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Improving mountain bike trails in Austria: An assessment of trail preferences and benefits from trail features using choice experiments

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ABSTRACT

Over the past two decades, mountain biking has emerged as an increasingly popular recreational activity. However, at least in Austria official trails do not necessarily match the preferences of bikers and therefore they often ride on unofficial trails or on trails where biking is not allowed. This behavior can result in conflicts with other trail users, landowners, hunters and conservationists. With data from an online choice experiment we confirm and extend results from previous studies on mountain biking, such as riders preferring technically challenging trails with lots of singletrack and vertical climb. However, the specific preferences depend on rider characteristics, especially experience and age. Through a simulation of market shares and the calculation of compensating surplus for riders in the study area in forests close to Vienna, we demonstrate how this research can provide insights about how to adjust trails to better match the interests of bikers while still respecting regulations which are in the interests of landowners, hunters and ecological concerns.

MANAGEMENT IMPLICATIONS

- To avoid conflict with other trail users, we propose tailoring trails specifically to the needs of the diverse group of bikers.
- For example, trails should have large amounts of technically challenging singletrack, at least on down hill sections.
- Trails should vary in their attributes such as vertical climb or length, to fit the preferences of riders with different socio-demographic background and experience.
- Multi-use trails for bikers and hikers can be recommended, however, horses on the same trails should be avoided.

1. Introduction

Mountain biking is an increasingly popular recreational activity worldwide. Technological advances have made riding easier and more comfortable, and fierce competition between established bike retailers and newer on-line sellers have made riding a quality bike affordable for many consumers. Annual bike sales in Austria have increased from 142,000 in 2007 to 155,000 in 2009 (Beckendorff, 2010). Furthermore, the market has quickly differentiated into different riding styles such as down-hill biking, tour and cross-country riding, competition style riding types such as free-riding or four-cross, among others (Quinn, & Chernoff, 2010). While mountain biking in Austria is exempt from the general free access to forests (Forstgesetz, 1975), the Austrian Federal Forests have responded to the rising demand for mountain bike trails by opening around 2100 km of logging roads to mountain bike use (Bundesforste AG, 2013).

Along with the rapid rise of mountain biking there has also been an increase in associated problems. Of particular concern are riders going off designated trails. Concerns of resource managers include the safety of all trail users, user conflicts, crowding, and environmental degradation (White, Waskey, Brodehl, & Foti, 2006). This paper tries to assess the trail preferences of mountain bikers to better understand why bikers choose to leave designated

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trails, and to be able to design policies that prevent them from doing so.

Environmental concerns include the degradation of soil, vegetation, and disturbance of wildlife (see e.g. Pickering, Hill, Newsome, and Leung (2010) for a literature review for the USA and Australia). Degradation of soil and vegetation can be similar between hikers and bikers, as several studies have found. For example, Thurston, and Reader (2001) report no significant differences between the impacts of hikers and bikers on soil and vegetation in an experimental setting. Pickering, and Barros (2015) and Pickering, Rossi, and Barros (2011) point out, however, that ecological impacts of hiking and mountain biking are only similar at low levels of use, while mountain bikers may have a more severe impact on vegetation if use levels increase. Trail widening due to mountain biking might be particularly pronounced in wet spots (Goeft, & Alder, 2001; White et al., 2006). Soil degradation specifically attributable to mountain bikers can also occur along steep slopes due to spinning tires when going uphill or poor braking technique (skidding) when going downhill. These problems are compounded by the fact that many bikers prefer technically challenging trails with steep slopes and obstacles (Cessford, 1995; Goeft, & Alder, 2001; Hollenhorst, Schuett, & Olson, 1994; Siderelis, Naber, & Leung, 2010), and might even seek these challenges on informal (social) trails, where the ecological impacts can be more severe (Havlick, Billmeyer, Huber, Vogt, & Rodman, 2016). Impacts on wildlife have been reported by Marzano, and Dandy (2012) in two broad categories: (1) flight behavior change, and (2) habitat change through trampling and erosion. Overall, the empirical evidence suggests that animal flight behavior does not differ dramatically between mountain bikers and hikers (Naylor, Wisdom, & Anthony, 2009; Taylor, & Knight, 2003). Also, as Lathrop (2003) points out, bikers might be less likely to go off trail and therefore cause damage by trampling, since trails provide an ideal surface for most mountain bikers.

A broad literature exists on the conflict between different user groups in recreation (e.g. Carothers, & Vaske, 2001; Cessford, 2003; Hoger, & Chavez, 1998; Jacob, & Schreyer, 1980; Jacoby, 1990; Ramthun, 1995; Watson, 2001; Watson, Williams, & Daigle, 1991). Management approaches to tackle conflict include zoning or trail designation for different user groups, or education of these user groups about behavior on shared trails (e.g. “trail rules”) (Carothers and Vaske, 2001). However, both approaches require trail users to respect the implemented management strategies, i.e. to respect zoning laws, or to adhere to the rules proposed to facilitate the common use of the trails. While inconsistent evidence has been reported on conflict between hikers and mountain bikers, some common denominators can be extracted from the literature. First, hikers and mountain bikers seem to perceive conflict differently, with hikers feeling their experience to be more negatively affected than the other way round (Jacoby, 1990 as cited by Hoger, & Chavez, 1998). Second, hikers may perceive safety issues due to the speed and quiet approach of mountain bikers (Chavez, Winter, & Baas, 1993; Watson et al., 1991). However, findings by Cessford (2003) indicate that perception of bikers by hikers can be largely positive, in particular among younger hikers, and the presence of bikers does not seem to detract from the overall hiking experience significantly. Finally, Chavez (1996) also reports safety concerns of horseback riders, with horseback communities engaging in organized protest against the use of “their” trails by mountain bikers.

A number of management issues with mountain bikers have also been observed in Austrian forests. For example, the integrated management of wildlife, recreation and commercial forestry in the Wienerwald forest did not receive wide acceptance by mountain bikers (Reimoser et al., 2008). Stoeckl (2010) found that riders tend to leave the designated trails, which are mostly routed along logging roads, for more technically challenging singletrack. Although most riders' knowledge of spatial and temporal riding restrictions was very good, many were reluctant to respect them. Reasons for going off trail included curiosity, looking for variety and more interesting trails, a lack of mountain bike trails or connections between designated trails, and to avoid crowded trails (Brandenburg, & Ziener, 2007). Brandenburg, and Ziener (2007) also mention that the interests of land owners and hunters were weighted more heavily over the interests of mountain bikers, when a new management plan was negotiated. Therefore they recommended a re-assessment of existing trails and a widening of the current trail system, while considering the preferences of various types of mountain bikers.

While the mountain-biking community is very diverse, we limited our investigation to the cross-country and touring community. These bikers prefer a variety of trails including uphill, flat, and downhill sections and levels of difficulty from easy dirt roads to rocky/technical terrain (Quinn and Chernoff, 2010). Therefore they use a wide variety of legal and illegal trails, which increases the potential for conflict with other users on trails. The goal of this research paper is two-fold: first, we assess preferred trail features of various subgroups of mountain bike riders (i.e. riders of different age, sex, and experience) and compare our findings with those from the international literature. Second, we will try to quantify these subgroups' trail preferences in order to estimate the benefits they derive from important trail features in terms of market share changes due to trail changes, and the resulting compensating surplus. These findings may help managers to design trails to reflect biker preferences and possibly reduce the necessity of measures to manage user conflicts and environmental degradation.

We proceed as follows: Section 2 outlines the theoretical background and methodological approach we took in experimental design and analysis. Section 3 summarizes the results of the experiment and demonstrates a practical approach for their use in exploring management issues. Finally, we discuss our findings and formulate some policy recommendations in Section 4.

2. Method

Several methods for the elicitation of preferences have been documented in the literature. A convenient conceptual framework is provided by the economic theory of utility maximization. In short, individuals are expected to make choices to maximize their satisfaction (utility). With recorded purchases of market goods, these choices are usually easy to observe and utility functions can be estimated using econometric methods. However, due to the free access to mountain bike trails in most locations, including Austria, they exhibit many of the features commonly recognized as non-market goods, including the non-excludability and non-rivalry (up to a point) (Just, Hueth, & Schmitz, 2004). These features make market observations challenging, and different methods of value elicitation must be used. In the field of non-market valuation methods, revealed preference (RP) and stated preference (SP) methods can be distinguished. Revealed preference methods usually include market observations, whose use is associated with some aspect of a non-market good (e.g. weak complementarity). An example in the context of mountain biking is the travel cost method applied by Fix, and Loomis (1997), in which mountain bike trails are valued by the amount of money people are willing to spend to get to a certain trail. Stated preference methods usually include an elicitation of preferences via hypothetical surveys; the most common among them are the contingent valuation method (CVM) and choice experiments (CE). The strengths of the CVM lie in the valuation of an entire good which is conceptually difficult to disentangle. Choice experiments, by the assumption of an additive utility specification proposed by Lancaster (1966), are the most powerful when the good being valued can be easily split into its attributes (Hanley, & Barbier, 2009). Hensher, Rose, and Greene (2005) and Louviere, Hensher, and Swait (2000) provide a detailed introduction to this method and its applications. In short, survey respondents are asked to state their preferences with choice sets of different products or states of their environment (*alternatives* from here on). Each choice set contains two or more alternatives, which differ in various attributes. In addition to these choice data, respondents' socio-demographic information is also recorded to infer factors that influence their preferences. By utilizing random utility theory (McFadden, 1974), survey results are analyzed in a multinomial logit model (MNL), random parameters logit model (RPL), or latent class model (LCM). The latter two allow accounting for preference heterogeneity in the sample. Once the model has been estimated, parameter estimates can be used for forecasting in simulations for likely product market shares or for policy impact analysis. We base our methodology on the earlier study by Morey, Buchanan, and Waldman (2002), who elicited the trail preferences of mountain bikers in Colorado using a choice experiment.

2.1. Experimental design

As in Morey et al. (2002), we assume that the attributes of mountain bike trails have a major impact on the utility which bikers obtain from a certain trail. To identify the most important trail attributes, we used Morey et al. (2002) as a starting point and conducted a rigorous literature research and key informant interviews in the mountain biking community. The final list of attributes and levels can be found in Table 1. As findings by Schulte (2003) suggests, trail preferences might be impacted by the level of maintenance, but it is not clear how intensive this maintenance should be. Therefore, we included the attribute *management intensity* (mana) to Morey et al.'s attribute list. Further, while it is known that mountain bikers like technically challenging singletrack, it is not clear whether singletrack should be predominantly placed on uphill or downhill sections, or if singletrack should be equally distributed among uphill and downhill sections. We therefore added the attribute *singletrack type* (stform) to the attribute list. The attribute *hikers or equestrians* (hikeeq) described if there would be hikers or equestrians on the trail. This attribute has three qualitative levels: (1) no hikers or equestrians on the trail, (2) only hikers on the trail, and (3) both hikers and equestrians are allowed on the trail. Level (3) served as the base category in the estimation. The attribute *singletrack* (single) is the amount of singletrack in percent. The names of the other attributes are self-explanatory. The attributes management intensity, singletrack type, and hikers or equestrians were dummy coded in the design and in the model, all other attributes were coded continuously.

A wide array of experimental design methods exists and the choice depends primarily on the number of attributes, the expected interactions between these attributes, and the labelling of alternatives (see Johnson, Kanninen, Bingham, & Özdemir (2007) for an overview). Similar to Morey et al. (2002) we chose to conduct an unlabelled experiment with generic alternatives. We used the software R (R Core Team, 2012) and the package RcmdrPlugin.DoE (Groemping, 2012) to generate a d-optimal design. Since Morey et al. (2002) found significant interaction effects of the attributes *climb***length* and *climb***peaks*, we included these two interactions in the design.

Pre-testing showed that respondents could comfortably evaluate up to six pair-wise choice sets. Therefore, to reduce the respondents' cognitive burden (Hensher et al., 2005), we split the design into ten blocks holding six alternatives each which results in a total of 60 alternatives. This step was done using the R package AlgDesign (Wheeler, 2011). As Hensher et al. (2005, p. 152) points out, generic designs only require within-alternative orthogonality, rather than between-alternative orthogonality. Therefore, choice sets were generated by replicating each block and randomizing the order of the second alternative within each block, while checking for identical and dominating alternatives (Hensher et al., 2005). We labeled the alternatives generically as TRAIL A and TRAIL B. Similar to Morey et al. (2002), and because trails are generally free in Austria, we chose not to include an opt-out alternative in the choice set. In addition, we asked two debriefing questions after the choice sets to gain additional insights into the choice process (Krupnick, & Adamowicz, 2007): First, respondents were asked to indicate which three attributes mostly influenced their trail choice. The second question was open ended, where respondents could express why they would not be satisfied with a certain trail they had chosen.

2.2. Survey implementation

The sample was collected from September to November 2012. We designed an online questionnaire using LimeSurvey (Schmitz, 2012) and used a random number generator to decide which block out of the 10 blocks of choice sets would be shown to the respondent. Links to the questionnaire were posted on internet forums (www.bikeboard.at, www.gipfeltreffen.at), where riders were asked to complete the questionnaire online. In addition, we distributed a separate link in a snowball sample among mountain bikers known to the authors and their friends. As an incentive we raffled off three purchasing vouchers worth €20.00 each for an online bike store as recommended in the literature (Dillman, 2007). To reduce the chance of multiple responses by the same individual, we used a cookie that prohibited access to the questionnaire after it had been completed from the same computer. This was a compromise between completely free access and restricting the sample to specific users by using login keys (which would most likely have reduced the response rate). While our sample is clearly not representative, with this convenience sample, determined by our budget constraints, we captured a wide variety of riders with different characteristics.

Similar to Morey et al. (2002), the questionnaire started out with some general questions on rider characteristics and experience, such as riding frequency, if they had racing experience, whether they saw themselves primarily as road riders or as mountain bikers, and how they would rate their own experience in mountain biking. Also, we asked whether their most frequently used mountain bike was a hard-tail or a full suspension bike, and how much it cost at the time of purchase.

This section was followed by the framing of the choice experiment. Respondents were asked to choose between two options for a one-day ride at perfect weather conditions (20 °C, sunshine). Following a list of the relevant trail attributes, the attributes singletrack vs. logging roads, and trail management

Table 1
Attributes and levels used in a choice experiment assessing mountain biker trail preferences in Austria.

Attribute (*Variable*)	Unit	Levels
Trail length (*length*)[a]	km	10/20/30
Vertical climb (*climb*)[a]	m	300/600/100
Number of peaks (*peaks*)[a]	#	1/2/4
Singletrack (*single*)[a]	%	0/30/70
Singletrack type (*stform*)[c]		Downhill/balanced/uphill
Management intensity (*mana*)[c]		Low/medium/high
Hikers or Equestrians (*hikeeq*)[b]		None/hikers only/both
Fee (*fee*)[a]	€	3/8/15

[a] Also used by Morey et al. (2002) as attribute.
[b] Also used by Morey et al. (2002) as attribute but extended.
[c] New attribute.

intensity, were described in more detail by using representative pictures. The three levels of trail management intensity were additionally described as follows:

Low: Grown over trails, branches/logs on trail, no blazes.

Medium: Trail edges are trimmed, branches/logs removed, blazes available.

High: Trails are maintained intensively, technical trail features available (ladder bridges, drops, jumps).

The framing was followed by the six choice questions, which were revealed one-by-one. A sample choice set is depicted in Fig. 1. After the two debriefing questions mentioned above, the questionnaire finished with some socio-demographic questions about age, gender, income and household expenditure, marital status, and the number of children. Finally, respondents were invited to leave their email addresses in case they wished to participate in the lottery for the voucher.

2.3. Statistical analysis

In the analysis, we assume that respondents choose trails by rationally maximizing their utility (Hensher et al., 2005). According to McFadden's (1974) random utility model, a person's utility from a certain choice consists of an observable part V and an additive unobservable part ε. Assuming an extreme value type 1 distribution for ε, the probability of an individual n of choosing alternative i out of all alternatives j can be expressed with the MNL model

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_{j=1}^{J} e^{V_{nj}}}$$

where

$$V_{ni} = \sum_{k=1}^{K} \beta_k X_{nik}$$

β_k are estimates describing the impact of the attribute X_{nik} on the alternative's choice probability. For some attributes, preference heterogeneity can be inferred from rider characteristics. For example, Schulte (2003) suggests that more experienced riders prefer more difficult trails. If a trail that has more singletrack and more vertical climb is associated with being more difficult, we can interact these attributes with self-rated rider experience (i.e. beginner, intermediate, or advanced) and infer by how much an attribute influences the utility function for these different rider types. Furthermore, rider characteristics such as age and gender have been found to influence preferences towards certain trail attributes (Morey et al., 2002). In a generic design, as the alternative labels hold no information themselves, individual characteristics can only enter the utility function if they are interacted with corresponding attributes (Hensher et al., 2005). Using the R package mlogit (Croissant, 2012), we obtained the parameter estimates by maximum likelihood.

The MNL model, however, comes with certain limitations. In particular, preferences about trail attributes are assumed to be homogeneous among the biker population, except for individual characteristics arbitrarily controlled for through interactions (Hensher et al., 2005). One way to include preference heterogeneity into a choice model is to assume that certain parameters follow a distribution instead of being fixed. The random parameters logit (RPL) model allows to define distributions (e.g. normal or lognormal) and to estimate the distribution parameters (i.e. mean and standard deviation, including their respective standard errors) instead of only a single parameter estimate (i.e. mean, including the standard error). We estimated a RPL model, where we assume that the coefficients (i.e. marginal utilities of attributes) are normally distributed. Similar to Siderelis et al. (2010), we fixed the fee coefficient as a constant to avoid a negative or zero utility of money. Also, parameters that did not robustly show a standard deviation that was significantly different from zero according to a Wald test were assumed to be fixed (i.e. only the mean and not the standard deviation was estimated) in the final models. According to Greene (2011), the parameter β_{jk}, which describes the marginal

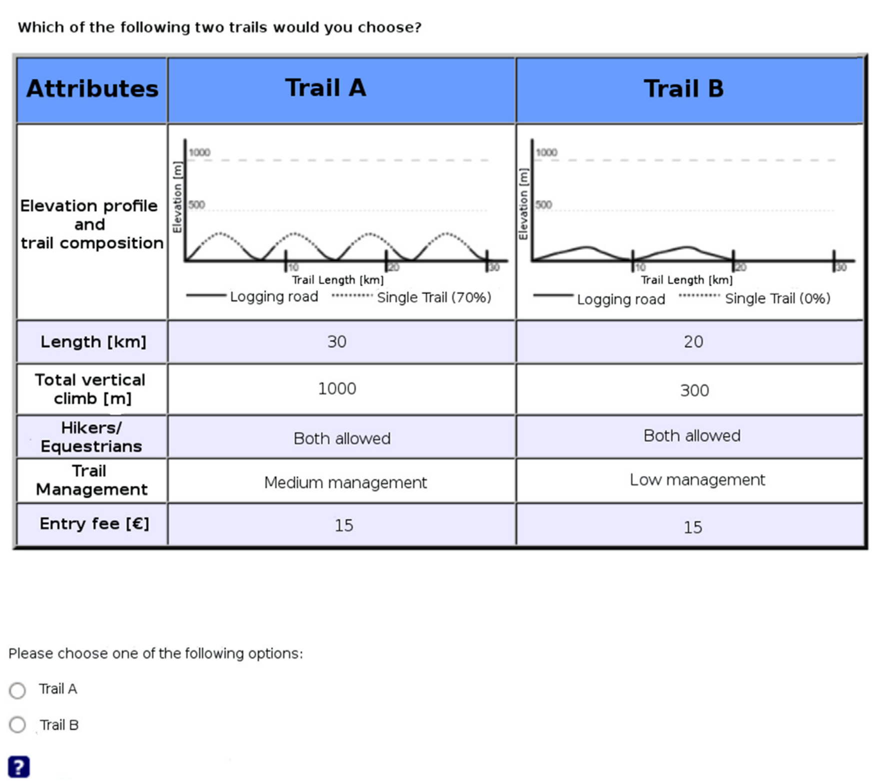

Fig. 1. Example of the choice sets presented to mountain bikers via an online survey to assess mountain bikers' trail preferences in Austria.

utility of the attribute that random preferences are associated with, becomes

$$\beta_{jk} = \beta_k + \boldsymbol{z}_i'\boldsymbol{\theta}_k + \sigma_k u_{ik}$$

where $\beta_k + \boldsymbol{z}_i'\boldsymbol{\theta}_k$ is the mean of the distribution, and $\mathbf{z}_i$ is a vector of person specific characteristics (Greene, 2011, p. 771). This allows preferences about specific attributes to vary across individuals, without specific interactions of personal characteristics with alternative attributes. Parameter estimates are reported by the population mean and the standard deviation (see Greene (2011) or Hensher et al. (2005) for detailed overviews), and were estimated by simulation using 100 Halton draws (Hensher et al., 2005).

To estimate the welfare effects of trail changes, we used the measure of compensating surplus. By definition, the compensating surplus of a policy is the amount of money that has to be subtracted from an individual's income (possibly negative, if the change leads to a lower level of utility) that makes the individual as well off as without the change (Just et al., 2004). We calculate the compensating surplus (CS) of a change in trail features by numerical approximation according to the formula

$$V_0(i, q_0, y) = V_1(i, q_1, y - CS) \tag{1}$$

where V_0 and V_1 are, respectively, the original and the subsequent utility level, q is a vector of non-market goods, i are individual characteristics and y is the individual's income (Haab, & McConnell, 2003, p. 7, modified). An intuitive explanation could go as follows: Assume mountain biker X gains utility from buying market goods (i.e. going to the cinema) and from mountain biking. This mountain biker particularly likes the attribute singletrack. If the length of singletrack on a given mountain bike trail is increased, this would increase her utility gained from riding this trail by a certain amount. Therefore, the level of utility would be unchanged if the trail had more singletrack parts and she would consume less market goods (e.g. seeing one movie less in a month). The measure of compensating surplus describes exactly the amount of money not spent on purchasing market goods that leaves her as well off (i.e. on the same utility level) as before the change in the non-market good (the mountain bike trail).

3. Results

3.1. Sample statistics

From the 350 respondents who started the survey, the final sample consisted of 261 completed responses. Unfinished responses were excluded from further analysis, as their majority did not answer any of the choice questions. The average age of the respondents was approximately 36 years (sd = 17.7). Only 15 out of 261 respondents were female (5.7%). Given the age structure in this sample, it is not surprising that 69% of respondents indicated that they were married or lived with a partner. The majority of respondents (62.5%) had no children living in their households, while 15% had one child, and 22% had two or more children. The average monthly net household income was €2562 (sd = 1051).

The majority of respondents (78%) rated themselves as being *intermediately* experienced, while 13.5% said they were advanced riders and 8.5% were beginners. Asked whether they would classify themselves to be primarily road riders or mountain bikers, 45 respondents (17.2%) classified themselves as road bikers, leaving 216 (82.8%) mountain bikers. With regard to racing experience, 149 respondents (57%) had participated in bike races before, while 112 (43%) had not. The majority of bikers (69%) would ride between 6 and 20 days a month, with only 3 bikers riding less than once a month.

A majority of respondents (61%) perceived mountain biking as an outing as well as training. Twenty-four percent saw mountain biking predominantly as training, while only 14% chose outing as their primary motivation to go for a ride. Nearly all respondents were equipped with suspension systems on their bikes. Of the bikes they most used for their rides, 115 (44%) used hard-tails, while 145 (56%) indicated that they used full suspension bikes. Sixty-two percent had purchased their bike in the last three years (2010 through 2012), 30% between 2005 and the end of 2009. The remaining bikes were purchased prior to 2005. The average purchase price was €2607 (sd = 1400).

According to the results of the debriefing questions, singletrack is the most important attribute influencing trail choice, followed by vertical climb. Fee, trail length, and singletrack type also influenced trail choice significantly, while management intensity, the presence of hikers or equestrians, and the number of peaks only seemed of marginal importance (Fig. 2). Also, the majority (65.5%) of the 145 respondents who answered the open-ended question about trail dissatisfaction expressed that they would not be willing to pay an entry fee.

3.2. Estimation results

To find out which trail features and individual characteristics influence trail choice, we ran several MNL and RPL models and present the results of the best fitting models in Table 2. The names of the attribute variables are described in Table 1, and the names of the dummy coded attributes and the interaction variables relating to rider age and experience in the lower part of Table 2 are described in Table 3. To account for preference heterogeneity, different model specifications were chosen. First, we ran a simple main effects MNL model (Model 1). Next, interactions of rider characteristics with selected attributes were added (Model 2). A third, main effects RPL model included several random parameters (Model 3). Finally, interactions were introduced into the RPL model (Model 4). Surprisingly, all models predict the given sample choices similarly well, with a range from 72.99% to 76.18% of true predictions (Table 2). Keeping in mind that there is a 50% chance to make a correct prediction by chance, these numbers are reasonable proportions of true predictions. All random parameters in the

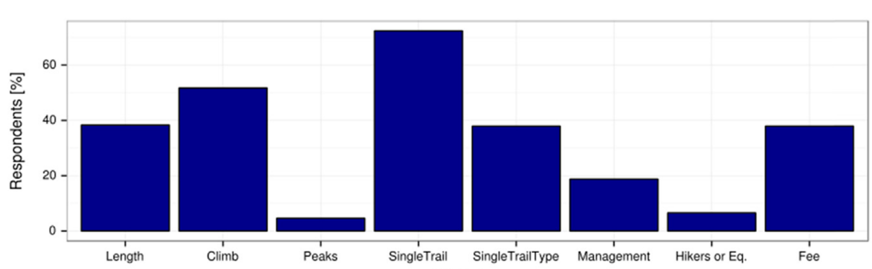

Fig. 2. Respondents to the online questionnaire were asked which three trail attributes mostly influenced their choice in the choice experiment. This figure shows the frequency distribution of responses to this question.

Table 2
Parameter estimates reflecting part-worth utilities of mountain bike trail features using multinomial logit (MNL) and random parameters logit (RPL) models. Models 1 and 3 only consider main effects of trail features on rider utility. Interactions between trail features with rider characteristics were included in models 2 and 4. See Tables 1 and 3 for more details on the variables used in the estimation.

	Variable	Model 1: MNL		Model 2: MNL+Int.		Model 3: RPL			Model 4: RPL+Int.		
		Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.	Std. Dev.[a]	Estimate	Std. Err.	Std. Dev.
Main effects	length	−0.2273	0.0634***	−0.3706	0.0756***	−0.2335	0.0781**	0.0363.	−0.4084	0.0873***	ns
	length05	1.9110	0.5504***	2.5627	0.6135***	1.9707	0.6812**	ns	2.7572	0.7090***	ns
	climb	−0.0030	0.0017.	−0.0078	0.0021***	−0.0024	0.0023	ns	−0.0092	0.0026***	ns
	climb05	0.2087	0.0862*	0.2007	0.0901*	0.2048	0.1142.	0.0820***	0.2120	0.1146.	0.0588*
	peaks	−0.2428	0.0328***	−0.4008	0.0942***	−0.2723	0.0412***	ns	−0.5051	0.1044***	ns
	stlength	0.0859	0.0069***	0.1146	0.0285***	0.1328	0.0131***	0.1437***	0.1740	0.0423***	0.1236***
	bal_st	−0.1020	0.1034	−0.0015	0.1094	−0.0331	0.1298	ns	0.0952	0.1336	ns
	downh_st	0.4184	0.1066***	0.4693	0.1120***	0.5118	0.1323***	ns	0.5395	0.1317***	ns
	no_hike	0.2967	0.1023**	0.2678	0.1080*	0.4171	0.1260***	ns	0.3362	0.1281**	ns
	yes_hike	0.3057	0.1035**	0.3179	0.1072**	0.3748	0.1281**	ns	0.3712	0.1287**	ns
	mana_low	0.1975	0.1114.	0.1074	0.1275	0.3078	0.1402*	ns	0.1402	0.1490	ns
	mana_med	0.0615	0.1230	−0.0730	0.1432	0.0796	0.1628	ns	−0.0714	0.1700	ns
	fee	−0.0612	0.0091***	−0.0614	0.0111***	−0.0866	0.0122***	ns	−0.0850	0.0139***	ns
Interactions	length:road			0.0327	0.0147*				0.0349	0.0188.	
	length:climb			0.0001	0.0000***				0.0001	0.0000***	
	climb:exp_i			0.0017	0.0005**				0.0024	0.0007***	
	climb:exp_a			0.0013	0.0006*				0.0022	0.0008**	
	climb:male			0.0012	0.0006*				0.0014	0.0008.	
	climb:peaks			0.0003	0.0001*				0.0004	0.0002**	
	stlength:road			−0.0994	0.0172***				−0.1435	0.0252***	
	stlength:exp_i			0.0516	0.0212*				0.0767	0.0286**	
	stlength:exp_a			0.0806	0.0275**				0.1111	0.0367**	
	stlength:age			−0.0015	0.0006**				−0.0026	0.0008***	
	fee:road			−0.0734	0.0258**				−0.0775	0.0327*	
Log-Likelihood		−878		−819		−820			−775		
True predictions		72.99%		76.18%		73.50%			75.73%		

[a] Standard errors of the standard deviations are not reported here, but the full tables are available from the authors upon request.
*** significance codes: 0.001.
** significance codes: 0.01.
* significance codes: 0.05.
. significance codes: 0.1; ns: not significant.

Table 3
Description of variables describing trail features and rider characteristics used in the estimated choice models in Table 2.

Variable	Description
bal_st	1 if singletrack is equally distributed between uphill and downhill sections, 0 otherwise
downh_st	1 if singletrack is predominantly placed along downhill sections, 0 otherwise
no_hike	1 of no hikers and equestrians are allowed on the trail, 0 otherwise
yes_hike	1 if hikers, but no equestrians are allowed on the trail, 0 otherwise
mana_low	1 if level of trail maintenance along the trail is low, 0 otherwise
mana_med	1 if level of maintenance along the trail is medium, 0 otherwise
road	1 if respondent sees himself primarily as road rider, 0 otherwise
exp_i	1 if respondent is an intermediately experienced mountain, 0 otherwise
exp_a	1 if respondent has advanced experience in mountain biking, 0 otherwise
age	Respondent's age in years

RPL models were assumed to be normally distributed. All parameters have the expected signs and most are significant (Table 2). Also, the signs were robust to changes in model specification, and the significant MNL and RPL parameters differ in magnitude, but not in signs. Running likelihood ratio tests confirmed that all models were significantly different from each other at a 5% level or less (detailed results are available from the authors on request). In particular, testing both RPL models against their MNL counterparts allowed to reject the hypothesis of having no uncorrelated random effects ($p < 0.001$).

We found that *trail length* has a positive impact on trail choice, but only up to a point; hence the negative sign on the *length* term, while the $length^{0.5}$ term is positive in all models. Also, those considering themselves road riders prefer significantly longer trails compared to mountain bikers, as shown in the models that include interactions. The density plot from the RPL model (Croissant, 2012) shows, that this attribute will eventually detract from utility for all riders, if the trail length becomes too large (Fig. 3). Therefore, practically 100% of the area under the density curves are below zero, for both RPL models respectively. However, there is heterogeneity within the population as to how much this attribute adds to utility.

The *total vertical climb* again positively impacts trail choice up to a point. More experienced riders prefer more vertical climb than beginners, while females prefer, on average, trails with less vertical climb, compared to males. The RPL model revealed, that some preference heterogeneity still remained, even after interacting the parameter with several rider characteristics. On average, more experienced riders prefer more vertical climb than beginners, as do males compared to females. The *number of peaks* on its own has a negative impact on trail choice, however, if the vertical climb is increased, riders prefer to go up multiple peaks.

While the impact of *singletrack* is positive on average, those considering themselves as road riders prefer lower amounts of singletrack, or even none at all. Also, everything else being the same, older riders will prefer trails with less singletrack compared to younger riders. Among the more experienced riders (intermediate and advanced), singletrack adds to trail choice even more than for beginners. In Fig. 3, the preference heterogeneity towards this attribute is also reflected by the density curve from the RPL models: between 8% (Model 4) and 18% (Model 3) of the sample gain negative utility from singletrack, while this attribute provides positive utility for 82% and 92% of riders respectively. There also seems to be a consensus of how singletrack should be placed on

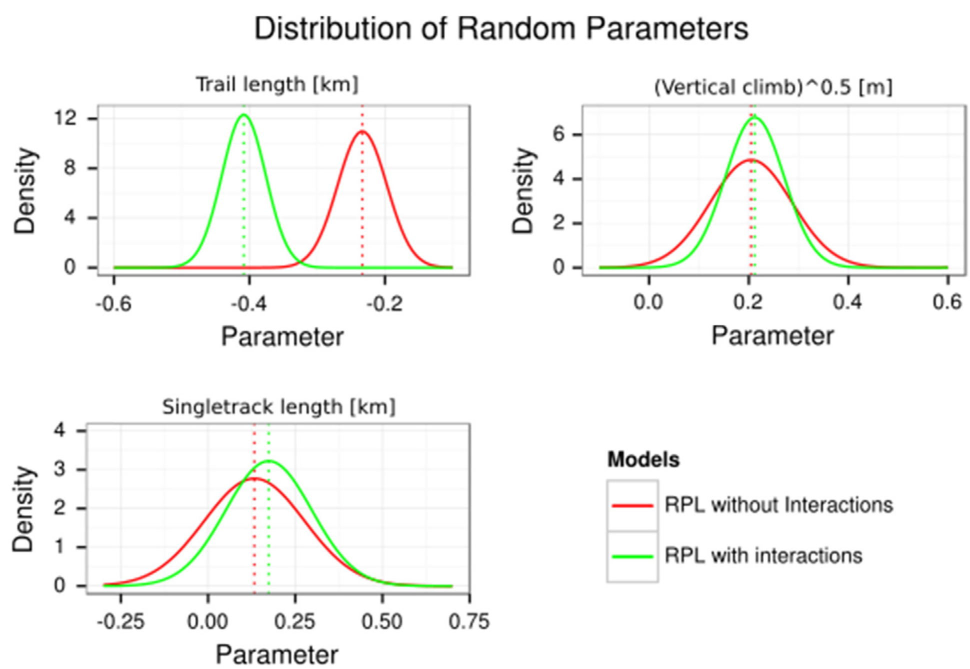

Fig. 3. Two random parameters logit models with three random parameters (trail length, climb$^{0.5}$, single track length) were estimated. This figure shows the distributions of the random parameter estimates. The negative parameter of the length attribute shows that eventually, trails will become too long for all riders (see Table 2 for the details on model specification).

the trail: *predominantly downhill*. This was by far preferred to other types of singletrack; the utility impact of uphill singletrack did not yield any significant results.

Not surprisingly, equestrians are not welcome on the trail, therefore the options of *hikers only* and *no hikers or equestrians* were significantly positive.

The *trail management intensity* was deemed somewhat important from the debriefing questions, however, no significant estimates for these attributes could be obtained. We therefore can, from this model, not draw any definite conclusions as to how intensive trails should be managed to fit biker preferences. Last, trail *user fees* would not be welcome, in particular by road riders.

The density plots in Fig. 3 show how including interaction terms between trail attributes and rider characteristics can influence the estimated parameters of random parameter models.. As mentioned above, we assumed for all parameters to be normally distributed. In contrast to the MNL model, this requires the estimation two parameters for each random parameter: a mean and a standard deviation. Each of these has their own standard error, which allows using the Wald test to test for significance. Only the parameters for the variables length, climb$^{0.5}$, and singletrack had a consistently significant estimated standard deviation in the random parameters models, which is why only these three parameters were assumed to be random in the estimation. First, for the length attribute, it can be seen in Table 3 that including the interactions with the "road rider" characteristic and the vertical climb attribute substantially decreases the mean parameter estimate (from -0.2335 to -0.4084), while leaving the standard deviation of the parameter almost unchanged. However, as shown in Table 2, the standard deviation estimated of the random length parameter turns from 0.0363 to being insignificant. This suggests that including the interaction term accounts for previously unexplained heterogeneity of the model. Second, the parameter of the climb$^{0.5}$ attribute without the interactions with rider experience and gender has a substantially higher standard deviation (0.0820) than the parameter of the model with included interactions (0.0588). This makes sense, because in the latter model, preference heterogeneity has been explicitly accounted for through the interactions, resulting in a lower heterogeneity that has to be accounted for by the random parameter. However, in this case, the standard deviation is still significant. Finally, the random parameter of the "singletrack" attribute hardly changes in mean (from 0.1328 to 0.1740) and standard deviation (from 0.1437 to 0.1236) by introducing interactions, which can also be seen in Table 2. This finding suggests that while the interactions with rider experience, age, and the "road rider" characteristic are important (i.e. statistically significant), a large amount of unexplained preference heterogeneity is still left and to be accounted for.

3.3. Trail management simulation

By applying the model results to a set of sample trails in the forests surrounding Vienna, we demonstrate how different trail configurations yield different market shares and compensating surpluses. In particular, we use our four models to predict how different rider types of our sample would be distributed on these two hypothetical trails. The sample was split into *road riders*[1] ($n_1=45$), mountain bikers with racing experience (*raced-mtb*, $n_2=117$) and mountain bikers without racing experience (*not-raced-mtb*, $n_3=99$). For this simulation we used a trail from the official trail network of the Wienerwald forest (Hirschengarten), and a trail that would be illegal to ride, but which has many desirable features (Table 4).

First, we predicted market shares on the two original trails. As can be seen from Table 5, the majority of riders from the sample (between 82.0% and 89.7%, depending on the model) would be predicted to choose the illegal trail over the official trail. However, as the integration of rider characteristics in Models 2 and 4 also allows disaggregating the market shares into the different rider types, it becomes clear that those considering themselves as road riders would be more likely to take the official trail than the other riders (Table 6). This choice is mostly associated with the

[1] Those riders indicating they would see themselves primarily as road riders as opposed to being primarily mountain bikers.

Table 4
Trail features of trails close to Vienna used in a trail management simulation example where an official trail (HG old) is changed to become more attractive to mountain bikers (HG new).

Trail attribute	Hirschengarten (HG old)	Illegal trail	New Hirschengarten (HG new)
Trail length (km)	39	24	28
Total vert. climb (m)	728	1000	828
Number of peaks	3	4	3
Singletrack length (km)	0	10	10
Singletrack type	–	Downhill	Balanced
Hikers or equestrians	Hikers only	Hikers only	Hikers only
Fee	0	0	0

Table 5
Average market shares (%) and compensating surplus (€) estimates predicted by the multinomial logit and random parameters logit models, before and after a change to the Hirschengarten (HG) trail.

	Multinomial logit model				**Random parameters logit**			
	Without interactions		**With interactions**		**Without interactions**		**With interactions**	
	HG	Illegal	HG	Illegal	HG	Illegal	HG	Illegal
% before (HG old)	17.98	82.02	15.16	84.84	10.30	89.70	10.59	89.51
% after (HG new)	46.41	53.59	44.39	55.61	42.70	57.30	39.47	60.26
CS [€]	22.44		21.38		21.61		18.22	

preference for logging roads over singletrack by this rider type.

When changing the Hirschengarten trail to be more mountain biker friendly by adding more singletrack and an additional peak (Table 4), market shares on average change to between 53.6% and 60.3% of riders riding on the illegal trail (Table 5). Therefore, a reduction of rides on the illegal trail between 32.7% and 36.1% would be expected, given that only these two trails are available for riding. Disaggregation by rider types shows that particularly raced-mtb and not-raced-mtb types would be more likely to change their behavior: after the improvement, only between 14.4% and 16.4% of road riders would shift from the illegal to the improved official trail. On the other hand, between 35.2% and 37.4% of mountain bikers with racing experience and mountain bikers without racing experience each would be expected to shift to the new Hirschengarten trail. These differences are also reflected in the compensating surplus reported in Table 6. These compensating surplus estimates were first calculated on the individual level according to Eq. (1), and then averaged for the respective groups. While, depending on the model, the trail improvement is only worth between €1.48 and €2.60 for road riders, compensating surpluses for the other two types range from €26.02 to €31.79. Those who have raced before are found on the upper edge of this range, while those who have not on the lower edge.

Of course, adding more trails to a simulation will change the outcome of market share predictions and compensating surpluses; in general, the more substitutes are available, the lower the compensating surplus estimate will be. Our models can be easily adapted to more complex situations (i.e. adding more trails or more rider types). Overall, our comparison shows that the models provide similar results in absolute terms (see also Table 5). While the MNL model with interactions has the highest predictive power, also the models not including rider characteristics predict reasonably well. However, including interactions of attributes and rider characteristics allows to analyze the effects of trail management options in more detail. In particular, the model can be adapted more easily to different regional settings with a different distribution of rider types as it shows more clearly which type would win and which type would lose from a proposed policy than models without interactions.

4. Discussion

Management of outdoor recreation areas requires balancing the interests of many different user groups. If not managed, this often results in conflict situations among user groups that pursue recreation activities that have different characteristics, as well as groups that use the resource professionally (i.e. hunters or foresters). Our study applied the choice experiment method to investigate the determinants of mountain biker trail choice, and how

Table 6
Average market shares (%) and compensating surplus estimates (€) predicted by the multinomial logit (MNL) and random parameters logit (RPL) models, before and after a change to the Hirschengarten (HG) trail. Predictions are split based on rider characteristics (see table footnotes).

Model	**MNL with interactions**					**RPL with interactions**				
	Market share (%) before change		Market share (%)after change		CS (€)	Market share (%) before change		Market share (%) after change		CS (€)
Rider type	HG old	Illegal	HG new	Illegal		HG old	Illegal	HG new	Illegal	
road rider[a]	37.48	62.52	47.76	52.24	2.60	34.13	65.86	43.59	56.41	1.48
raced-mtb[b]	9.81	90.19	43.52	56.48	31.79	5.02	94.98	38.52	61.48	29.00
not-raced-mtb[c]	11.37	88.63	43.89	56.11	29.19	6.50	93.50	39.43	60.57	26.02

[a] All riders who see themselves primarily as road riders.
[b] See themselves primarily as mountain bikers and have raced before.
[c] See themselves primarily as mountain bikers, have not raced before.

the characteristics of mountain bikers influence trail preference. We used these findings in a trail management simulation to calculate market share predictions and welfare effects (compensating surplus).

Among the previous studies on this topic, the one which comes closest to ours was published by Morey et al. (2002). While Morey et al.'s (2002) study was done twenty years ago and on a different continent, our overall findings are in line with this and other comparable studies. For example, the largest group of bikers consists of upper-income males (Morey et al., 2002; Reiter, & Blahna, 2011; Symmonds, Hammitt, & Quisenberry, 2000), which is also reflected in our sample. Similar to the findings by Symmonds et al. (2000), the mountain bikers in our sample see themselves to be rather skilled, look for challenges in their rides, and ride often. The technological progress is reflected in the number of riders with suspension on their bikes: two decades ago, only 40% of bikers rode such equipment (Morey et al., 2002), while in our study it was almost the entire sample. Unless the share of female riders is actually lower in Austria, it might be explained by the limited number of female riders using the internet forums we used to collect our sample. This explanation applies to all groups of riders which do not (regularly) use the mentioned internet forums and renders the sample used not representative for the local biker population.

With regard to preferences for trail attributes, our findings also correspond very well with Morey et al.'s results. It makes sense that quantitative trail attributes such as trail length or total vertical climb affect utility in a non-linear way, as the increased physical strain will lead to a negative marginal utility above a certain point. We followed Morey et al. (2002) in choosing a non-symmetrical functional form (i.e. the combination of a linear term and the square root) for the length attribute. This allows the calculation of the optimal trail length while keeping the levels of all other attributes fixed. The same can be done for the vertical climb attribute, which also enters the utility function non-linearly. The peaks attribute shows the same behavior as in Morey et al. (2002): just adding a peak without increasing the vertical climb (e.g. re-routing the trail to go across two low peaks instead of one high one) will decrease the utility gained from this trail. However, if the additional peak also adds vertical climb, the overall effect on utility will be positive (up to a certain point). The interactions of vertical climb and singletrack with rider experience make our model sensitive to rider skill, which has important management implications: if Stoeckl (2010) writes that riders go off designated trails to seek challenges, our model explains that the more experienced riders leave the designated trails in search of singletrack.

Accounting for heterogeneous trail preferences is important to understand the potential ecological impact of trail use by different rider types. For example, as the ecological impact of bikers who like steep downhill slopes is greater under wet conditions, these bikers might be targeted with information campaigns regarding their impact on soil and vegetation, and be offered alternative trails with similarly attractive features. On the other hand, bikers that see themselves primarily as road riders are likely to have a smaller impact on soil and vegetation, due to their relatively stronger preference for logging roads. The models proposed here allow identifying similarly attractive trails (i.e. those yielding the same utility level for the respective biker type), and linking preferences for ecologically harmful trail characteristics to socio-demographic characteristics. This in turn allows targeting the specific biker group with suitable information.

An interesting finding, and somewhat contrary to Morey et al. (2002), is that our sample does not mind as much sharing their trails with hikers. They are, however, reluctant to share their trails with equestrians. Recommendations for the design of shared trails are outlined in Cessford (2003). However, the sensitive issue of social conflict should be examined from all sides, in order to find the best policies to minimize conflict potential. Our findings thus suggest that, as mountain bikers would prefer separate trails for bikers and equestrians, zoning or some type of trail-designation should be implemented to minimize conflict between equestrians and bikers. To facilitate the common use of trails between hikers and mountain bikers, both should be targeted with information campaigns regarding mutual respect and courtesy. This might include, for example, educating bikers to slow down and make themselves noticeable to hikers, to reduce feelings of danger by hikers as outlined by Watson et al. (1991).

Apart from the differences mentioned above, our results stand in agreement with the findings by Morey et al. (2002) regarding the trail preferences of mountain bikers. While our compensating surplus estimates cannot be directly compared to Morey's, because of different model specifications and example trails, we can confirm his finding that riders who are more "involved" (more experience, racing, etc.) experience a greater compensating surplus from improvements in trail quality, regardless of model specification. This might, according to our estimates, make them likely to change their behavior if supplied with attractive alternatives to illegal trails.

The question now arises how these findings could be integrated into trail design and management. As was made clear from the estimated models, bikers have distinct preferences regarding the trails they ride. However, a manager might know only the preferences of those riders who are most active in communicating them. We propose that our model results should be integrated into the design of new trail networks, particularly in the early stages of planning. After using a simple survey to get to know the local biking community, these results can then be used to calibrate our model towards the needs of the local population. As we tried to keep our experiment as generic as possible, it should be applicable to a quite large range of geographical contexts, or at least serve as a basis for further investigations. Based on the resulting model, trail designs can easily be compared quantitatively with regard to their welfare effects. Moreover, the costs of trail building can be compared to the benefits in terms of (aggregated) compensating surplus. This, of course, would require aggregating the estimated benefits to the local biker population. It is important to mention that our model cannot capture every single local detail of a given (proposed) trail system, so local knowledge is still indispensible.

With regard to our research questions, we highlight five important features which should be considered when designing a new trail network: *First*, mountain bike trails should have substantial proportion of singletrack, in particular on down-hill sections, while uphill on logging roads seems to be okay for the majority of riders. However, as was mentioned in the introduction, specific attention should be paid to sensitive soil conditions to avoid unnecessary erosion, the development of ruts, and other degradation. *Second*, riders do not seem to be disturbed by hikers on trails, therefore, from the view of a biker, multi-use trails can be recommended, as long as there are no horses allowed. However, a successful management will have to include all forest users, and the types of conflict between the different user groups, in particular with equestrians, should be analyzed in detail depending on the local context. *Third*, when designing a new trail network, one should opt for a mix of longer and shorter trails according to the rider population at the location. *Fourth*, depending on the geographical features of the area, trails with lots of vertical climb should have multiple peaks. *Fifth*, for those who see themselves primarily as road riders, but go for a mountain bike ride now and then, logging roads should be provided.

The market share changes in our management simulation example suggest that, under the right conditions, making legal trails more interesting to mountain bikers may indeed relieve pressure of sensitive areas. In particular, hunters who want to protect wildlife breeding areas from pressure through mountain biking could use our model to evaluate whether mountain bikers would be likely to switch to alternatively offered trails. This could make trail closures and expensive trail monitoring operations less necessary. However, further research and case studies are required to see whether this management approach works in practice.

From a modeling perspective, all models have predicted the observed choices reasonably well. We confirm Train's (1998) findings of the MNL model being robust, and in our specification it even out-predicts the RPL model by a small amount. Including rider characteristics into the model makes it more flexible towards riders of different preferences, age, gender, or experience. This allows to gain a clearer insight into who gains and who loses from different management policies.

Some aspects of mountain biking were left to future research: For example, a biker might have different preferences whether he or she just goes for an after-work ride, or for a full (multi-) day tour during weekends or holidays. Also the influence of variety-seeking behavior as well as a possible overall increase in the number of bikers due to more attractive trails has not been addressed. A possible extension of this model would be to use the parameter estimates in an integer programming exercise when trying to maximize utility when designing a new trail network. Further, estimates could be used in agent based recreation models, combined with preference data from other user groups. An elicitation of the preferences of other forest users, such as land owners or hunters, would make it possible to design a model that accounts for interactions and trade-offs between these user groups.

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