does. By joining the two tables one is able to retain this information. Export as final feature class. Delete any irrelevant attribute fields

Extracting Washington Ski Resorts

1. Download Google Earth
2. Search for Ski resorts in Washington
3. In this case you have to zoom in to each resort until you see a little ski man symbol
4. Right click, save to My Places
5. Do this for each individual location,
6. In this case, Google Earth did not have some of the smaller resorts. Therefore, those had to be individually searched for; a placemaker was added and named appropriately.
7. On the left hand column you should see the individual location names listed. If the points end up in the temporary places: right click> save to my places.

8. Once you have all the points in my places, right click on My Places > Save Place As
9. Open ArcMap, use the tool KML to Layer, this will add the file to map.
10. In order to edit > export to shapefile or feature class.
11. Fill in attributes, manually, based on a number of criteria to be used for the “attractiveness measure”. The attribute information was obtained from <http://www.liftopia.com/ski-resort-info/statemap/WA/Washington>

Appendix F: Huff Model as Local Park Visitation Predictor

Introduction to HUFF Model as an opportunity to predict visitation rates to local and county parks.

As established, the Huff Model is traditionally applied to the analysis of retail store placement in relatively confined geographic areas, before we elected to focus on its application in the ski industry at the scale of Washington State. We conducted a test a ground truth method for determining how useful the HUFF model could be at predicting accurate visitation rates. Having acquired the visitation rates for the National Parks, we proceeded to test the models results against know reality.

Inputs:

- WA State Boundary
- WA State Census Tracts
 - Total Population for “Sales Potential”
- National Park Points
 - Total acres as “attractiveness” measure
- Euclidean distance

As an example of results, Figure F1, represent results for the Olympic National Park predicted visitations based on census tract. The models predicted visitation was 2,704,872, versus the actual 2,844,563. While these results look promising even with fairly simple inputs, if one looks at Whitman Mission NHS from the same run, Figure F2, there is a large discrepancy in predicted results versus actual results.

Limitations and Speculations of Huff Model for Natl. Parks

- National Parks receive out-of-state visitors and have different visitation patterns
- Model assumes every resident will visit a park
- Street-Network malfunctions and network analysis only includes tracts within a certain distance.
- Modifiable aerial unit problem: the model the boundary as if it were an island (Huff and Mcullum 2008, 9). People from outside the boundary will not travel within.

Therefore, it was concluded that this is not an appropriate analysis method for estimating visitation rates.

Figures F1-2

