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The Influence of Site Design and Resource Conditions on Outdoor Recreation Demand: A Mountain Biking Case Study

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Abstract

We investigated the influence of several choice variables on the demand for six mountain biking sites in the Research Triangle area, North Carolina. In combining on-site data collected from users and land survey data from the sites, mixed logit analyses revealed both trail condition and site layouts significantly influenced users' site choices. Specifically, users favored sites with higher quality trail conditions and routes that were more challenging. The welfare benefits delivered to users ranged from $1.12 to $7.73 per-user per-outing depending on the site. We also applied a generalized estimating equation to the demand data for use in estimating the annual outings and in calculating the consumer surplus of mountain biking activity in the Research Triangle area, North Carolina. Overall, the case study findings have direct implication for high-priority trail assessments, site monitoring, and resource protection.

KEYWORDS: Outdoor Recreation, Mixed Logit, Recreation Ecology, Recreation Demand, Mountain Biking, Travel Cost Model, Consumer Surplus

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Outdoor recreation consumers create the demand for managed recreation resources and facilities. Under the economic assumption of rationality, a consumer when making the decision to engage in a particular activity evaluates all the potential recreation sites (Bockstael, Hanemann, & Kling, 1987). Ultimately, the consumer considers the different site characteristics and attributes offered at the alternatives with the final choice being the one that maximizes utility (Hensher, Rose, & Greene, 2005). Resource managers must be aware of how consumers judge the resource conditions of the sites if managers are to ensure users receive the desired on-site recreation experiences. More specifically, resource managers need to be aware of how a site's resource conditions will affect the demand for those sites. While this type of information would be ideal for resource managers and analysts, appropriately measuring and accounting for dynamic site characteristics as well as the behavioral aspects that produce the latent utility is often a difficult task (Ben-Akiva & Lerman, 1985). The difficulties compound further in measuring site conditions when managers are responsible for numerous sites each with their own unique set of resource conditions and amenities (Parsons & Massey, 2003).

This research attempts to overcome these difficulties by examining the influence of two choice variables, trail condition and site layout, on the recreation demand for six mountain biking sites in Research Triangle area of North Carolina. For the purposes of this research, we define mountain biking as the sport of riding durable bikes with special riding gear off-road, usually over rough terrain along narrow trails that wind through forests, mountains, deserts, or fields (Chavez, 1996). The activity has grown rapidly over the past several decades. The most recent figures from the National Survey on Recreation and the Environment reveal that 41 million American participants engaged in mountain biking between 2005 and 2008 (Cordell, Betz, Green, & Mou, 2008).

We utilize a common set of metrics for assessing the trail condition and the site layout in determining if these choice variables influence consumers' choices of the mountain biking sites (Hawes, Candy & Dixon, 2004; Marion & Leung, 2001; White, Waskey, Brodehl & Foti, 2006). The findings from this study have direct implications for the relevance of trail assessment and site monitoring programs. For example, should the data suggest resource degradation has a negative influence on the utility that users derive from sites; it would be prudent for resource managers to focus on improving, or at least maintaining, trail condition. Furthermore, if specific site layouts have a direct influence on the utility derived from the mountain biking sites, we would recommend that resource managers in the future plan to provide trails and other on-site facilities that meet the needs and desires of the current users.

Trail Condition, Site Layout, and Recreation Demand

Much like the demand for many other outdoor recreation activities, users' travel costs to mountain biking sites and the sites' characteristics are likely influences on recreation demand. Previous research attempting to discern the specific trail and the characteristics of mountain biking sites that positively influence recreation demand have been mixed, in regards to both methodology and findings. The majority of research on mountain biking participation relies on the stated preferences of participants instead of the objective land measures in their empirical estimates of trail conditions. For example, Louviere, Anderson, and Louviere (1991) investigated Chicago trail users' responses to pairs of hypothetical bicycle trails that varied with respect to 18 trail choice-related variables. Their analysis found cyclists in Chicago preferred trail layouts that were varied (i.e., both curvilinear and straight), trails allowing different return trips, trails with lengths less than 80 miles, and trails with new pavement and good limestone surfaces. More recently, Morey, Buchanan, and Waldman (2002) conducted a series of innovative choice experiments using travel cost parameters in computer simulations. The analysts had respondents make paired-choices among hypothetical mountain biking trails. The purpose was to demonstrate how changes in trail characteristics, trail closures, and access fees could be useful in transferring welfare benefit estimates to the actual trail sites. Other research has utilized surveys administered by mail. Specifically, Goeft and Alder (2000) administered a questionnaire to mountain bikers in Western Australia and found users preferred natural setting and trails with firm surfaces. Goeft and Alder also concluded that mountain bikers who raced preferred technically challenging trails with downhill sections, curves and jumps; while recreational users preferred trails that were less challenging, well-marked, and provided drinking water. Finally, Symmonds, Hammitt, and Quisenberry (2000) presented a unique set of survey results in that mountain bikers stated that they preferred degraded trail conditions, such as the presence of eroded ruts, exposed roots, and steep slopes to provide challenging riding experiences. The author's findings may not be a concern in designated, derelict, or private lands, however acting upon these findings may pose a significant dilemma for public resource managers responsible for resource protection and the provision of outdoor recreation.

Study Objectives and Hypotheses

This research contributes to the body of knowledge developed through the stated preference studies above. With this aim in mind, one of the investigators conducted a series of informal focus group interviews with Triangle area mountain biking participants in the summer of 2006. When asked about what site characteristics determined where they went on their mountain bike outings, the participants reported the surface condition of the trail and the challenging nature of the site layout. The two primary decision considerations are comparable with the reported stated preferences of biking participants. We therefore construct two composite measures for the choice variables (a) *trail condition* and (b) *site layout* that we test in this study.

The primary objective of this study incorporates the users' revealed preferences of not only those mountain biking sites chosen but also the trail conditions and the site layouts of sites not chosen as well into a formal model of recreation demand. Taken together, the users' preferences for the trail conditions and site layouts guide this study's hypotheses in questioning their influences on individuals' choices of mountain biking sites. Specifically, the null hypotheses of particular interest are:

H_1: The trail conditions will have no statistically significant effect on individuals' choices of sites.

H_2: The sites' layouts will have no statistically significant effect on individuals' choices of sites.

A secondary objective of this research is to estimate the welfare benefits of mountain biking activity from allowing users access to mountain biking sites analyzed in this case study. There are six remaining sections. The next section concisely presents the repeated mixed logit of site choices that analyzes the influence of the choice variables on demand. We discuss the demand data and report the rankings of the choice variables in the methods section. The results follow from the findings of the repeated mixed logit and the joint significance of the choice variables. Next, we provide the explanations of the welfare benefits and the application of a panel-data estimator of mountain biking demand. We conclude with a discussion on users' preferences for mountain biking sites and welfare benefits of mountain biking to the Research Triangle area, North Carolina.

Site Choice Theory

For the typical travel choice setting, we consider a user's choice of a mountain biking site from a set of many possible sites for that one outing. In deciding on the mountain biking site to visit on that outing, we assume that the outing t to site j give the user utility u_{jt} where j = 1… J sites, so that,

$$u_{jt} = v_j(C_{jt}, q_{jt}; \beta\text{'s}) + e_{jt}. \tag{1}$$

The β's are the parameter estimates, C is the travel cost, q is a vector of the choice variables, and e is the random error term. In Equation 1, the indirect utility v_j is a linear function of the travel cost and the choice variables that matter to the site choice. The utility function is deterministic while the random error term in Equation 1 captures site preferences important to the user in making the site choice, which of course the user knows, but are unknown to us. Consequently, we depend on the random error in determining the utility of the site choice and the influences of the choice variables in that decision (Ben-Akiva & Lerman, 1985). We therefore model the utility of the user's site choice as well as those decisions not to visit the remaining five sites on that choice occasion. Incorporating this substitution among the alternative sites into the statistical estimation enables us to observe the direct connections between the expected random utility (probability) of that outing occurring in comparison to the expected utilities of the remaining five choices (Haab & McConnell, 2003).

Earlier efforts in modeling recreation demand by means of Equation 1 assume that the different users choosing the same mountain biking sites would also have the same preferences for the choice variables, despite the fact that the users may differ greatly in their preferences and tastes (Morey, Rowe, & Watson, 1993). Train (1998, 1999) introduces the mixed logit into outdoor recreation applications that better deals with the random heterogeneity of mountain biking participants. The mixed logit overcomes two important limitations of the standard logit that are important in understanding users' choices among the sites and especially their preferences of the two choice variables in this study (Train, 1999).

First, the property of the "independence from irrelevant alternatives" holds in the mixed logit. In the standard logit, the ratio of the logit probabilities for, let us say, site A and site B does not depend on any of the alternative mountain biking sites other than the two sites under consideration here by users. Since the ratio is independent from the any of the alternative sites, it is "independent from irrelevant alternatives." The independence from irrelevant alternatives implies that by adding a site C to the site choices, the additional site C does not affect the relative odds of the users choosing between site A and site B. The implication of the limitation would simply not be realistic for participants in this study. In fact, the mountain biking sites in our choice set may be similar from the users' perspectives.

Second is the limitation that users when visiting a particular mountain biking site reveal the same preferences for that site. This assumption is valid for the standard logit because the means and standard deviations of their revealed site preferences are unknown to us. In the mixed logit however, the users' site preferences vary in a normally distributed pattern and their preferences revealed to us from the random parameters of the standard deviations for the preference variables. As a result, the mixed logit overcomes the second limitation in determining the demand for mountain biking sites.

Train (1998, 1998); Parsons and Massey (2003); Hensher, Rose, and Greene's (2005) recommend modeling the heterogeneity among users' choices of sites with the random parameters in a mixed logit so that demand models more accurately account for the variations in the choice variables. In fact, Herriges and Phaneuf (2002) in testing different choice models find that the repeated mixed logit outperforms other logit models in providing the most realistic outcomes of the users' utilities for annual recreational trips to various wetland sites in Iowa. However, the authors report that the repeated mixed logit comes at the cost of increased computational time. Even with this disadvantage in mind and our own experiences, we felt the mixed logit would more accurately capture the users' choices among the sites and more importantly their revealed preferences for the different layouts and trail conditions.

Specification of the Repeated Mixed Logit

Assigning the letter *b* to the fixed coefficients of the means and β to the random coefficients (standard deviations) of the choice variables in the indirect utility function (v), the compensating demand is:

$$u_{jt} = v_j(C_{jt}\,,\ q_{jt};\mathrm{b}) + v_j(q_{jt};\beta) + e_{jt}. \tag{2}$$

In applying Equation 2 developed here to the site choices by users, the estimation of the indirect utility requires the decomposition of the coefficients for the travel cost and the choice variables into their means (Train, 1998). We also specify in Equation 2 the further decomposition of the site layout and trail condition choice variables into their random coefficients to accommodate the heterogeneity for each user's preferences. In specifying this, we are introducing the random effects attributable to the heterogeneity of the users' preferences for the choice variables that matter. Consequently, the varying site layouts and the severities of the degradation in trail conditions could influence the choices of the mountain biking sites either positively or negatively. We therefore assume the normal distributions for the random coefficients.

With respect to the travel cost, there cannot be a negative or zero measure for the marginal utility of income (Parsons & Massey, 2003). Consumer theory assumes that a user's marginal utility of income is constant and does not change in the compensating demand for outings to mountain biking sites (Pearce, 1995). In meeting this assumption, we specify that the travel cost coefficient remain fixed and specify no random coefficient in Equation 2. The mean coefficient on travel cost then accounts for the change in utility that users face when traveling to the alternative mountain biking sites because the sites vary in their distances and travel times from the users' points of origins.

An extension to the mixed logit accounts for the repeated mountain bike outings to the same site and involves another expansion of the demand data set with the statistical software (Train, 1998). The inclusion of repeated outings not only provides for the more accurate representations of users' site choices, but the evidence suggests their inclusion would provide a better insights into the influences of the site layouts and the trail conditions on users' site choices (Parsons & Massey, 2003). The repeated outings in the mixed logit do not account for the variations in the users' outings based on either the sequences of previous site experiences over time (i.e., their habits), or the psychological meanings that users may associate with the sites. We are simply incorporating the dynamic demand effects of repeated outings to avoid incorrectly specifying the mixed logit.

Methods

The selection criteria for a site's inclusion in this Research Triangle area study (2006) of mountain biking required (a) the existence of a regulated legal trail, (b) a defined public agency managing the site, and (c) a single-track trail. Having met the selection criteria were Beaver Dam State Recreation Area, Lake Crabtree County Park, Garner Recreation Park, Harris Lake County Park, Little River Trails, and Legend Park. Once identified, we obtained data used in determining the influences of site design and resource conditions on demand from two separate survey efforts. One effort involved the administration of on-site user surveys and the second concentrated on obtaining land measurements of specific site characteristics at the six mountain biking sites.

On-Site User Surveys

We collected the demand data from on-site users with a temporal, on-site random sampling strategy. We chose the strategy because a random household survey of residents in the Research Triangle area was unlikely to produce a representative sample of mountain biking respondents to the six sites.

None of the six mountain biking sites maintained self-registration records or user counts. Given this, we reviewed a voluntary self-registration log compiled from 2001 to 2006 kept by officials at San-Lee Park in Lee County, which is adjacent to the Research Triangle. Inspection of the San-Lee Park registration log revealed check-in times, days of the week, and monthly usage. The length of stay per-outing was approximately one-hour, and approximately 75% of all visits occurred on the weekends during the months between September and November. With this information, we developed a systematic sampling schedule for the six sites. Sampling occurred during three-hour time blocks allocated to either weekends or weekdays accordingly. If a site closed due to adverse weather, the site and time block went to the end of the sampling schedule.

Trained survey personnel administered the on-site questionnaires by intercepting users at the trailheads or parking lots at the conclusion of their rides. The questionnaires took, on average, about five minutes to complete and solicited information about (a) the number of mountain bike outings the user took to each of the six sites over the past 12-months, (b) their mountain biking on-site experiences, and (c) their socio-demographic information. Survey personnel requested that users under the age of 18 and users having previously completed the questionnaire not participate. In total, survey personnel intercepted 413 respondents at the six sites of which 398 of these respondents completed usable questionnaires.

For the descriptive overview of the sample of users at the six sites, 82% of the respondents were male and 18% belonged to at least one mountain biking organization. On average, the respondents traveled just under 30 minutes and 15.5 miles to reach a site. The mean length of stay was 1.75 hours and about 70% of the mountain bike outings occurred on Saturday and Sunday. While at the site, respondents rode 10.3 miles on average. Respondents took, on average, 15 (M = 14.70; SD = 20.76) related outings to approximately three (M = 2.91) different sites over the past 12-months. Their responses also indicated that they have been mountain biking for approximately seven years. Furthermore, the average group size was roughly two users. Their mean age was 35.6 years old, most respondents had some graduate education, and the average annual household income was approximately $90,915.

In preparing the data for mixed logit analyses, we expanded the original demand data to account for the six site choices the respondent faced when deciding on an outing with the Stata (2007) statistical software. If the user visited a site, we assigned the dependent choice variable a value of one; if not visited, we assigned a zero value.

We required information relating to the time and distance from an individual's point of origin to each of six mountain biking sites to determine the travel costs. From the respondent's address on the questionnaire and the latitude and longitude coordinates for the six sites, we calculated the mileages from each respondent's origin to the six-destination sites using geographic information system software. Importing the mileage measures into the expanded data set, the computations involved doubling each mileage to reflect the round-trip distance and then, multiplying this value by $0.62 per mile (American Automobile Association, 2006). The opportunity cost of travel time took a respondent's reported annual income, divided the income by the 2080 work hours in a year, multiplied this imputed wage by a constant value of 33%, and then multiplied the adjusted wage by the travel time (the round-trip travel distance divided by 45 miles per hour). Having summed the travel expenses and opportunity costs, we repeated the same computations for each observation in the demand data set. Overall, the mean travel cost per-outing was \$64.18 (*SD* = \$36.57).

Land Surveys

We collected data from six land surveys that measured the physical characteristics of the mountain biking sites for use in evaluating the trail conditions and site layouts (Table 1). Specifically, we constructed a composite index from the rankings of five land measurements of the site's suitability to support mountain biking activity for use in assessing a trail's condition. The land measurements were percents taken of the (a) extent of soil erosion, (b) tree root exposures, (c) excessive grade, and (d) widening of the trail. Included also were the unavoidable trail obstacles that users encountered in their riding pursuits. This set of land measures represented the extent to which the trail was degraded (Marion & Leung, 2001).

In addition, we constructed a composite index from the ranking of 13 land measurements of a site's design elements (e.g., trail width, slope, etc.) for use in evaluating the site's layout. The land measures came from two sources. The first

TABLE 1: LAND MEASUREMENTS OF SITE CHARACTERISTICS

Site Characteristics	Land Measurement
Severity of Trail Condition	
Trail eroded	Percent of trail with soil erosion exceeding 4 inches in depth.
Trail grade	Percent of trail with the grades exceeding 20 percent.
Trail root exposed	Percent of trail with tops and sides of roots exposed.
Trail widening	Percent of trail with the widths exceeding a 20 percent expansion.
Unavoidable obstacles	Unavoidable trail obstacle (≥ 6 inches) per mile.
Site Layout	
Average slope	Change in slope in feet and averaged for entire trail.
Average width	Trail tread width measured in centimeters and averaged for entire trail.
Avoidable obstacles	Trail obstacle (≥ 6 inches) with option to bypass via side trail per mile.
Elevation change	Cumulative total in feet of the absolute value of elevation change along total length of trail.
Curves	Count of trail curves with less than 90-degree turn and less than 10 ft in turning radius per mile.
Intersections	Count of all trail intersections per mile.
Locking restroom	Presence of locking restrooms.
Loops	Count of all trail segments and/or loops per mile.
Human-made features	Count of all the structures on trail (water bar, drainage dip, lateral drain, retaining wall, culvert, steps, and trail corduroy) per mile.
Parking	Presence of dedicated parking lot.
Picnic tables	Presence of picnic tables.
Surface length	Lineal measurement in feet of trail's surface.
Trail alignment angle	Trail's alignment angle to the prevailing landform near the sample point and averaged for all sample points on the trail.

was from the stated preferences for selected physical design elements by Chicago area residents, as summarized in a US Forest Service study of bike trail choices (Louviere, Anderson & Louviere, 1990). The second was White, Waskey, Brodehl, and Foti's (2006) comparative study of mountain biking impacts (trail degradation) on the natural resources in the southwestern United States. The assessment of the site's layout included land measurements taken of (a) the complexity in the flow of the trail, (b) the number of intersections, (c) the median trail width, (d) the number of loops, and (e) a combination of the trail's length and the percent of the average slope. The combined measure was indicative of the site's difficulty in challenging users' biking abilities. Also included in the site layout were the remaining integral parts of that site's design, like the presence of a dedicated parking lot. This set of land measurements represented the overall quality of the site's layout of a trail by design.

Given the limited land data from only six sites, traditional multivariate techniques requiring a large number of observations for classification were not applicable. Instead, we applied the following series of steps in calculating the rank-sums for the trail conditions and site layouts of surveyed sites:

1. Rank the q_{ij}'s on a scale from one (lowest) to six (highest) for each of the 13 land measurements of the site's layout and then the five land measurements of the site's trail condition taken at the j = 1…6 mountain biking sites,
2. Reverse the rankings for the trail condition measures, only, so that the smaller values represented the more degraded trail condition.
3. Calculate the rank-sums, so that $q_j = \Sigma q_{rank}$
4. Display the resulting rank-sums in Table 2

The sites with the best overall layouts (q_1) were at Legend Park (47) and Crabtree Park (44), whereas the site at Little River displayed the least favorable layout

TABLE 2: MOUNTAIN BIKING SITE LAYOUT AND TRAIL CONDITION SCORES

Mountain Biking Site	Site Layout Rank-sum (q_1)	Trail Condition Rank-sum (q_2)[a]
Beaver Dam	42	28
Garner	39	7
Harris Lake	43	25
Lake Crabtree	44	22
Little River	34	13
Legend Park	47	10

[a] The higher the score the less severe was the trail condition in comparison to the remaining sites.

(34). Regarding the best trail condition (q_2), Beaver Dam (28) maintained the most favorable trail condition, whereas the site at Garner Recreation Park (7) presented the most severely degraded condition to users.

Results

We applied the repeated mixed logit in Equation 2 because the purpose of this study was to analyze users' site choices among the six mountain biking sites and of particular interest to us were the users' preferences of the site layouts and trail conditions. Table 3 displays the results. The demand data conformed to a balanced panel design when being subjected to a maximum simulated likelihood method (Hole, 2007). The choice variables were significantly different from zero at the 99% confidence level. The coefficient values were positive, revealing users tended to favor a site with a non-degraded trail condition and a more challenging trail layout. The magnitudes of the coefficients implied that a site's layout had a greater variability in affecting site choices than a trail's condition. The estimations of the random coefficients for the standard deviations were also highly significant. The random coefficients indicated the presence of heterogeneity among the sample of users from their choices of sites with varying site layouts and trail conditions.

TABLE 3: REPEATED MIXED LOGIT CHOICE MODEL WITH INDEPENDENT RANDOM COEFFICIENTS

	Mean (b)		**Standard deviation (β)**	
Explanatory Variables	**Estimate**	**z-value**	**Estimate**	**z-value**
Site layout	0.1213	11.74	0.3490	28.22
Trail condition	0.1204	27.77	0.1379	25.38
Travel cost	-0.0504	-60.17		
Log-likelihood at convergence	-15,737			

Notes. The z-value is just the coefficient estimate divided by the standard error. The comparison of the z-value to the standard normal distribution tested the hypothesis that the coefficient equaled zero. There were 79,584 choices for the 13,264 observed outings in the sample of six sites in Research Triangle area, North Carolina.

Trail condition. The positive fixed mean coefficient on the trail condition revealed respondents favored mountain biking sites with fewer incidents of (a) soil erosion, (b) root exposure, (c) widening of trails, (d) unavoidable obstacles, and (e) uneven trail grades. The trail condition had a fixed mean coefficient of 0.1204 and a random coefficient of 0.1379. We used the cumulative normal distribution (Φ) in Microsoft Excel's NORMSDIST to calculate all the preference values. In this case, we arrived at the rounded value with the fraction of the fixed and random coefficients multiplied by 100 resulting in 81% of the users finding the less degraded trail conditions at sites more appealing, while 19% chose outing to sites having the more degraded conditions.

Site layout. The distribution of the coefficient values for the site layout had a fixed mean coefficient of 0.1213 and a random coefficient of 0.3490. Including the two coefficient values as a fraction in the cumulative normal distribution function found sites with more challenging and appealing layouts to be a positive inducement for 64% of the users and a negative factor for the remaining 36%, apparently preferring the less challenging sites.

The results, when taken together, indicated that users when faced with choice decisions about outings to the mountain biking sites *tended to favor mountain biking sites having non-degraded trail conditions as well as site layouts that offered complexity and challenge*. This outcome suggested to us that a positive correlation might exist between the random coefficients of the choice variables. We therefore re-estimated the repeated mixed logit with random coefficients correlated and normally distributed (Table 4). The resulting log-likelihood of this second model was smaller than the log-likelihood estimated from the first repeated mixed logit (Table 3). This difference provided evidence of a better fit of the demand data to the users' choices of sites. We next proceeded to test the joint significance of the off-diagonal elements of the covariance matrix shown near the bottom of Table 4. A likelihood-ratio test rejected the null hypothesis of uncorrelated coefficients, 162.54 [= 2 · (15,737.58 – 15,565.31)]. The test was chi-squared distributed with one degree of freedom and the random coefficients for the choice variables correlated positively ($r = 0.75$).

TABLE 4: MIXED LOGIT CHOICE MODEL WITH CORRELATED RANDOM COEFFICIENTS

	Mean (b)		**Standard deviation (β)**	
Explanatory Variables	**Estimate**	**z-value**	**Estimate**	**z-value**
Site layout	0.5382	20.51	0.6957	26.01
Trail condition	0.2519	24.47	0.1995	33.93
Travel cost	-0.0477	-60.15		
Log-likelihood at convergence	-15,565			

	Convariance matrix	
	Site layout	Trail condition
Site layout	0.6957	–
Trail condition	0.1498	-0.1318

Notes. The z-value is just the coefficient estimate divided by the standard error. The comparison of the z-value to the standard normal distribution tested the hypothesis that the coefficient equaled zero. There were 79,584 choices for the 13,264 observed outings in the sample of six sites in Research Triangle area, North Carolina.

Given the different log-likelihood values and confirmation of correlated coefficients, the repeated mixed logit with the correlation of the random coefficients (Table 4) was the appropriate statistical model. The interpretations of trail layout and site condition coefficients were identical to those presented in the first mixed logit model with the independent random coefficients (Table 3). In summary, 78% of the users placed a higher value on a site's layout, and 89% of the users preferred a better-maintained site with less degraded trail condition. The fixed travel cost coefficients in Tables 3 and 4 behaved as expected having negative signs and high statistical significances. In the next section, we utilized the cost coefficient from Table 4 in computing the welfare benefits of the mountain biking sites to users.

Welfare Benefits

When making decisions about recreation sites and the benefits that users derive from those sites, resource managers and analysts frequently use measures of consumer welfare, such as the compensating variation, or the consumer surplus. In this section, we began by computing the welfare losses from the hypothetical closures of the six mountain biking sites to a user. Next, we computed the consumer surplus for mountain biking activity and then compared that consumer surplus to those derived in previous studies.

Compensating Variations

Conceptually, the compensating variation was a welfare loss measure when computed with the repeated mixed logit results. It was defined as "the maximum amount of income that could be taken from someone who gains from a particular change while still leaving him no worse off than before the change" (Pearce, 1995, p. 78). Theoretically, the user's income would change with the hypothetical closure of a mountain biking site assuming the remaining sites remained open. The income necessary to compensate the user would exceed the user's initial income, the user would be worse off, and the change in income would provide a measure of the welfare loss (Parsons & Massey, 2003). Pursing this line of reasoning, the change in compensating variation from the hypothetical closure of a site was:

$$\textit{Compensating Variation} = \{ln \textstyle\sum_j exp(u_{jt}) - ln \sum_{j-1} exp(u_{jt})\} \;/\; \text{-}b^c. \tag{3}$$

The expression $exp(u_{jt})$ was the anti-logarithm of a predicted utility from the repeated mixed logit results for each observation in the demand data (Hole, 2007) and $-b^c$ was the mean coefficient of the travel cost (Table 4). Assuming the constant marginal utility of income, we expressed the compensating variation in terms of the mean per-user per-outing loss due to the hypothetical closure of a site ($j–1$) assuming all other sites remained open. The positive compensating variations in parentheses are for Beaver Dam ($6.67), Garner ($1.12), Harris Lake ($4.16), Lake Crabtree ($7.73), Little River ($1.72), and Legend Park ($2.41). Among the closures, the most popular mountain biking sites, Lake Crabtree and Beaver Dam, had the largest mean welfare losses. The closure of either site would be of a greater loss to the user than the remaining sites. Therefore, these sites were most valuable from the perspectives of users who visit them.

Even though the compensating variations appeared low, keep in mind these were per-outing and not per-year measures. To arrive at the annual welfare losses for mountain biking activity in the Research Triangle area, we took the average of the six compensating values of $3.97 and the actual mean of 14.7 outings per-user in the past 12-months. The product of which was a welfare loss of $58.33 per-user per-year (Train, 1998). The welfare losses accounted for the displacement of users to the remaining open sites and did not account for the non-participation in mountain biking due to the site closures.

Consumer Surplus

While compensating variation values can provide reliable estimates of welfare losses, recreation planners often opt to estimate the ordinary consumer surplus from the consumption of outings to recreation sites. The compensating variation is not directly comparable to the ordinary consumer surplus. Consumer surplus is the amount that a user would be willing to pay, but does not have to pay; the value is the net of the trip expenses and charges, if any (Pearce, 1995). Ordinary consumer surplus is unrelated to the conceptual notions of indifference or compensation with respect to the user's income. Furthermore, the computations of the compensating variations are exercises in comparative statistics that depend on the initial and adjusted prices at corresponding initial and the new supply and demand equilibrium levels (Haab & McConnell, 2003).

Moreover, the compensating variation in this case study was the demand for a mountain biking site on one choice occasion as opposed to the annual demand for that site. We therefore needed the expected demand for mountain biking activity by users to each of the six mountain biking sites in the past 12-months to compute the annual demand and consumer surplus for mountain biking (Egan & Herriges, 2006). We transformed the annual counts of the repeated mountain bike outings to the natural logarithm of the conditional mean in the Poisson regression. The conditional mean of the expected outings r per-year for user i to site j was the sum of the independent variables and the unobserved heterogeneity among users with theta (θ_j),

$$ln[Expected\ (r_{ij})] = (C_{ij},\ q_j;\ \beta\text{'s}) + \theta_j. \tag{4}$$

We defined the travel cost and choice variables earlier for Equation 1. The count panel-data consisted of the demand data expanded from the 398 survey respondents to include the 2,388 separate observations of the repeated mountain bike outings to each of the six sites in the past 12-months. The repeated outings were non-negative integer counts and the outing count could be zero as well for any of the six mountain biking sites not visited by the user. We corrected the counts of the past outings for endogenous stratification bias by subtracting one from the counts as reported by the respondents at those sites where intercepted by survey personnel (Egan & Herriges, 2006). As a result, the sample mean of mountain bike outings to the six sites was 5.39 (*SD = 14.29*) per-user in the past 12-months.

The recommended count panel-data estimator for Equation 4 was the negative binomial estimation for recreation demand (Hilbe, 2007; Egan & Herriges, 2006). The estimator processed (a) the Poisson model with a gamma distributed error term for the mean counts of mountain bike outings, (b) allowed for the systematic and random variations in the mean outings across users, (c) and the overdispersion in the outing counts (Hilbe). In modeling this negative binomial process as a generalized linear model with the StataCorp (2007) statistical software, the variance estimator was not included in the model as a stand-alone parameter. Rather, the estimation allocated the variance of the unobserved individual heterogeneity across the panels with an ancillary parameter, referred to as alpha. Following Hilbe's (2007) approach, we obtained alpha from a preceding maximum likelihood, negative binomial estimator. A Wald test on the alpha's dispersion coefficient ($\alpha = 4.184$) confirmed that we had the correct specification for the overdispersion ($g_1 = 6.37$, positive skew) of the outing counts. Rejected then was the hypothesis that the data had a Poisson distribution where the conditional mean equaled the conditional variance. We included the alpha value as a constant in the subsequent generalized estimating equation. The equation averaged the marginal effects of the estimation over the unobserved individual heterogeneity and provided the appropriate exchangeable correlation structure for first-level nested data. The marginal effects, actually the average partial effects, quantified the effects of the travel cost and the choice variables on the day-outing counts (Wooldridge, 2002).

The findings from the estimation of the generalized linear equation appear in Table 5. The significant Wald χ^2 indicated that the count panel-data estimator with the travel cost and choice variables was a better fit to the demand data than just the constant. The travel cost coefficient displayed the expected inverse relationship between the travel costs and the consumption of mountain bike outings, which was consistent with consumer theory. The price elasticity of demand ($e_c = -1.16$) for mountain biking was elastic, meaning that as the travel cost increased by one percent the demand for mountain bike outings decreased by a greater percent. We next tested the significances of the main effects for the choice variables. The site layout was positive in sign and statistically significant and the trail condition was negative in sign and insignificant at the 0.001 level.

On an annual basis, users who took the more frequent mountain bike outings preferred sites with a higher degree of complexity, layout, and natural surroundings. The findings also suggested that users who took the less frequent outings traveled to the sites having less challenging site layouts. Moreover, we rejected the

TABLE 5: GENERALIZED LINEAR MODEL RESULTS OF ANNUAL MOUNTAIN BIKE OUTINGS

Explanatory Variables	**Coefficient**	**z-value**	**Mean**
Travel cost	-0.0160	-11.11	$72.86
Site layout	0.0116	4.05	62.83
Trail condition	-0.0140	-2.18	53.17
Site layout · trail condition	0.0002	3.81	
Constant	1.3047	9.26	
Wald $\chi2(4)$	596.84		

Notes. The z-value is just the coefficient estimate divided by the standard error. The comparison of the z-value to the standard normal distribution tested the hypothesis that the coefficient equaled zero. All the coefficients were significant at the 0.000 level with the exception of trail condition at the 0.02 level of significance. There were 398 users and the six sites in Research Triangle area, North Carolina, for 2,388 observations. The mean outings to all the sites was 5.39 (SD = 14.29) per-user per-year.

equality of the site layout and trail condition coefficients [$\chi2(1) = 12.03$, $pr > \chi2 = 0.000$]. We were confident the choice variables were not measuring the same site conditions.

We also included an interaction between the site layout and trail condition variables in the estimation to determine their roles as decision variables. As suspected, the significance of the positive interaction term reaffirmed a similar result found earlier for the repeated mixed logit with the correlation of the random coefficients. Respondents in making decisions on annual mountain bike outings to sites considered both the site's layout and to an insignificant extent the overall trail condition.

The sample's mean of the expected outings equaled the observed mean with the negative binomial regression. This characteristic of the negative binomial allowed the computation of a consumer surplus (Egan & Herriges, 2006). Dividing the sample mean of the mountain bike outings ($M = 5.39$) per-user by the travel cost coefficient yielded a point estimate of willingness-to-pay of \$336.88 per-user per-year, or on a per-outing basis of \$62.50 per-user in 2006. A host of sources was available for comparing our estimate of consumer surplus. In 1998, Fix and Loomis calculated per-day surplus estimates of \$53.00 and \$55.27 for mountain biking sites in Moab, UT. For comparison purposes, we inflated their values by 1.31% to 2006 dollars (Financial Trend Forecaster, 2007). In real dollars, their per-day consumer surplus was \$69.54 and \$72.40. A USDA Forest Service estimate of the use value for biking activity for 1998 had a mean \$56.27 per-user in the southeast area of the United States (Rosenberger & Loomis, 2001). In a 2005 updated report that included eight published studies, Loomis (p. 9) calculated the per-day consumer surplus as \$49.62 (SE = \$5.69) for the southeast region of the United States. The mean adjusted consumer surplus per-day for the southeast United States then was \$54.10 (SE = \$5.89) in real 2006 dollars.

Conclusions

We began this study by speculating *that users would take more outings to sites having mountain biking trails in natural surroundings, with challenging layout features, and less severely degraded trail condition.* The statistical significances of the mean coefficients of the trail condition and site layout from the repeated mixed logit reject this study's two null hypotheses. Further, we mentioned *a priori* that a correlation might exist between the random coefficients of these choice variables. We empirically accounted for this using a repeated mixed logit with correlated random coefficients ($r = 0.75$). Provided with the results, we can report with confidence that users who place a high value on a site's layout also tend to place a higher value on less degraded condition of the trails. In sum, what motivates users questioned in this study are the complexity and challenge of site layouts in natural surroundings and their awareness's of the current trail conditions, which together enhance their continued enjoyments of mountain biking experiences.

We have previously noted that past research indicated users stated they repeatedly choose mountain biking sites to test their endurance, coordination, fitness, and so forth. One might then speculate that such active participation should add to the deterioration of a trail's condition with the more severely degraded sites contributing to a user's greater enjoyment. Initially, this outcome appeared plausible and to an insignificant extent confirmed the generalized linear model result for the trail condition (Table 5). However, our repeated mixed logit findings significantly support users preferring the less degraded trails on a well-designed site having superior maintained conditions (Tables 3 and 4). We therefore wondered was the trail condition index possibly capturing proactive maintenance actions instituted by users and resource managers to protect the integrity of the resource base in sustaining the desired mountain biking experiences and not capturing the users' choices.

An informal investigation to explain the resulting positive coefficient on the revealed preferences for the trail condition uncovers a variety of maintenance and monitoring actions undertaken by park personnel at the less degraded sites at the time. Actions involve actively monitoring the amounts of moisture in the soil following wet weather conditions, closing site access until conditions improve to an acceptable level, repairing deteriorated trail surfaces, following prescribed maintenance practices, and rotating site access points. The actual choices of users revealed their preferences for less degraded trail condition at sites where proactive maintenance procedures are in place. Consequently, it appears as though the trail condition variable has predictive validity. The index's value may lie in facilitating communication with decision makers about not only spending public funds on trail maintenance, but also in support for additional spending on trail assessments and monitoring to obtain the necessary resource protection benefits for users.

Overall, we concluded that our estimate of $62.50 per-user per-outing (2006 dollars) was similar and appeared reasonable for mountain biking activity in the Research Triangle area, North Carolina, and speculatively for mountain biking activity in the southeastern United States. We could have extrapolated the choice utilities and welfare losses to the annual population of users in the Research Triangle area, if known. Additionally, resource managers in evaluating their mountain biking sites with the site indexes outlined in this paper may relate their management situations to the corresponding compensating variations in estimating annual welfare benefits for planning purposes, if the annual counts for those sites are available to the valuation processes. If so, the applications of consumer surplus to other mountain biking settings should follow the benefits transfers of recreation use values as described by Rosenberger and Loomis (2001).

From a statistical computing standpoint, applying the repeated mixed logit command in Stata (2007) to our demand data of 79,584 choices from the sample of 13,264 outings to the six mountain biking sites in Research Triangle area took approximately 15 minutes for the maximum simulated likelihood to converge on a personal computer. The increase in the computational time burden of the repeated mixed logit and the potential inability of the statistical process to converge to a satisfactory mathematical fit of the data can be disadvantages. The possibility of an unsatisfactory search solution might be attributable to either the misspecification of the demand model, or inadequate measurements of the site characteristics, or both. Even with this potential drawback, we believe that the repeated mixed logit and the estimation steps outlined in this paper offers analysts the potential to identify more accurately user preferences in a variety of outdoor recreation settings in future research applications.

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