Literature Review

Recreation Conflicts Focused on Emerging E-bike Technology

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Acknowledgments

E-bikes are still a nascent technology, and the research surrounding their use and acceptance within the recreation space is minimal. However, with the careful and constructive guidance of our consultants, the report outline morphed into chapters and, eventually, into a comprehensive document. We are deeply indebted to Mary Ann Bonnell, Morgan Lommele, and Stacey Schulte for guiding our thinking and research process and for supplementing our findings with resources and other support.

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Executive Summary

As a rapidly evolving hybrid technology, e-bikes are challenging the notions of traditional, passive, non-motorized recreation. The goal of this literature review is to inform policy discussions and decisions for the quickly growing e-bike market in four of Colorado's northern Front Range open space programs: Boulder County Parks & Open Space, City of Boulder Open Space and Mountain Parks, Larimer County Natural Resources Department, and City of Fort Collins.

A 2018 nationwide study of nearly 1,800 new e-bike owners found that older adults and those with physical limitations use e-bikes mostly for fitness and recreation, whereas younger adults tend to use e-bikes more heavily for utilitarian purposes, such as replacing car trips for commuting, errands and hauling cargo. The electric-assist makes it possible for more people to ride a bicycle and generates more and longer trips. Many users feel safer riding an e-bike because of their increased confidence in getting through a wide intersection or navigating more challenging terrain.

E-bikes offer positive outcomes for accessibility and inclusion, and many agencies allow them as "other power-driven mobility devices" (OPDMDs) under the Federal Americans with Disabilities Act (ADA) guidelines. Several studies have established positive health benefits of e-bike use, given that e-bikers ride more frequently and longer. E-bikes are particularly attractive to aging baby boomers.

Safety, speed, crowding, and user conflict are common concerns related to bicycles generally, and these concerns are heightened for e-bikes. Recreation conflict literature suggests that most conflict follows an asymmetrical pattern, and research on e-bikes shows that experience informs perceptions. Several studies show that trail users unfamiliar with e-bikes express a preference to not share the trail with them, but the majority did not notice that they were sharing the trail with e-bikes. Similarly, once trail users were exposed to e-bikes, concerns about them decrease for many.

Another negative in the recreation arena is a concern about technical abilities and riders on e-bikes exceeding their experience levels or needing rescue. Additionally, some recreational mountain bikers believe that e-bike riders should "earn" their ride. There is not much research on the impacts of e-bikes to physical trail conditions. The only study to date found that soil displacement resulting from eMTBs was not significantly different from mountain bikes, and both kinds of bikes cause significantly less damage than dirt bikes.

Ecologically, some evidence suggests that the impacts of e-bikes (erosion, noise pollution, effects on wildlife) are no different from conventional bikes, but e-bike batteries may exacerbate problems associated with battery production and disposal. On the positive side, although they emit more CO2 than conventional bikes, the potential emissions reduction from e-bikes could be significant if widely adopted and used for utilitarian purposes.

Many Colorado jurisdictions have acted to allow some or all classes of e-bikes, including the City of Boulder (certain multi-modal trails), Durango, Jefferson County, Eagle County, Summit County Rec Path, and Rio Grande Trail. Many other local jurisdictions allow e-bikes by default under the August 2017 change in state law. Colorado Parks and Wildlife allow e-bikes wherever conventional bikes are allowed. In August 2019 the Department of the Interior (DOI) issued a Secretarial Order directing all DOI lands (National Park Service, National Wildlife Refuge, Bureau of Land Management, and Bureau of Reclamation) to exempt e-bikes from the definition of motorized vehicles and allow e-bikes on all paths where conventional bikes are allowed. The Order provided agencies 30 days to develop proposals guiding implementation.

Chapter 1 - Introduction

Technology has the potential to act both within and outside the wilderness and outdoor recreation arenas. It cannot only shape our preferences with the natural world but also our expectations of how wilderness and recreation areas should be managed. As technology becomes more mainstream in outdoor spaces, general concerns over its integration fall into three categories: 1) the accelerating rate of technological innovations affecting outdoor recreation and their incorporation into the mass market; 2) the increasing amount of social impacts (conflict, crowding, and displacement) and environmental impacts (increased erosion and wildlife disturbance); and 3) the structure and cultural roles of parks and nature.

One realm of innovation changing outdoor recreation preferences is electric-assisted recreation modes, including e-bikes, e-scooters, and e-skateboards. Electric-assist bicycles are a small but rapidly growing segment of the U.S. bicycle market, not just in the realm of active transportation but as a substantial contributor to outdoor recreation preferences. The regulatory landscape for e-bikes is also evolving as land management agencies at all levels of government, from federal agencies to state and local jurisdictions and special districts, are working to develop policies to address this emerging hybrid technology. In August 2017, the HB1151 was enacted that updated the law that regulates the operation of bicycles in the state. Under the new law, e-bikes are no longer classified as motorized vehicles, and the definition is expanded to three classes. Class 1 and 2 e-bikes are allowed on bike or pedestrian paths where bikes are allowed unless local governments take action to prohibit them. Class 3 e-bikes are not permitted on bike or pedestrian trails unless local authorities take explicit action to allow them.

Definitions

E-bikes, also known as electric bicycles, power bikes, pedelecs, or booster bikes, are bicycles with an integrated electric motor that does not exceed 750 watts of power.

- Class 1: Low-speed pedal-assisted electric bicycle equipped with a motor that provides assistance only when the rider is pedaling and that ceases to provide assistance when the e-bike reaches 20 mph.
- Class 2: Low-speed throttle-assisted electric bicycle equipped with a throttle-actuated

motor that ceases to provide assistance when the e-bike reaches 20 mph.

- Class 3: Pedal-assisted electric bicycle equipped with a motor that provides assistance only when the rider is pedaling and that ceases to provide assistance when the e-bike reaches 28 mph. Note: class 3 e-bikes are prohibited on all open space trails.

Funding and Scope

This literature review was funded by four land management agencies in the north Front Range of Colorado. Three of these agencies are in the process of evaluating policies regarding e-bike use on their trails in the wake of the changed Colorado State law, and the fourth will take up the issue in the near future:

- Boulder County Parks & Open Space (BCPOS) began a one-year pilot on Jan. 1, 2019, allowing e-bikes on certain open space and regional trails located in the plains of the county. Research conducted during the pilot period will inform a policy recommendation for electric-assist bicycle use on Boulder County open space and regional trails.
- Larimer County Department of Natural Resources (LCDNR) took the opportunity to consider appropriate regulations associated with e-bikes as part of its update to departmental regulations in 2018. The decision was made by LCDNR to allow Class 1 and 2 e-bikes on paved trails (which include River Bluffs, Lions Park, and Long View open spaces). LCDNR does not currently allow motorized use on park and open space natural surface trails. LCDNR is in the process of collecting information on e-bikes via public outreach, which will include an online LCDNR survey, informal stakeholder meetings, and discussions with the department's two advisory boards to evaluate whether or not these policies should change.
- City of Fort Collins City Council started a one-year pilot program in May 2019 to allow Class 1 and Class 2 e-bikes on **paved** trails (currently prohibited except for users with a temporary or permanent disability). Prior to and during the pilot program, Fort Collins will conduct extensive education and evaluation to help inform future e-bike regulations.
- Although the City of Boulder has allowed e-bikes on its multi-use paths since 2013 following a pilot study, e-bikes are not allowed on the city's open space and mountain park trails. The city plans to take up a review of this policy in the near future.

The purpose of the literature review is to gain a better understanding of the demographics and use patterns of e-bike riders in the recreation sphere and to learn about positive and negative issues surrounding their use, from a visitor use perspective, as well as impacts to trails and natural resources. Another goal is to discover how other jurisdictions are addressing these issues.

Because e-bikes are a relatively new technology with limited research results to draw from, the scope of this literature review includes research on the broader topic of recreation conflict to uncover how this research might inform discussion about e-bike policies.

The scope of this research was confined to publicly available, peer-reviewed documents, with the exceptions of articles within the *Journal of Leisure Research*, from the University of Colorado (CU) Boulder Norlin Library. This review drew upon literature from multiple research disciplines and numerous countries and regions, including China, Australia, Europe, Canada, and the United States.

Chapter 2 - Theoretical Frameworks for Recreation Conflict

This chapter explores the concept of recreation conflict, how conflict arises in outdoor experiences, and the user types associated with specific conflicts. Anecdotal findings often confuse the symptoms of conflict, such as vandalism and arguments, as the cause of conflict, yet the studies in this chapter found that conflict is as complex and diverse as recreation activity itself. Conflict can occur as goal interference (interpersonal conflict) or because of differences in social values and norms (social values conflict). In general, conflict originates through four interactions: activity style, resource specificity, mode of experience, and tolerance for diverse activities. Through an investigation of these interactions, this literature review will provide insight for identifying outdoor recreation management strategies related to emerging technology, specifically e-bikes, in Boulder County.

a. Evolution of Recreation Conflict Research

Recreation conflict has been a challenging topic for recreation managers since the 1970s. Early research defined conflict using the *discrepancy theory*, which states that dissatisfaction results from a difference between actualized and desired goals. In other words, conflict is an individual's dissatisfaction caused by the interaction of another individual's behavior [1]. In the 1980s, researchers measured conflict using the *goal interference model*, which states that conflict originates from the interference or interruption of goals among different types of users and assumes that users recreate to achieve specific goals or outcomes [2]. By the 1990s, however, the *social values conflict* model became the preferred method for understanding conflict, stating that conflict arises among user groups who do not share similar norms or values. As a result, contemporary research explores the relationship between goal interference and social values conflict as direct contributors to recreation conflict [3].

Because of its abstract nature, recreation conflict is viewed through two lenses: asymmetrical, in which conflict is felt by one user but not the other, and symmetrical, where both users experience conflict from the presence of each other. Studies identified in this chapter focus on both types of conflict and are primarily based on multi-use trail users, including hikers, equestrians, mountain bikers, commuting cyclists, e-bike riders, 4-wheel drive users, all-terrain vehicle users, and snowmobilers.

The term "multi-use trail" is defined as any trail that can accommodate multiple users; however, single-use trails are considered as well, as they accommodate several types of activities. Other types of recreation are mentioned in this chapter to discuss the conflict that can arise between motorized and non-motorized recreation activities such as anglers, oar-powered boaters, river rafters, and motorboaters. Table 2.1 provides a list of research associated with recreation conflict.

Table 2.1 Studies on Recreation Conflict

Author	Topic
Discrepancy Theory	
Knopp & Tyger, 1973	Cross-country skiers & snowmobilers
Stankey, 1973	Backpackers & horse packers
Fishbein & Ajzen, 1975	Belief, attitude, intention & behavior
Lime, 1975	Paddling canoeists & motorboats
McCay & Moeller, 1976	Compatibility of Ohio trail users
Nielsen & Shelby, 1977	River-running in the Grand Canyon
Schreyer & Nielsen, 1978	Whitewater river recreation
Goal Interference Theory	
Jacob & Schreyer, 1980	Goal Interference Theory
Shelby, 1980	Motors and oars in the Grand Canyon
Gramann & Burdge, 1981	Effect of recreational goal on conflict perceptions
Adelman, Heberlein, & Bonnicksen, 1982	Paddling canoeists & motorboats
Jackson & Wong, 1982	Cross-country skiers & snowmobilers
Social Values Conflict	
Whittaker, Anderson, & Mosby, 1990	Oar-powered & motor-powered whitewater rafters
Kuss, Graefe, & Vaske, 1990	Visitor impact management
Watson et al., 1991	Hikers & mountain bikers
Watson et al., 1994	Hikers & stock users
Vaske et al., 1995	Interpersonal versus social values conflict
Ramthun, 1995	Hikers & mountain bikers
Vaske et al., 2000	Recreation conflict among skiers and snowboarders

b. Origins of conflict

Interpersonal (Goal Interference) Conflict

Interpersonal conflict is defined as the interference of goals based on the behavior of two or more user groups. For a conflict to arise, the two groups involved must have direct or indirect social interaction. For example, a hiker may experience interpersonal conflict if a fast-moving mountain biker is attempting to pass [4]. This type of conflict is often asymmetrical, such that the hiker may experience conflict with the mountain biker, but the reverse is not the case. This one-way pattern has been described in studies on water recreation activities as well. Paddling canoeists in the Boundary Waters Canoe Area in Minnesota disliked seeing motorboat users; however, the people using a motorboat enjoyed seeing and interacting with the canoeists [5].

Interpersonal conflict has also been observed in other forms of outdoor recreation, including hikers and equestrians [6], oar-powered rafters, and motor-powered rafters [7], as well as cross-country skiers and snowmobilers [8]. In general, these studies have shown that recreationists who say they have experienced a negative interaction, either from a disruption in their intended activity or negative behavior from other user groups, tend to dislike the opposing activity or recreationists. Although the interpersonal concept is highly generalizable across recreation activities, it does not explain how conflict originates in the absence of contact among user groups.

Social Values Conflict

Conflicts are known to occur among different trail users and users within the same group, yet they can also occur as a result of factors unrelated to user activities altogether. Behavior and attitudes toward other forms of recreation present a source of conflict associated with differing norms or values, often referred to as social values conflict [9]. A study of interactions between llama packers and backcountry hikers in Yellowstone National Park, for example, found that despite low interaction numbers (fewer than 30% user encounters), 56% of backpackers expressed disagreement with the appropriateness of allowing llamas in the area [10]. Similar conclusions were found in a study between hikers and mountain bikers in the Rattle Snake National Recreation Area near Missoula, Mont. Roughly two-thirds of the hikers surveyed had not encountered a mountain biker but objected to their presence on the trail [11]. In both of these situations, a difference in social values resulted in conflict even though the groups had little to no interaction. Unlike the interpersonal conflict theory, social values conflict focuses on an individual's perception of a situation, thus creating a conflict in the absence of direct interaction between users.

Although these studies consistently confirm the presence of interpersonal and social values conflict, the procedures used to operationalize and manage social values conflicts are not conceptually explicit. In their study, Vaske et al. operationalize the social values conflict in two ways: 1) people who do not witness a behavior but believe it to be a problem, and 2) assessing the responses of people who express an interpersonal conflict just knowing that other user groups are in the area. With the first method, problems arise because it is unclear whether people have a problem with a specific behavior or merely a difference in social values. A hiker, for instance, may avoid a particular area because he/she knows that mountain bikers are allowed to ride there. This response could have been received through second-hand knowledge or from direct interaction with a mountain biker at an earlier date. In this case, there is no guarantee that the reported problem represents a social values conflict, as it may be a result of something the respondents have heard, rather than firsthand knowledge. The issue with the second operationalization method is that it is difficult to measure social values on different subgroups. Some groups are classified based on observations or evaluations of behaviors, while others base their responses on previously learned information.

Merging Expectancy and Discrepancy Theory

Initial theoretical models for understanding recreation conflict focus on the origins of why conflict arises among user groups and how trail managers can resolve these issues [12]. In this model and previously in the chapter, conflict is defined as the interference of goals as related to another's behavior. This definition is primarily based on both the expectancy theory, in which behavior is seen as goal-orientated, and the discrepancy theory, where satisfaction is determined by the level of desired and achieved goals. Within this context, conflict is seen as a unique attribute of the discrepancy theory, where dissatisfaction is caused by the interaction or perception of two or more opposing goals.

Jacob and Schreyer suggest that conflict is linked to four significant factors:

1. *Activity style*: the personal meaning associated with a recreation activity, which may include the intensity of participation, equipment status, range of experience, and definition of quality.
2. *Resource specificity*: the significance accredited to the type and quality of resources used in the activity. For many users, this difference may invoke a sense of possession and status based on the knowledge and expertise of the resource used.
3. *Mode of experience*: the varying expectations placed on how users should perceive and interact in the environment.
4. *Tolerance of diverse activities*: whether a user will accept or reject a lifestyle different from his/her own, which may result from differences in technology, attitudes, perceptions about the environment, resource consumption types, and social prejudices.

From these four factors, Jacob and Schreyer generated a list of 10 propositions that suggest the conditions most likely to cause recreational conflict (Table 2.2). According to their findings, conflict is not purely objective but rather an interpretation of the experience, beliefs, and attitudes of a particular activity, whether or not physical interaction has taken place.

Table 2.2 Propositions of Conflict [13]
1. The more intense the activity style, the higher the likelihood of social interaction with less intense participants will result in conflict.
2. When the private activity style confronts the status-conscious activity style, conflict results because the private activity style's disregard for status symbols negates the relevance of the other participant's status hierarchy.
3. Status-based interactivity conflict occurs when a participant desiring high status must interact with another viewed as lower status.
4. Conflict occurs between participants who do not share the same status hierarchies.
5. The more specific the expectations of what constitutes a quality experience, the higher the potential for conflict.
6. When a person who views the place's qualities as unequaled confronts behaviors indicating a low evaluation, conflict results.
7. Conflict results when users with a possessive attitude toward the resource confront users perceived as disrupting traditional uses and behavioral norms.
8. Conflict occurs for high-status users when they must interact with the lower states users who symbolize devaluation of a heretofore exclusive, intimate relationship with the place.
9. When a person in the focused mode interacts with a person in the unfocused mode, conflict results.
10. If group differences are evaluated as undesirable or a potential threat to recreation goals, conflict results when members of these two groups confront one another.

c. Experience, Specialization, and Recreational Conflict

The propositions of conflict listed above (Table 3.2) and the discussion of social values and discrepancy theory as origins of conflict highlight interactions between users with different motivations, values, and goals. The following section will further explore differences between users by examining the impacts of experience and specialization on recreational conflict.

Definitions and Measurements of Experience

Under its most basic definition, recreation experience is the amount of time or frequency of participation that an individual spends doing a specific recreation activity. Commensurate with higher degrees of participation, the experience is divided into three levels of expertise (novice, experienced, and expert) determined by the amount of knowledge an individual maintains about an activity [14]. These categories exist along a spectrum and are inherently subjective, highlighting the rationale used by many researchers for attempting to give standardized values to different levels of experience.

Some studies measured experience only, for example, asking respondents to estimate their frequency of participation for a specific activity [15], while others have measured experience as a potential determinant of "recreation-related attitudes, preferences, and behavior" [16] by employing multi-dimensional indices of experience [17]. Such research led to a generally acknowledged belief that levels of experience and their associated differences in knowledge may determine the attitudes, behaviors, and preferences of individuals [18], thereby indicating significant discrepancies among participants of the same activity. These discrepancies and their effects will be discussed in the following section.

Dimensions of Experience

Empirical research relating specialization and experience have primarily included studies of water-based recreation, such as river-floating and non-motorized boating. This research found that experience dictates whether an individual chooses to participate in private vs. commercial recreation opportunities: i.e., more experienced individuals were less likely to be on a commercial trip than a novice [19]. This finding suggests that those with lower levels of experience may not have the equipment or knowledge-base to engage in the activity without professional assistance. A study of backpacker motivations in the Great Smoky Mountains National Park found that more experienced users rated their motivation for seeking solitude as higher than non-experienced users [20]. More experienced users also expressed greater awareness of ecological disturbances and support for management than non-experienced users [21].

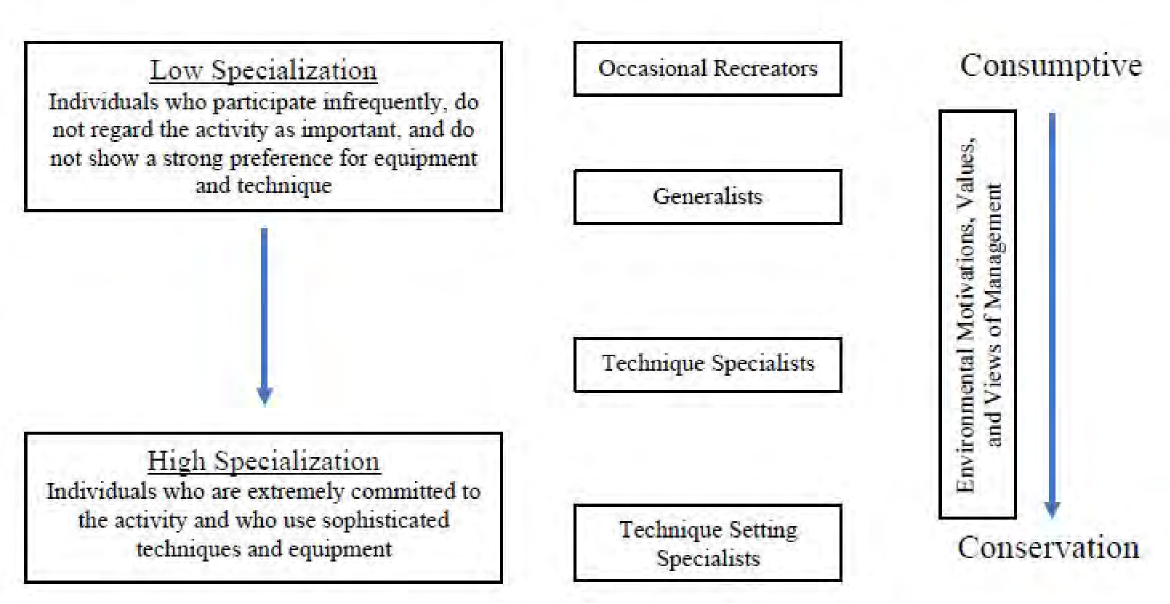
While several studies confirm that experience influences an individual's attitude, a laboratory study examining the relationship between experience and wilderness preferences found that both high-level and low-level experience respondents had similar attitudes about wilderness areas. The study also found that higher levels of experience corresponded with a "cognitive distinction among wilderness attributes" and a broader judgment about the acceptable state of place settings [22]. In other words, this study contradicts the previous findings by stating that experience has a marginal influence on place attachment. Such contrasting results highlight the complexity of measuring and interpreting the effects of recreation experience. In light of this complexity, other research has emerged that seeks to categorize specialization and the behavioral aspects of the experience.

Specialization: Origins of the concept

Specialization research began with the work of Bryan (1977), whose primary goal was to provide "a concept for understanding and investigating diversity among outdoor recreationists engaged in the same activity.[23]" Specialization is not just a measure of involvement intensity, but a developmental process in which participants progress to higher stages of involvement as their length of activity participation increases. Several other researchers acknowledged and supported this belief in their research [24], finding that specialization is associated with performing the activity itself rather than obtaining a goal.

Bryan expanded on this definition, stating that recreational specialization is "a continuum of behavior from the general to the particular, reflected by equipment and skills used in the sport, and activity setting preferences" [25] (see Figure 2.1). With each progressive stage, an individual's motivations, values, views of management (from consumptive to conservation-focused), and setting preferences are subject to change. In this way, specialization is a product of behavior (length and degree of involvement), and attitudes and values (i.e., centrality to one's identity), and can be measured as such [26].

Figure 2.1: Continuum of Specialization Behavior (Bryan 1977, p. 323)



Specialization as a Progression

Scott and Shafer (2001) define specialization as a progression in three steps:

1. Focusing behavior: an individual will focus on one activity at the expense of other activities because of time and economic constraints.
2. Acquiring skills and knowledge: increased participation equates to decreased dependence on equipment.
3. A tendency to become committed to the activity, such that it becomes a central life interest: an individual will develop a strong behavioral and personal commitment to an activity, so much so that the activity becomes a central life activity, thereby defining his/her lifestyle, personal identity, and social networks.

Once the activity becomes a central life interest, it can further dictate familial and career decisions, allowing the individual to spend the maximum amount of time involved in the activity, either through proximity to recreation access, schedule flexibility, or on-the-job skill-building.

Personal investment can also include monetary expenditures, most often through the purchasing of activity-specific equipment [27]. Scott and Shafer also note that progressing to high levels of specialization may induce social, physical, or temporal sacrifices [28]. They propose this specialization is why many people choose to be generalists and participate in a wide range of recreation activities, thereby straddling multiple social and physical demands but presumably, enjoying the benefits of each.

The notion that increased specialization develops into a central life activity raised the question of how this progression affects costs or benefits. A study of bird watching and specialization found that the benefits of specialization outweigh the costs, especially in regards to the presence of "enduring benefits" or the social, physical, and emotional benefits experienced independently of time spent recreating [29]. Furthermore, individuals who display a behavioral and personal commitment to an activity, but do not have high levels of skill or knowledge, still experience the same enduring benefits of the activity, which explains why individuals self-segregate based on their recreation interests and specialization. As individuals become more specialized over time, they experience the benefits of their activity, even if they never reach the elite levels that their peers do, likely reinforcing the tendency for their sport to become a central life activity.

The finding that specialization is proportional to the participation and commitment was corroborated by a study of anglers [30]. Findings suggest that high specialization anglers attached less importance to activity-specific experiences and more to non-activity-specific. Activity-specific experiences are associated with the mechanics of the activity itself, while non-activity-specific experiences describe attributes that surround the activity, usually in relation to the place setting. For example, as anglers become more specialized, they become less focused on the catch itself (activity-specific) and more focused on their experience on the water (non-activity-specific). In other words, building more confidence and specialization in a particular activity may alter the motivation for doing said activity.

This activity preference was also found to be associated with place attachments. Another study of anglers found that over time, highly dedicated or skilled anglers who are satisfied with the activity-specific elements are more likely to seek non-activity specific outcomes and acquire a secure connection to a place. Explicitly, in terms of place identity, over time (and with an increase in specialization), an angler equates a fishing site to a significant place in his/her life [31].

This research suggests that experience within an activity and access to the recreation activity significantly influences feelings of respect and adoration for specific place settings. The implications of this finding and others are discussed in the following section.

Implications for recreational management

From a management perspective, the relationship between specialization and place attachment is particularly compelling, especially when considering conservation practices. Using a comparison of willingness to pay (WTP), recreation specialization, and management support, Oh and Ditton found WTP positively affects recreation specialization and correlates to the "management support construct" (catch-related and general fishing regulations). The study also found consumptive orientation (the drive to fish with the motivation of catching and keeping fish) to be negatively correlated with WTP. Since WTP was used as a measure of awareness of environmental issues, the authors theorized that those with higher levels of specialization are more willing to support conservation efforts, while those with more consumptive orientations were less likely to support management they perceived to be “micromanaging.” Given that this finding came from a study of anglers, its carryover to non-consumptive forms of recreation such as hiking, biking, and viewing wildlife is not necessarily clear-cut. However, the connection between high levels of specialization and high levels of management does suggest that management planning for high-use areas should consider the specialization of its visitors.

Given that specialization is seen as a progression of skills and knowledge, personal and behavioral commitments, and increased place attachment and conservation support, the question remains whether users across the spectrum of specialization create specific challenges for recreation management. A study of mountain bikers in North Carolina found that the level of specialization was significantly related to trail attributes and that as specialization increased, the desire for more challenging and varied terrain increases. The study also found that mountain bikers across the specialization spectrum prefer to bike in natural/remote settings [32], highlighting the importance of trail design and accessibility for recreationists across the specialization spectrum.

d. Specialization and Conflict: Anecdotal Findings

This chapter would not be complete without exploring how advances in recreation technology have affected specialization, experience, and outdoor conflict. Innovations in material, function, and design have undoubtedly changed how people use recreation equipment and access the wilderness landscape. Although these advances might inspire some people to explore the outdoors, technology has also prompted conflict between users for various reasons.

A study of reservoir visitors in Oregon, for instance, found that motorized and non-motorized use prompted a symmetrical conflict, meaning that each party disliked the presence of the other. Distinct clustering between the user types and specialization was also noted, whereas both groups (motorized and non-motorized with both skilled and novice users) were adamant about floating near similar users and skill types. This study suggests a within-cluster similarity to the extent that recreationalists seemed desensitized to the obtrusiveness of individuals within their cluster [33]. In other words, technology creates both an internal division within recreation groups and an external division between user types. (This section is abbreviated to include articles relevant to recreation conflict. To read more about technology and its impact on recreation, consult Chapter 5: Emerging Technology and Outdoor Recreation).

Anecdotally, online and intercept surveys conducted during Boulder County's pilot study revealed that cyclists with high levels of experience (i.e., pro-cyclist) are opposed to sharing the trail with e-bikes. The most common dispute is that e-bikes provide an unfair advantage for less experienced riders who have not "earned their stripes" in the cycling world. Many online survey respondents significantly disliked e-bike use on trails because they believed less skilled riders would ride too fast and cause accidents. One respondent, in particular, sums up the general negative disposition toward e-bike users.

> *"During my commute to work, I am frequently passed on uphill by bikes going insanely fast. As in class 3 speeds. On flats, same deal. I can easily go 20-23 mph on flats, and these bikes pass me like I'm almost standing still…An accident caused by the faster moving and inevitably less skilled 20 something e-bike riders would be unavoidable. It is always the young 20-30 something riding the e-bike like a maniac." - Dawne Dem, 6/26/2019, Broomfield*

Overall, findings throughout this section suggest that experience and specialization can significantly affect an individual's attitude and preference toward other users and how recreation spaces should be managed. Individuals with high levels of experience attach greater importance to activity-specific experiences, thus creating strong place-attachment characteristics.

e. Conclusion

Throughout this chapter, many variations on the origins of recreation conflict have been discussed, including interpersonal versus social values, asymmetrical versus symmetrical, and experience versus specialization. Interpersonal conflict occurs when an individual's activity interferes with the goals of another. A social values conflict arises out of a difference in norms or values between two parties, such as feelings toward environmental stewardship. Both types of conflict can have a symmetrical relationship, where each party feels equally put off by the other; however, most studies suggest that conflict follows an asymmetrical pattern. This pattern is also evident in studies on experience and specialization, where varying levels of expertise result in an asymmetrical pattern of conflict. Individuals with less experience in one activity showed more significant levels of aversion toward individuals in another activity, such as novice hikers and mountain bikers. Social values theory suggests that inexperience equates to reduced levels of self-identification with the activity, whereas novice individuals feel less comfortable interacting with other users. On the other side of the spectrum, a conflict between "expert" users tends to follow a symmetrical pattern, where highly skilled individuals believe their activity or social values outweigh other users or activities. From a management perspective, the connection between a high level of specialization and conflict suggests that managers should consider the specialization of its users when planning outdoor recreation areas. Higher skilled users require more specialized recreation features, such as technical mountain bike trail designs or white-water rafting areas, and should be separated from lower-skilled areas to accommodate all levels of experience.

Chapter 3: Cultural Influences on Recreation

The "not in my backyard," or NIMBY, phenomenon is an influential grassroots social force organized in response to proposed changes such as new developments or management shifts in the outdoor recreation space. In this chapter, the connection between NIMBYism, place attachment, and recreation are explored in an attempt to understand further the best practices for land managers seeking to alter lands under their jurisdiction. In addition, the well-developed mobility culture of several countries and regions is examined as a means to explore the proliferation of e-bikes. Each of these cultural influences suggests that both the commuting and recreation landscape of a country or region is a direct reflection of its culture and underlying values. To further this finding, we suggest continued research examining the market share and use of e-bikes for recreation across demographics and regions in the United States.

a. Place attachment and NIMBYism

NIMBY describes negative attitudes toward proposed development or change [34], often stemming from an attachment to a place. The range of responses to such proposals can include public displays of discontentment, such as sit-ins, protests, and organized protests. These reactions have occurred in response to proposed additions and/or changes to a wide variety of proposed development that could pose environmental, social, or health impacts [35].

In practice, NIMBYism is a powerful social force that can determine the success of a proposed development or management change. Part of this power derives from the social-environmental phenomenon associated with the NIMBY mentality, including place attachment, identity, and disruption;

- Place attachment is defined as both the process of attaching oneself to a place and the product of this attachment [36].
- Place identity refers to the ways in which the physical and symbolic attributes of specific locations contribute to an individual's sense of self or identity [37].
- Place disruption can be perceived as a threat or potential disruption to place identity

or attachment. Such change can result in emotional loss or psychological trauma, as these disruptions affect both the physical places themselves and the social networks on which communities rely [38].

Place attachment can predict recreation experience preferences, which imply that an individual's attachment to a setting may influence his/her motivations of visitation and use. Furthermore, significant places can be a landscape in which social relationships are nurtured, prompting users to become more knowledgeable about the area and to seek solitude or personal growth [39].

NIMBYism opposition is either a product of proximity, principle, or ignorance [40]. For instance, an individual may support the development of wind farms to reduce carbon emissions but be opposed to having them visible from his/her house. This is a form of spatial discrimination and opposition determined by proximity. Examples of principle as a determinant of opposition include individuals who hold a NIMBY mentality." NIMBYism has also been conceived as a product of self-interest or ignorance and the so-called "information deficit," [41] in which the public is perceived to be ignorant of environmental science and irrational in response to perceived risks. Subsequent education and engagement are often deemed necessary to convert the public to a more "objective view." However, this view ignores the fact that many opponents of proposed projects or changes are highly educated and well-informed [42].

NIMBY research often focuses on public perceptions of renewable energy developments. In a study of a proposed hydro development, place attachment was shown to explain differences in attitudes more than social demographics, finding a negative relationship between attachment and support of the project [43]. Research also shows that the type of attachment (social vs. physical) matters, with those who believe a place to be of social importance less likely to oppose development than those whose attachment is based on the physical properties of a specific environment [44]. According to this research, the most effective public engagement strategy should include a discourse that considers social psychology instead of discounting the emotional response of opponents. This engagement should be "mindful of the symbolic, emotional, and evaluative aspects of place attachments and place identities" [45] (p. 437).

In many cases, however, public engagement does not always exclusively include the residents of a community, as there are often visitors to the area. Hence, this issue becomes more complicated when factoring in the effects of tourism. NIMBYism can increase with an associated increase in the actual or perceived amount of tourism. This effect rests upon the amount of interaction that the residents of host communities have with tourists and the perceived difference between benefits and costs of tourism, including economic benefits countered by crowding and environmental impacts [46].

Neighborhood open space areas are a conduit for place attachment and NIMBYism. Such spaces can provide residents with recreational and aesthetic values and a variety of deeper nature-based psychophysiological and spiritual values [47]. A study comparing local greenway trails in Chicago to regional trails on the fringe of the city found local greenway trails to be used by those living less than a mile from the location and often under their own power. These users were more likely to be loyal to the trail and not view other trails as substitutes for their experience. They were also more likely to use the trails for commuting (if possible).

Regarding regional greenway trails, users often drove to the trailhead, took longer trips, and were more likely to be first time users. The implications of this study are threefold;

- First, this study highlights the importance of developing trails in close proximity to neighborhoods in order to accommodate the recreation and commuting needs of its most frequent users.
- Secondly, regional trails in close proximity to diverse neighborhoods provide access to people across demographics [48].
- Finally, each of these findings also suggests such an intense feeling of place attachment may impart NIMBY reactions if neighborhood communities believe that their beloved spaces are threatened by change or development.

NIMBYism Implications for Recreation

As discussed earlier, place attachment can affect the motivations of use and visitation [49]. This notion suggests that the physical or social characteristics of the trail can determine its use. In addition, since place attachment and NIMBYism are closely related, it can be inferred that the physical and social characteristics of a place may inform the degree to which an individual feels compelled to his/her cherished values and resist change [50]. In many land-use cases, the primary opponents are local landowners who oppose the development for various reasons. In the case of less tangible changes, such as regulations for land use areas, the opponents are often trail users themselves. On one side, users may be wary of changes to their prized recreation area; while on the other side, people are ready to support changes in accordance with shifting needs and demands. This connection should be further explored as land managers attempt to answer whether specific trails with designated characteristics determine local opposition to change. With such knowledge, land managers could better plan for local opposition to change in areas under their jurisdiction.

In this section, the concept of NIMBYism and its role in curtailing or altering management decisions in recreation were explored. The next section will explore another cultural force by examining the mobility culture in the United States, Europe, and China as they relate to shifting transportation and recreation trends.

b. Cultural Influence on Mobility Culture in Europe, China, and the United States

Mobility Culture in Europe

The differences in mobility cultures among western nations have deep roots. Though the prominence of cycling culture differs among European countries, taken as a unit, their use is more widespread than in the United States, Canada, Australia, and Britain [51]. Nordic countries lead the pack when comparing a city's mobility share (or the percentage of bicyclists out of the entire transportation sector) with the cities of Copenhagen and Amsterdam exhibiting 35% and 32 % cycling modal share in 2010 and 2012 respectively [52]. The Dutch and the Danish are at least partially responsible for the so-called democratization of cycling. During the 1920s, the bicycle became a national symbol of The Netherlands, in part because of the agreeable geographical conditions of the country. The country has little elevation change and relatively undeveloped cities and has promoted the egalitarian identity of the sport within the national imagination. This adoption was a result of a concerted effort by several Dutch cycling organizations and by government policies. This identity was strengthened in the WWII era; and although there was a brief re-emergence of car-dependence in the 1970s, modern-day Denmark and The Netherlands more closely resemble the culture of the 20th century. The result is a robust multi-modal mobility culture that prioritizes and enables safe cycling through a diverse set of policies and cultural norms [53].

A study by U.S. transportation experts documented the conditions that support such a robust mobility culture [54]. The countries visited—Denmark, Sweden, Germany, United Kingdom, and Switzerland—each exhibited numerous factors that contribute to higher rates of pedestrian and cycling safety, including:

- Integration of transportation and land-use policy
- Transportation planning and design policies that are mode neutral or give preference to vulnerable road users (bicyclists and pedestrians)
- Political support at all levels: elected officials, government staff, and the public
- High costs of owning a vehicle (sales tax, annual registration fees, gas, parking, and other fines)
- A comprehensive, continuous, integrated approach to promote higher levels of walking and bicycling

This integrated approach to cycling includes the widespread availability of public transportation, highly connected and accessible on- and off-street bicycling networks, traffic safety education for school children that includes both knowledge and skill-based learning, routine photo enforcement to mitigate speed and traffic signal risks, and the prohibition of preferential treatment for cars, such as no right-turn-on-red intersections [55]. The study also found many of the foreign hosts to have an established "urban street user hierarchy," giving preference to walking, biking, and public transit. This hierarchy supports several public policy goals, including livability, public health, sustainability, climate change mitigation, congestion reduction. The hierarchy also dictates the course of transportation planning, design, operations, and maintenance. Street designs under this planning process consider the needs of pedestrians and cyclists over the needs of drivers. At the core of the planning mentality is the notion of "safety in numbers"—the idea that when pedestrians are the most common urban-street user, motorists will take precautions and drive with prudence because of the guaranteed presence of pedestrians. This notion reduces conflict points and improves safety for all road users, thereby instituting a culture that promotes multi-modal transportation [56].

Mobility Culture in the United States

While cycling in Europe has thrived since the industrial revolution, in the United States, cycling did not take root until the post-war era of the 1950s [57]. During this time, cycling increased in popularity, helped by tourist bicycle organizations that helped the sport's transition from its competitive nature into the broader community-driven realm of outdoor recreation [58]. Jensen's theoretical framework for studying different mobility practices suggests that these differences reflect different cultures, arguing that such cultures are more than just the result of planning and infrastructure but from the inner workings of culture and experience within a city. Jensen's model suggests that the bike as a recreation, rather than commuting tool, is a reflection of American culture [59].

In contrast to The Netherlands and Denmark, in the United States (and in other western nations), the private car dominates the political, social, and infrastructure landscape. In effect, the sheer number of cars and their overwhelming comparative speed have forced cyclists off the road [60]. According to the 2017 American Community Survey, 76.4% of the 148 million Americans age 16 or older drove to work alone while only 2.7% walked, and 1.8% traveled by other means [61]. Bicycle-friendly policies, if they exist at all, are not broadly supported and fail to incentivize individuals who might otherwise be willing to cycle instead of drive. In terms of infrastructure, reported travel time and type of infrastructure are the most critical factors in determining route choice. Specifically, bicycling facilities segregated from traffic are favored by cyclists [62]. Socially, cycling is still largely pigeon-holed into the realm of outdoor recreation and exercise. It is more closely associated with a childhood pastime, younger men, yuppie culture, or, conversely, with poverty and or low social status. In the United States there is a relatively small contingent of dedicated cyclists, each of which is intimately familiar with the prevalence of adverse bicycling conditions and often adheres to an alternative lifestyle categorized by a rebellion against the dominant-SOV/economic culture [63].

In comparison to U.S. cities, cycling is more prevalent in Canadian cities. Even when controlling for population differences, the share of cycling is about three times higher in Canadian than in American metropolitan areas. This statistic may sound counterintuitive given the significant difference in climate between Canada and the United States; however, this result is caused by several convergent factors. Canada maintains higher urban densities and mixed-use development, shorter trip distances, lower incomes, higher costs of owning, driving and parking a car, safer cycling conditions, and more extensive cycling infrastructure and training programs [64]. These differences result from different land-use and transportation planning policies between the two nations and not from "intrinsic differences in history, culture or resource availability" (p. 265), which is likely the cause between Europe and the United States.

The result of this mobility culture is evident in nearly every major U.S. city. The car dominates while the bicycle and pedestrian are left fighting for space. The next section will explore the effects of this infrastructural and cultural landscape with regard to e-bikes.

E-biking in Europe and the United States

Taking advantage of the existing physical and cultural infrastructure for conventional cycling, e-biking popularity is soaring in Europe. According to a Bosch market study conducted in 2016, there were 1.6 million e-bike sales across Europe, an increase of more than 22% from 2015 [65]. The momentum for this market continues to increase as e-bikes continue to account for more significant percentages of market share with each reporting quarter. Table 3.1 illustrates this market share growth.

Table 3.1 2018 E-bike Market Share in Several European Countries [66]

Country	E-bike Market Share (%)
Austria	33
Belgium	50
Denmark	10
France	40
Germany	25
Netherlands	>50
Spain	11

There were early signs for this boom in popularity. A 2015 survey conducted in Norway found that when given access to an e-bike in exchange for their car--a so-called “bike for keys swap”--people increased their average number of biking trips and average distance per day when compared to a control group. In addition, biking as a share of total transport increased locally from 28% to 48%. In comparison, the control group of conventional cyclists did not see an increase in the amount of cycling frequency, distance, or transport share. Finally, e-bike usage increased with time, especially for women [67]. This finding was echoed by a study of university students in The Netherlands that found a high-potential for e-bikes to be used by younger generations and as a substitute for public transportation use. However, the study also found the high price of e-bikes to be a limiting factor, as the price tag diminishes their competitiveness in comparison to conventional cycling and public transportation [68].

E-MTBs in Europe and the United States

The acceptance of e-bikes extends into the European electric mountain bike (eMTB) community, as well. The differences between the United States and Europe regarding eMTB acceptance start with recreation expectations stemming from higher development density in Europe and less of the "rugged individualism" found in the American West. This breeds a different outdoor ethic in which greater emphasis is placed on participation and recreation rather than a non-motorized, solitude-oriented ethos. Reportedly, e-bike interactions involve less of a pejorative "you're cheating" attitude and more of a "good for you for being out here and riding" perspective. The omnipresent tourism infrastructure of Europe also allows for more investment in outdoor participation in general, but specifically in e-bikes as the newest avenue for revenue generation.

Tourism companies in the Alps are more inclined to accept e-bikes into their establishments since their trails are characteristically steeper and more technical than those in North America; thus, the allowance of e-bikes opens the door to more riders[69]. In addition, eMTB riders and regular MTB riders do not differ in their motivations to cycle, suggesting that the sport attracts similarly minded individuals [70]. In effect, MTB tourist destinations are merely expanding their infrastructure by providing charging stations for e-bikes on the trail, creating e-bike specific routes that cater to different experience levels, and hosting eMTB races. It is important to note that these destinations are not trying to dissuade or heavily regulate eMTB's; instead, their goal is to attract these visitors in order to tap into this rapidly expanding market. This practice is in contrast to land managers interested in providing the best recreation experience for all their users [71].

E-biking in China

Similar to the explosive growth of Europe, the Peoples Republic of China saw a boom of e-bike sales beginning in the late ’90s that has lasted well into the current era. Annual sales in 1990 totaled around 40,000 and grew to 10 million in 2005. As of 2013, this number had increased to 150 million [72]. This rapid increase in popularity occurred well before other international growth. This was due in part because of their status as a low-cost and convenient means of private transportation for the average consumer, coupled with the promotion of e-bikes by local and national governments due to their low emissions, a vital consideration in the highly congested and polluted urban areas within the country [73]. Despite e-bikes' popularity, however, the rise of the private vehicle has countered the dominance of the e-bike. The increase in car ownership is primarily concentrated in 20 large cities across China. These cities are centers of purchasing power and sustain the infrastructure and services necessary for private car ownership [74]. Interestingly, both the increase of e-bikes and private cars derive from rising Chinese income levels, though the e-bike remains the most cost-effective of all personal motorized transportation options when considering maintenance, fuel, vehicle cost, and battery replacement [75].

Several other factors have contributed to these two transportation trends. The rise of the automobile has resulted in crippling congestion throughout many of China’s significant cities [76], pushing more people towards public transportation, bikes, and e-bikes. However, both public transit and biking face crowding in the form of long lines and hectic bike infrastructure [77]. In addition to private e-bike ownership, China is enjoying the proliferation of e-bike shares across the country. After a failed initial launch during the 2008 Beijing Olympics, Chinese cities have adopted both docked and dock-less e-bike-share systems in various cities across the county, giving rise to their popularity and use in crowded yet sprawling urban areas [78].

Increases of e-bikes have not occurred without significant issues. The main concerns articulated across the country involve: congestion, etiquette, speed, safety, and environmental impacts of lead in e-bike batteries [79]. In many ways, these concerns mirror those present in the and will be further discussed in Chapter 5.

It is important to note that these issues primarily involve the use of e-bikes for commuting instead of recreation. In addition, many of these concerns arise from the literature on e-bike usage within bike shares across China. There is significant research on e-bike shares in

China and Europe, and while that research body is not the focus of this literature review, the discussion of them may be applicable to land managers who are considering e-bike usage close to urban centers where e-bike shares exist.

c. Discussion: Effects of Mobility Cultures on E-bikes and Recreation

It is not altogether surprising that the e-bike has gained quicker and more widespread acceptance as a commuting and recreation tool in Europe than in the United States, given their differences in mobility culture. The history and egalitarian cycling culture in Europe predispose the region towards accepting new technology that makes cycling more comfortable and more accessible for recreation and commuting. While in the U.S. the car-dominant culture hinders widespread adoption. Likewise, on public lands there is a divide between areas open to motorized use and those exclusively reserved for non-motorized. Perhaps it is precisely because of these two factors, the dominance of the car and the limited areas in which bikes can purely be used for recreation that makes the acceptance of e-bikes into that recreation sphere so rife with conflict.

When considering this divide from a land manager's perspective, both in the forms of cultural resistance and infrastructure limitations, several questions come to the forefront.

- How can land managers balance the desires of those who do not want their recreation environment to change (NIMBYs) against a group of cyclists (e-bikers) from utilizing and enjoying off-road infrastructure?
- Can change the underlying restrictions governing motorized use on U.S. lands disassembles the dominance of the SOV?
- Is opposition to updating motorized use regulations a philosophical issue, and do opponents maintain a “not in anyone’s backyard mentality?
- Is opposition to updating motorized use regulations a localized strain of NIMBYism induced by place attachment of neighborhood non-motorized areas?
- Does support either for or against change creates friction among trail users with the potential to increase recreational conflict?
- Can a prescriptive public engagement process surrounding e-bike use successfully change the minds of local opponents and decision-makers?

Unfortunately, there is little empirical research to provide answers. However, the response from major regulatory and public land agencies to updating motorized-use regulations will be explored in greater detail in Chapter 7.

As an interesting comparison to the unanswered questions on the domestic scale, China experienced the rapid proliferation of e-bikes primarily from government support. This top-down approach is unique within the global e-bike market since, in Europe, Canada, and the United States, e-bike proliferation has been primarily industry and consumer-driven. However, such growth occurred for commuting purposes in extensive urban areas rather than recreation on public lands. This result offers an exciting insight into how effective government programs can be in altering transportation in a county. Taken together, through the examination of each mobility culture it can be inferred that mobility has direct ties to recreation culture. However, more research is necessary to determine the exact extent of this relationship in each of the markets discussed above.

d. Lessons from Cultural Factors

The previous discussions about NIMBYism, mobility cultures, and e-bike popularity across the world highlight several key takeaways about the future of transportation and recreation.

- NIMBYism is a robust social force that is deepened by place attachment. Both forces can create significant resistance to change and give rise to barriers for recreation management regulation changes. Whether NIMBYism also affects the motorized vs. non-motorized debate, perhaps hindering changes to e-bike allowance in recreation areas, has yet to be fully explored.
- For cycling to flourish in the U.S., be it by conventional bicycles or e-bikes and for both commuting and recreation purposes, requires both cultural and infrastructure changes.
- There remains a different ethos surrounding recreational biking in much of Europe that fosters a more accepting market for e-bikes to enter.
- The sheer size of the Chinese economy, coupled with top-down support for the adoption of e-bikes, led to the technology's proliferation.
- The Chinese market is not comparable when examining the recreation of e-bikes, given their primary commuting purpose.

Chapter 4 - Emerging Technology and Redefining Outdoor Recreation

Advances in technology have always been accompanied by a familiar dissonance in opinion; those who embrace technology (early adopters) and those who resist or oppose change (Luddite). The term Luddite harkens back to the early 19th century in which English textile workers destroyed weaving machinery as a way of protesting job insecurity [80]. In its modern conception, a "neo-Luddite" represents a resistance toward a world where digital technology is inseparable from the daily human experience. Neo-Luddites do not employ the same destructive methods as their predecessors, but they still resist electronic, communication, data visualization, and media sharing devices. This resistance is also prevalent in the outdoor recreation field, particularly regarding electric-assisted bicycles, augmented reality, drones, and social media, and their appropriateness in wilderness areas.

This chapter explores the complicated relationship between outdoor recreation, emerging digital technology, and electric mobility modes (e-bikes, e-scooters, e-skateboards), illustrating both the resistance and acceptance to change. Comparisons are also made on the role of social media and its influence on perceptions and behaviors for both visitors and managers. The chapter concludes with a discussion on the implications of technology and its effect on specialization and level of experience in the field of outdoor recreation.

a. Virtual Reality & Augmented Reality in Outdoor Recreation

VR uses computer technology to create a simulated environment by incorporating sight, sound, touch, and smell that immerses the user into a deeper level of interaction than a traditional computer game. Currently, there are two kinds of reality-based technology on the market: virtual reality (VR) and augmented reality (AR). Aside from its gaming capabilities, VR has set the stage for inclusivity in other realms of life, mainly outdoor recreation [81]. In a report by NPR, a man with muscular dystrophy was able to experience the sensation of surfing standing up. The technology provided the experience by using film from professional surfers and creating an immersive cinematic experience that convinced the man he was surfing [82]. Outdoor brands like Moosejaw Mountaineering, The North Face, and Mammut are using the technology to make an emotional connection with their consumers.

Like VR, AR is rapidly becoming a crucial means for people to experience outdoor spaces. Instead of completely immersing the user in a fabricated world, AR technology overlays virtual elements with real-life events, such as a virtual map of a city with interactive elements or activities.

b. Pokémon Go

Today, one of the most popular AR systems is Pokémon Go. During the first two months of its launch in 2016, downloads reportedly exceeded 500 million, with users walking over 8.6 billion kilometers (The Pokémon Go Team, 2019). The popularity of Pokémon Go stems from its ability to facilitate physical activity through social interaction. In one preliminary study using location and sensor data, Althoff et al. (2016) found that Pokémon Go users had significantly increased their levels of physical activity after using the game. Similarly, a number of studies found that the game had motivated players to spend time outdoors, socialize with friends, bond with family, and make new connections [83].

On the other hand, the game has been linked to several negative consequences such as traffic accidents, physical injuries, addictive and obsessive behaviors, and child safety issues [84]. A report out of Indiana found that within the first six months of its release, Pokémon Go contributed to roughly 145,000 vehicular crashes and 256 fatalities with an implied economic cost between $2 and $7 billion [85].

Overall, these studies suggest that AR developers need to keep a close eye when it comes to the safety and welfare of their users; yet comparisons can be drawn about technology specific to outdoor recreation activities. Advances in micro-mobility modes can provide people with access to places they might not otherwise visit. Similar to the safety concerns surrounding AR technology, e-bike riders could potentially get themselves into risky situations (i.e., restricted areas, wild animal habitats, treacherous terrain) more so than conventional bikes because of their speed and power (e-bikes will be discussed further in section g. below).

c. Drones

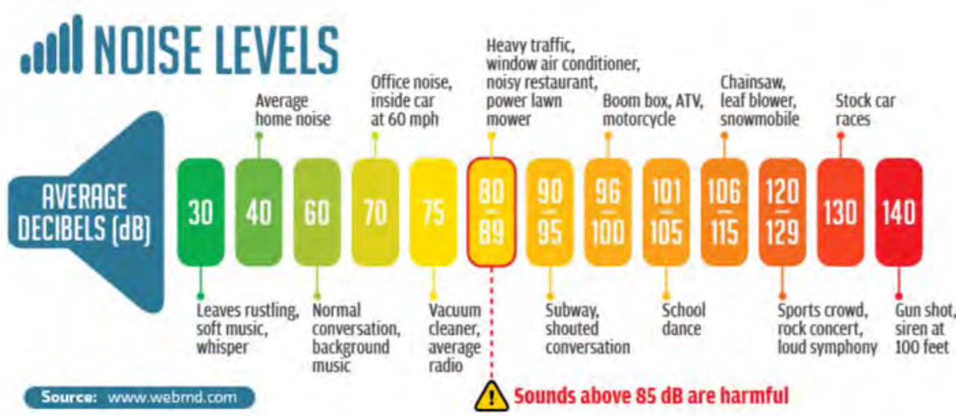
Remotely piloted aircraft (RPA), also known as drones, is a broad category of small electronically controlled aerial vehicles. Advancement in drone technology was predominantly driven by the military, government, and industrial applications. In the past two decades, however, the rapid development of high-speed controllers and battery technology has led to smaller, more affordable drones that have considerably expanded that market for public use [86]. Publicly available drones are significantly smaller than commercial drones but still require an Unmanned Aircraft Systems (UAS) remote pilot certificate to operate [87]. Despite their growth in popularity, the debate continues over the use and appropriateness of drones in wilderness areas with regards to wildlife and recreation conflicts, privacy, and safety.

Drones have been used for a range of applications in both scientific and commercial settings, which benefit from their affordability, versatility, transportability, and ease of use compared to piloted aircraft survey instruments. Drones also benefit wildlife and conservation managers, adding an essential capability to their observational methods and ecological data research. The absence of a human pilot allows flight operations into environments that might otherwise be too difficult, dangerous, or inaccessible [88].

The appropriateness of drones in wildlife areas is also an essential topic for recreation managers in the United States. According to a survey of park and recreation personnel [89], 37% of respondents agreed that drones should not be allowed in outdoor recreation areas, citing noise, impact to privacy, and the recreational experience. Those who agreed with drone use (42%) commented that drones could be a helpful management tool (i.e., security, data collection, disaster recovery). In fact, only 61% of respondents knew that parks and recreation agencies use drones for work-related purposes. Regarding drone policies, more than 50% of respondents said their community either prohibited drones or permitted them with limitations.

Although some commentary suggests that drone use in conservation management may reduce disturbance effects presented by human interaction, other research argues that drone interactions have adverse impacts, including those described in studies on black bears [90], Adelie penguins [91], and seagulls and raptors [92]. In these cases, a disturbance occurred at low altitudes when noise and visibility were high. According to a study measuring drone noise disturbances, both fixed-wing and rotary-wing drones produce an average outdoor ambient sound between 33-40 decibels [93]. The study also measured the sound generated from a large beehive and found that they produced similar noise levels compared to a single drone. On a decibel scale, these levels are comparable to noises generated inside a busy restaurant or moderate rainfall (see figure 4.1 [94]).

Figure 4.1: Decibel Scale



Currently, there are no studies measuring the decibels generated from electric bicycle motors or components; however, one study investigated how wind noise exposure can affect hearing for cyclists. The study found wind-noise levels are proportionate to the speed and directionality of the wind current, from 84 decibels at 10 mph to a maximum 115 decibels at 60 mph. Given that it is rare for an average cyclist to reach speeds of 60mph or above, except possibly on long downhill sections with little wind resistance, it is unlikely that prolonged high decibel exposure would occur [95]. Additionally, the fastest commercially made e-bike on the market (class 3) has a cut-off speed of 28 mph, which according to the study, could produce wind noises up to 100 decibels.

d. Social Media

In past generations, outdoor recreationists have enjoyed the tranquility away from technology; however, in recent years, this motivation has shifted to a culture focused on technology and social media. In a study of National Park attendance, researchers found that younger generations were apprehensive about exploring places without access to Wi-Fi or mobile data [96]. With so much of modern life being inundated with wireless technology, many National Park managers have considered building infrastructure to support the demand. (The estimated number of U.S. wireless subscribers grew from 28.1 million in 1995 to 400.2 million in 2017 [97].) In 2013, the National Park Service (NPS) introduced a pilot program to test if visitor numbers would increase if they provided access to cell reception and internet services. In conjunction with its mission statement--which is to provide high-quality opportunities and maintain an inviting atmosphere for all visitors--the NPS believed that this addition would attract younger populations [98]. The pilot was introduced through a series of reception towers and mobile apps, which included amenities like trail map systems, wildlife identification, and emergency response support. Mobile apps, like the GPS Ranger in Cedar Brooks National Monument, were very popular with new visitors. Overall findings suggest that visitors enjoyed using the GPS ranger to navigate the park and learn about geology, wildlife, and plants more so than interactive signage or brochures. One reason for this response, according to the study, is that typical visitors arrive with only general expectations of the site, while GPS users tended to be more curious about their surroundings and used the GPS ranger to find information [99].

Although support for the added technology was abundant, many visitors expressed opposition to the idea, stating that national parks should be a respite from the technology chatter. Several visitors believed that cell towers and internet services would diminish the natural beauty of the park. Others suggested that an increase in technology would attract people with less knowledge or skill level into the park, further diminishing the capabilities of rescue operations [100].

> *"One of the worst trends we have seen in the past 20 years is the proliferation of cell phones and technology in the backcountry … It gives people a false sense of security. It is the idea that - who cares how bad of a jam I get myself into because if there is cell coverage, I'll just call and someone will come get me."* [101] - Tim Smith, an instructor at Jack Mountain Bushcraft School in Maine.

e. Strava, FitBit, and other Fitness Tracking Devices

Much like the controversy over social media platforms and their influence on outdoor recreation, one of the newest trends sparking debates in the last two decades is fitness tracking apps and devices. Using GPS, heart rate monitors, and a plethora of other tracking technologies, fitness trackers enable people to keep tabs on their personal fitness goals as well as the fitness goals of their friends [102]. Apps like Strava, Fitbit, My Fitness, Google Fit, and many others not only encourage users to push their physical and mental limitations, they can also provide a wealth of data for recreation administrators attempting to catalog and manage outdoor spaces [103]. The growth of these apps (combined with the introduction of electrically assisted modes), however, has led to more people fabricating their fitness achievements.

A recent news article in *The Wall Street Journal* found that several Strava users were "cheating" on their fitness times (i.e., using an e-bike while recording their activity on a conventional bike). The app does allow users the opportunity to switch their mode of use via a drop-down menu, yet the problem lies with the overall scoring system. "The cycling segment leaderboards are for conventional bicycles," stated a representative from Strava, "and should only reflect human-powered achievement rather than unattainable, motor-assisted times." [104] Despite these restrictions, much of the backlash against e-bike riders came from the purist cyclists who do not like having their "king-of-the-mountain" scores defeated by an e-bike.

f. E-bikes, E-scooters, and E-skateboards

Electric-powered recreation modes (e-bikes, e-scooters, and e-skateboards) represent a unique and challenging problem for recreation managers and urban planners for several reasons. The first is a safety concern: because of the potential to reach higher speeds than conventional modes, e-powered modes may cause more collisions. Unlike traditional trail uses, electric-assist modes allow users to attain higher speeds, travel farther distances, and carry more gear/equipment. These characteristics can present safety problems for hikers, conventional bicycle riders, and horse or stock animal users who generally travel slower, shorter distances, and carry less equipment [105]. Considering the speed and increased accessibility to natural surface trails, the impact of e-bikes on natural areas is similar to that of traditional bikes. A study by the International Mountain Bicycling Association (IMBA) compared the impact of a mountain bike with a pedal-assisted electric mountain bike (e-MTB) and a gas-powered dirt bike. Researchers concluded that conventional and e-MTB had similar impacts, while the dirt bike significantly displaced more soil [106].

The second concern relates to the increased ability for riders to venture into more remote areas and their potential for trespassing in undesignated areas. Advances in electric motor technology have made it possible to travel longer distances while decreasing the overall weight and size of most electric modes. This aspect presents a problem for recreation managers as it could create more search-and-rescue operations for inexperienced riders as well as increased conflict with private landowners [107].

The third concern is the potential increase in trail maintenance. Trail impact studies reveal that bikes can decrease trail longevity (over a long period of time) and may degrade specific areas prone to erosion if managed improperly [108]. Mountain bikes on natural surface trails, in particular, have been shown to cause environmental damages such as trail erosion, reduction in water quality, and increased runoff, as well as disruption of wildlife and vegetation [109]. This disruption was also documented by Larson et al. (2016) in a global literature review of 274 articles on the effects of non-consumptive recreation on animals. Overall, the study found that 93% of the articles documented at least one effect of recreation on animals, with the majority (59%) being classified as a negative impact [110].

Contrary to public perception, this review found that summer-based, non-motorized activities were 1.2 times more likely to negatively affect wildlife than motorized activities. For snow-based recreation, non-motorized activities were 1.3 times more likely to disrupt wildlife areas than motorized. One explanation for this discrepancy could be that motorized trails tend to be more prominent and placed outside wildlife areas, creating a corridor of displacement that animals know to avoid. Non-motorized users, on the other hand, can travel off the beaten path more frequently, resulting in a less predictable travel pattern [111].

For an in-depth discussion on the ecological impacts of e-bikes and other motorized recreation modes, see Chapter 6: Costs and Benefits, section f. E-bikes and Potential Ecological Impacts.

g. Implications of Technology in Outdoor Recreation

Although park and recreation managers have to deal with the influx of technology, the concerns over its integration into outdoor spaces fall into three categories: 1) the accelerating rate of technological innovations affecting outdoor recreation and its incorporation into the mass market; 2) the increasing amount of social impacts (conflict, crowding, and displacement) and environmental impacts (increased erosion and wildlife disturbance); and 3) the structure and cultural roles of parks and nature. One of the overarching themes within these categories is the increased pressure placed on park staff and recreation managers. Advances in recreation technology create more opportunities for people who might not otherwise venture into outdoor spaces. This influx of new, less experienced users can, and does, create conflict for individuals at a higher skill level, as well as search-and-rescue operations. These findings correlate with the theoretical framework of experience and conflict presented in Chapter 3: Recreational Conflict, which shows that experience dictates the level of voluntary risk. Visitors with experience in one activity, such as conventional biking, might be inclined to try e-biking without further educating themselves on the specific features because it seems familiar to them.

Technology also forces recreation managers to deal with diverse demands of specialized user groups, as each new technology-based activity creates clientele with distinct values, motivations, and attitudes. This increased level of management is what Weil and Rosen (1997) describe as “technoStress,” which is the individual and societal costs of dealing with the consequences of technology. The impacts of technoStress affect outdoor recreationists and park managers in unique ways. Fifty years ago, for example, hiking on a backcountry trail required a physical map, a printed guidebook, a compass, and the expertise to operate and navigate these tools. Today, most people can explore remote areas via GPS or other mobile applications without having to read a physical map. For recreationists, these advances have been particularly revolutionary in terms of making outdoor spaces more inclusive and accessible. For park managers, these advances equate to higher visitor numbers in backcountry areas, which, if coupled with inexperience, can mean increased burden on search-and-rescue operations [112]. On the other hand, GPS technology has made it much easier for park managers to locate visitors in rescue situations.

h. Conclusion

Modern innovations have proven to be a double-edged sword for both recreation managers and users alike. Technological advances have significantly changed how people access wilderness areas through improved transportation, safety, comfort, and information; yet advances in recreation technology create more opportunities for people who might not otherwise venture into outdoor spaces. This influx of new, less experienced users can, and does, create conflict for individuals at a higher skill level as well as search-and-rescue operations. As a result, park managers have adapted their social, environmental, and cultural practices to accommodate this emerging brand of users. From the user’s perspective, technology has significantly shifted how individuals perceive nature and pursue outdoor recreation opportunities. Modern technology allows us to venture farther into remote areas, yet begs the question: will this traffic eventually alter the outdoor recreation experience? Database and memory technology, combined with a higher level of public access, might take away the “unknown” aspects of recreating in nature so commonly associated with discovery and mystery. Instead of developing local knowledge from direct interactions, more decisions and expectations could be based on media-driven experiences.

Regarding the threat of increased noise pollution caused by e-bikes, there has been little research indicating that bicycles produce a substantial amount of noise compared to other transportation and recreation modes, although research on wind noise suggests that noise levels can be significant for cyclists depending on travel speed, and wind speed and directionality.

Chapter 5 – Costs and Benefits of E-bikes

In this chapter, the positive and negative dimensions of e-bikes are examined. This research has occurred in response to the relatively recent market penetration of e-bikes and the associated concerns and potential benefits voiced by land managers, trail users, and transportation professionals. Concerns exist over e-bike speed and safety on roads and trails, as well as the potential ecological impacts. The potential benefits of e-bikes include increased accessibility for a diverse range of trail users, health and wellness effects, and congestion/emissions reduction.

a. Active Recreation and Health

Despite warnings about the negative health consequences associated with a sedentary lifestyle, a substantial portion of the population in the United States, Europe, and Asia remains physically inactive [113]. Regular participation in a moderately intense physical activity, such as walking, biking, or swimming, can provide essential health benefits. In 2007, the American College of Sports Medicine (ACSM) and the Centers for Disease Control and Prevention (CDC) updated national physical activity recommendations, which list the types and amounts of physical activity needed by healthy adults to improve and maintain health. Recommendations include new data relating physical activity to the sedentary lifestyle health concerns, such as an increased risk of cancer, anxiety or depression, cardiovascular diseases, overweight or obesity, decreased skeletal muscle mass, as well as elevated blood pressure and cholesterol levels [114].

To promote and maintain health, the ACSM and CDC recommend all healthy adults, ages 18 to 65, need at least 30 minutes of moderate-intensity-endurance physical activity five days each week (e.g., brisk walking) or 20 minutes of vigorous-intensity physical activity (e.g., jogging) three days each week. The updated recommendation states that individuals should strive to combine moderate- and vigorous-intensity activities into their daily lives [115]. According to a 2017 report by the CDC on physical activity, fewer than 20% of American adults met the recommended amount of moderate-intensity activity recommendations, with 26% of adults stating they do not participate in any physical activity [116].

While these recommendations may improve the well-being of the average adult, they do not take into consideration the roughly 43 million (13%) Americans living with a mobility disability [117]. Because most outdoor activities require some physical aptitude, the experience level for someone with limited mobility would be far less achievable than the average adult, yet recent advances in VR and AR seek to change this outcome. For a detailed discussion on VR/AR technology and its role in changing outdoor recreation experiences, see Chapter 4: Emerging Technology and Redefining Outdoor Recreation.

Health Benefits of E-bikes

Bicycling, both for commuting and recreation purposes, has been shown to improve physical performance [118], health [119], and prevent diseases associated with overweight or obesity[120]. Several studies have looked at the health impacts of e-bikes by comparing physiological performance factors with traditional bike riding.

In The Netherlands, a study measured 12 physically active individuals while riding the same distance on an e-bike using three power settings: no power assistance, eco-mode, and maximum assistance. Measuring the heart rate, oxygen consumption, and power exertion of each rider, researchers concluded that all three power settings contributed to the riders' meeting the minimum physical activity requirements. Even with the maximum assistance, riders achieved the recommended physical activity intensity, which reduces the chances of sedentary lifestyle diseases. Not surprisingly, riders using the most assistance achieved higher average speeds and traveled a farther distance in a shorter amount of time [121]. Although reducing the overall riding time can limit the amount of exertion, research suggests that those riding an e-bike tend to spend more time on their bikes than if they were using a traditional bicycle [122].

The results were mirrored by a study in Switzerland that sought to determine whether e-bikes could provide enough physical activity for users to gain health benefits [123]. The study compared the metabolic effort of walking, biking, and e-biking in high and standard power-settings up a hill. The walking and e-bike trip with the high-power setting resulted in a metabolic effort of 6.5 and 6.1, respectively. The e-bike with the standard power setting and the conventional bike resulted in a metabolic effort of 7.3 and 8.2, respectively. Results show that e-bikes are effective in enhancing overall health through physical activity.

Similarly, a U.S.-based study measured rates of physical exertion on 19 users as they walked, rode a bicycle, and an e-bike from the University of Tennessee bike-share system [124]. Using a combination of laboratory, GPS, and onboard power meters, the research found that e-bikes require 21% less energy than a regular bike and 62% less energy than walking when considering overall trip characteristics, including distance traveled.

Another U.S. study from CU Boulder quantified the health benefits of replacing sedentary commuting (cars) with a class 1 e-bike. The study found that over a month, compared to driving a car, commuting via e-bike helped participants reach their physical activity recommendations, increased essential cardiovascular endurance, and improved blood sugar control [125].

Finally, a study in Germany measured the physical exertion rates for eight sedentary females who were instructed to ride an e-bike and a conventional bike along a 9.5 km route [126]. Significant findings of the study included: 1) e-bikes required less muscle activation in lower limbs, 2) reduced overall cardiovascular effort, 3) increased fat metabolism, and 4) reduced perceived exertion but increased enjoyment. Despite the lower levels of exertion required to pedal an e-bike, the total amount of energy used can improve health outcomes for most riders.

Overall, the research shows that e-bikes have a positive effect on physical activity and health. Trips using an e-bike contribute to improved health outcomes. Given that e-bike riders tend to ride more often and on longer trips than regular bike riders, e-bikes could contribute to improving physical activity levels for most users. E-bikes may start replacing other forms of transportation, yet they are not a complete substitute for meeting daily physical activity recommendations unless the total trip time and distance are increased.

b. Speed and Safety

Although much has been discussed regarding e-bikes and the health benefits they can provide to counteract sedentary lifestyle diseases, many studies have examined how their increased speed and distance affect user behavior, mainly as related to safety. As a reaction to these concerns, much of the worldwide regulation on e-bike use, designations, and purchases are focused on safety concerns. These concerns exist in both recreation and transportation literature, especially regarding the speed and safety of e-bikes when interacting with others. However, the current literature provides insight into these concerns only in the transportation context.

Although e-bikes are an emerging form of transportation in the United States, several concerns are related to user behaviors rather than the technology itself. In the state of New York, for instance, until April 2019, riding an e-bike was illegal because it was considered riskier than a conventional bicycle. If caught riding an e-bike, the cyclist could be charged a $500 fine. Mayor de Blasio, who instituted the ban in October 2017, justified the decisions, citing that e-bike riders are more reckless and dangerous than other users on the road, despite motor vehicle data that suggested only 0.7% of vehicle collisions were caused by e-bikes in 2018 [127].

In April 2019, however, after considerable backlash from voters and e-bike advocates, New York amended the ban on electrically assisted devices. In the State Bill S5294, legislators both redefined e-bike categories specific to New York and how they should be operated, stating that all electrically assisted devices shall be treated alike and abide by all traffic laws applying to other human-powered devices. “Every person riding an electric device upon a roadway shall be granted all the rights and shall be subject to all of the duties applicable to the driver of a vehicle [128].”

Although the ban on e-bikes in New York is an extreme example, the issue of user behavior continues to be a significant safety concern for many state transportation and recreation regulators. However, given the evolving status of e-bikes, most research to date on e-bike user behavior is concerned with transportation rather than recreation. When faced with e-bike legislation, many legislators and stakeholders question the safety, speed, and allowed locations for an e-bike. This attitude holds for public opinion, too. As a part of an e-bike survey conducted in 2015 by the League of American Bicyclists, 72% of Americans stated their top concern was safety. Mirroring this concern, the State of California requires all e-bike riders to use a helmet but does not require helmets for regular bicycle riders. This restriction is primarily rooted in a misunderstanding of the technology rather than scientific data. In addition to California, seven other states have helmet requirements, including Arkansas, Colorado, Connecticut, Michigan, Tennessee, and Utah. As another safety precaution, 10 states restrict the operation of e-bikes to individuals over the age of 16 [129].

Perceived Safety and Behavior with E-bikes

One of the most common adverse reactions to e-bikes is that their potentially increased speed makes other trails or street users feel unsafe, yet evidence suggests that e-bikes can change riders' perception of safety compared to traditional bikes. In a North American survey, 60% of e-bike owners said they felt safer riding their e-bike, while another 42% said their e-bike helped them avoid crashes. In both scenarios, reasons ranged from having enough acceleration to clear an intersection, keeping pace with traffic, and improving self-balance at higher speeds [130]. Similar results were found in China. In one study, women who rode an e-bike felt more confident about traversing an intersection than on a regular bike [131]. In another study, roughly half of e-bike riders thought it was safer than a regular bike [132]. These findings were mirrored in Boulder County's 2019 pilot study in both the online survey comments and the intercept survey. In both surveys, several respondents acknowledged that e-bikes would significantly improve their capabilities and confidence as a biker. Others recognized that e-bikes could be beneficial to aging populations and those with mobility limitations, while a few mentioned that an e-bike had replaced much of their car trips as observed by the following comments. (See results of the intercept and online survey for a more detailed description.)

> *"The electric-assist gives me the confidence to take longer jaunts to pearl street in Boulder (17 miles from home) or even to Lyons. The throttle is the thing that has surprised me the most. If I were to have to stop at a light or stop sign even on a weak incline, I might have difficulty getting started."*
>
> *"As a senior with a disability, being able to use my e-bike is allowing me to go outside, exercise, use my car less, and enjoy life!"*
>
> *"I have been replacing at least 50% of my car trips. I run errands, go out to dinner, go grocery shopping, and visit friends and family on my bike when I used to take my car."*

Like China, studies in the United States found that e-bike owners generally felt safer and tended to obey traffic rules (stopping at stop signs, hand signaling, alerting presence) compared to traditional riders [133]. Many participants noted that e-bikes boosted their confidence on portions of the route that interacted with traffic. Several riders expressed that the throttle made it easier to stop at stop signs because they did not have to worry about making drivers impatient. Other participants felt very comfortable riding an e-bike simply because of its flexibility to operate as a conventional bike, as illustrated by this comment:

> *"I like the flexibility of it. I have a boost if I need to get through an intersection, but I can also slow down and mingle with pedestrian traffic on the sidewalk". - male, 51 comments (Popovich et al. 2014)*

However, some research demonstrates that an e-biker's increased perception of safety does not improve his/her on-road behavior. One study found that e-bike and bicycle riders behave very similarly in traffic control settings [134]. For both bicycle types, more than 40% of riders traveled the wrong way on directional roadway segments. For intersections with stop signs and traffic signals, the violation rates for both riders followed a similar trend, with a high violation rate at low speeds. Roughly 80% of riders did a rolling stop at speeds less than 3 mph, with 30% riding through at high speeds (above 8 mph). These high rates of violations for both conventional bicycles and e-bikes suggest the need for better bike-safety education, regardless of the presence of a motor.

c. Accessibility

Efforts by municipalities and advocacy groups to encourage biking for transportation and recreation have been associated with improvements in emissions reductions, economic development, public health, and social equity [135]. However, increasing the availability of bike infrastructure is not enough to single-handedly increase ridership [136]. Several other barriers to cycling exist, including the expense of owning, maintaining, and storing a bicycle, as well as safety concerns based on motor traffic [137]. It is likely that these barriers exist for recreational cyclists as well; however, most of the accessibility research has focused on using bikes for transportation. As a result, that body of research is reported here.

Despite municipal and advocacy efforts and, as mentioned in Chapter 4, across the United States, the single occupancy vehicle is the dominant mode of commuting to work. In 2013, 86% of American workers drove to work, and three out of four of these commuters drove alone. The percentage of pedestrian and bicycle commuters is paltry in comparison, as 2.1% of individuals walk, and only 0.6% bike to work [138]. This disparity occurs despite the well-established economic, ecological, and social benefits of increasing rates of bicycle use for transportation purposes. Economically, individuals are more likely to stop and patronize a business from a bicycle than a car, and a bicycle does far less damage to roads than cars do [139].

Ecologically, the bicycle provides a transportation option that contributes no noise or air pollution, both of which have negative health consequences for city residents [140]. Finally, bicycle use encourages physical activity, thereby improving public health [141]. Given all these benefits, one would expect city planning departments to invest in bike infrastructure projects to encourage bicycle use. However, such investments must be carefully considered, and it is difficult to discern how exactly to change people's modal choice for commuting. One of the most effective strategies done across the United States is to identify the primary barriers to biking among commuters. A study in Portland, Ore., identified the significant barriers to bicycle use to be safety concerns about motor traffic and the cost, expertise, and space required to purchase, maintain, and store a single bicycle [142]. Other studies have pointed to topography, the duration of the planned trip, and space limitations in terms of cargo and passengers [143]. These barriers may affect individuals all at once, at different times in their life, or simply on individual days.

To overcome these barriers, numerous strategies have emerged through the work of municipal governments and community organizations. Figure 5.1 is a conceptual diagram that illustrates significant barriers to cycling and the strategies that seek to address them. This chart includes color-coded connecting lines that illustrate the connection of barriers to strategies.

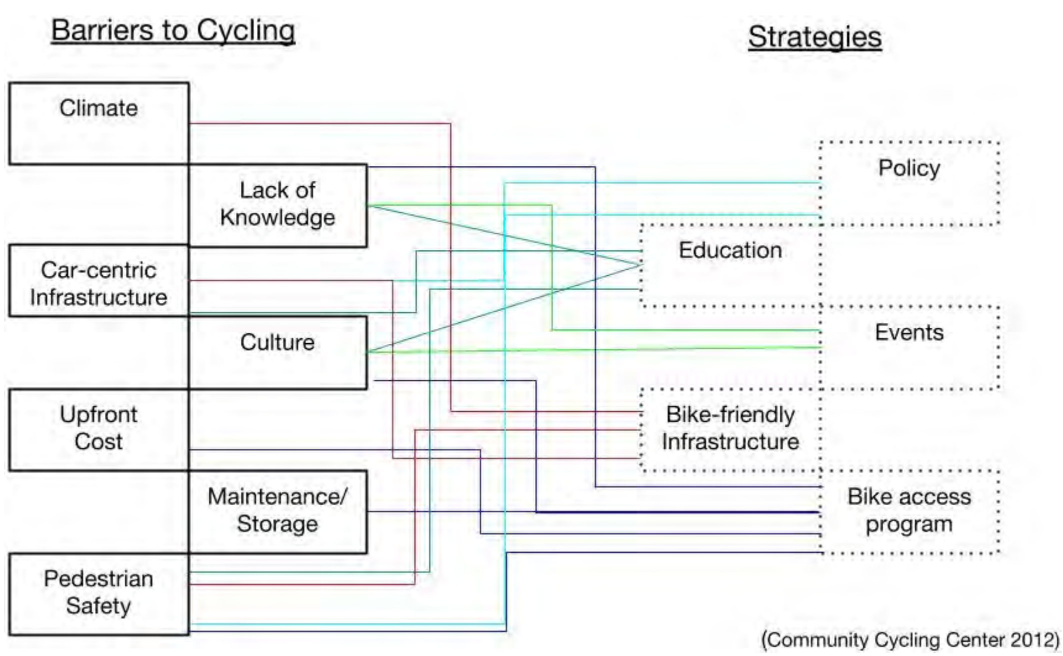


Figure 5-1. Barriers to cycling and strategies employed to address them. (Created by Sadie Mae Palmatier)

As illustrated by the overlapping and intersecting lines in Figure 6-1, multiple strategies can be employed to address the same barrier; and in the same vein, multiple barriers can be addressed by the same strategy. This nuance is especially crucial, given that it highlights the interdependence of these strategies. For instance, public policies that aim to institute bike safety programs in local schools can create and further the goals of the "education" strategy while addressing the barriers of lack of (bike) knowledge and culture. Similarly, if policies address pedestrian and "bike-friendly infrastructure," the dominance of "car-centric infrastructure" and the concerns of "pedestrian safety" could be addressed. Although it is essential to highlight the mutually reinforcing nature of these strategies, it is perhaps equally important to recognize that there is no necessary order of implementation for these strategies to be effective. For example, the implementation of bike-friendly infrastructure and the hosting of bike-related events, such as a community ride, can happen simultaneously or chronologically. Although the results of the two-timing scenarios may differ from each other slightly, the overall effect will likely be the same in that there is an increase in knowledge about biking and perhaps a small reduction in a car-dominated culture.

Research has found the same barriers to exist for e-biking as well. However, current research is still attempting to fully grasp how these barriers are affecting consumers rather than discerning the best methods to overcome them. As with conventional bikes, the associated cost of owning an e-bike can dissuade an individual from purchasing one. The most current averages, from January through June 2019, relate the average cost of an e-bike at $2,314, up 2.4% from the same period last year. On the low end, e-bikes can sell for around $500 from mass retailers and can exceed $10,000 for high-end road bikes or full-suspension electric mountain bikes [144].

Moreover, the maintenance of an e-bike includes the motor, an added cost not found in conventional bicycles. Like cost, a barrier for potential e-bike users includes the fear of theft [145]. Since e-bikes are relatively expensive and the battery can be removed from the frame in standard models, theft is a concern. Some e-bike manufacturers have attempted to circumvent this issue by adding a locking function, thereby securing the battery to the frame [146] and lowering the possibility of theft.

In addition to cost, market penetration is hindered by the current state of technology: battery range/life-cycle and weight of the bike. Depending on the type of e-bike purchased, batteries can have minimal ranges and lifespans. Associated with technology, the total weight of e-bikes is a barrier for many potential users, especially women and older riders who have difficulty lifting or maneuvering e-bikes (such as going upstairs or over curbs) when they are turned off or not being ridden, and therefore not using the pedal-assist function [147].

E-bikes face the same infrastructure barriers as bicycles. The lack of sufficient bike lanes and perceptions of safety while on the road are both significant barriers to e-biking [148]. A study of e-bikes in Portugal found the absence of segregated cycle infrastructure and the absence of cycle lanes within the road infrastructure to be the first and second most significant barriers to cycling. This concern implies that bike infrastructure is at the core of the decision to bike or not to bike for e-bikes too.

However, a 2015 study from Zurich Switzerland, suggests that the presence and absence of bike infrastructure affect bicyclists and e-bicyclists differently. Using GPS tracking data, this study found that conventional cyclists were more likely than e-bikers to choose bike routes that included physically separated bike lanes, a street with low or banned traffic, and in areas that included cycling facilities. Conversely, e-bikers were more likely to ride in areas with increased vehicular traffic and listed "low traffic volume" as less essential criteria when deciding upon transit routes. Finally, although both e-bikes and conventional cyclists cited route choice that included "minimal distances" as a high priority, the perception of effort (primarily in uphill sections) from e-bikers was less than that for conventional cyclists [149]. Another unique infrastructure difference between an e-bike and conventional bikes includes the presence of charging stations along popular bike routes. Based upon an individual's desired commute or transit route, the e-bike may need to be stopped and recharged, a severely limiting factor in the decision to use an e-bike as a commuting tool [150].

Similarly, E-bikes also face policy barriers that limit their use to specific bike paths, designated greenways, or road access only. For instance, in Toronto, Ontario, e-bikes face the barrier of murky legal distinctions. In Ontario, e-bikes are grouped into the same class as e-scooters. This designation affects public acceptance and outreach, as well as education efforts, thereby restricting their functionality as a practical transportation tool [151]. Chapter 7 covers the status of other restrictions on public lands throughout the United States.

Although e-bikes face many of the same barriers as conventional bicycles, research has found several barriers that do not apply or to apply to a lesser degree, such as weather, physical ability, and topography. A study of e-bike participants in and around Davis, Calif., did not cite weather as a limiting factor to using e-bikes as a commuting tool but referenced their ability to bike on hot and windy days. In regards to physical ability, e-bikes have been cited as an "equalizer" for aging populations, those with physical limitations, and for those who may benefit from extra assistance [152]. E-bikes can also increase the distance traveled and the type of terrain ridden, making climbs seem less formidable [153]. A reduction or elimination of these barriers opens opportunities for different types of riders, the results of which will be explored in the following section.

Who is Using E-bikes, and How?

Given the dichotomy between the barriers present for e-bikes and those barriers that e-bikes eliminate, research is attempting to understand who is using e-bikes and for what purpose. Several demographic groups have been identified as those most likely to benefit from e-bike ownership [154]. These three potential beneficiaries of increased e-bike access and infrastructure include commuters, rural residents, and students.

- Commuters benefit from increased physical health, mental wellbeing, and affordability of transportation. They experience barriers to facilities, comfort, and ease.
- Rural residents can travel longer distances, connect to other transportation options, and have flexible ad affordable transportation. However, they also experience the barriers of distance and inadequate facilities.
- Students experience boosts to their independence, health, and cycling habit-forming, while affordability and image (e-bikes can sometimes be considered “an old-person’s bike”) plague their use [155].

One area of research that has not been thoroughly explored and could not be covered in this review is how e-bikes are expanding options for individuals with mobility disabilities. In many areas along the front range of Colorado, municipalities allow individuals to use e-bikes as other power-driven mobility devices (OPDMDs) on their open space and parks trails based on federal ADA regulations (as mentioned in Chapter 7). However, to date, no empirical research exists to suggest the extent of which e-bikes are being used to this end in Colorado or elsewhere in the county.

d. Congestion Reduction and Potential Substitutability of E-bikes

E-bikes are like conventional bicycles in terms of function, yet their ability to maintain travel speeds and extend trip durations make them a reasonable replacement for other forms of transportation. E-bikes have the potential to overcome barriers associated with riding a conventional bike, such as hilly topography, temperature and humidity, distance, and time spent riding between destinations [156]. One of the most frequent motivations for purchasing an e-bike is the ability to travel longer distances at a comfortable and efficient speed [157]. An online survey conducted in North America found that 65% of e-bike owners purchased an e-bike to reduce car trips. Within this group, 55% rode weekly or daily before owning an e-bike, versus 93% after buying an e-bike. Researchers also found that nearly 21% reported having a medical condition that limited their ability to use a conventional bike, and 60% of owners lived in a hilly area and wanted to ride with less effort [158]. Similar results were found in Australia, with 42.6% of respondents buying an e-bike to replace a car trip [159]. Most respondents, roughly 80%, rode their e-bike weekly, while 34% took daily trips.

Another study in China found a similar trend in e-bike purchases, yet the mode choices differed based on the respondent's original travel mode, sheltered (bus, subway, vehicle, or taxi) and unsheltered (walk, bike, motorcycle). Only 28% of travelers accustomed to sheltered modes were willing to use a conventional bike compared to 72% of unsheltered travelers. When given an e-bike, however, 47% of sheltered travelers and 53% of unsheltered travelers were willing to change modes [160]. These results show that a behavior change could encourage a shift in mode choice. If travelers who usually take the bus, subway, or drive alone view e-bikes as an alternative and efficient mode, they might be willing to switch their daily trip patterns altogether.

As studies in China illustrate, e-bikes are becoming a dominant replacement for other motorized travel. In Kunming, for instance, 25% of all riders use e-bikes to substitute their car trips, and another 60% use them to replace public bus trips [161]. This finding is replicated in other cities with high-quality transit systems, including Shijiazhuang [162] and Shanghai [163]. In both studies, researchers suggest that e-bikes replace short public transport trips more often than they replace automobile ownership. As described in these studies, most e-bike purchases are made by those living in areas underserved by public transit [164].

While e-bike market penetration has been slow in North American cities, there is evidence that e-bikes are replacing car trips. A survey of e-bike owners by the NITC found that roughly 75% of all respondents would ride an e-bike to replace a car trip, while 67% said that reducing the number of car trips was essential to them [165].

e. Climate change mitigation

As described above, in the early stages of e-bike market penetration, some evidence suggests that e-bikes are replacing car trips. Since car travel represents a significant source of air pollution and greenhouse gas emissions, moving away from them could result in a significant shift [166]. Estimates of the role of e-bikes in potential climate change mitigation via carbon dioxide (CO2) emission reductions are based on a modal share of e-bikes in the transportation sector. Currently, e-bike users fill a niche of green enthusiasts and early adopters of the technology despite the potential for e-bikes to represent a more significant percentage of the modal share usurping the dominance of cars. The difficulty with achieving this reality is rooted in the fact that modal share and travel behavior are habitual; thus, getting more people out of cars and on e-bikes means breaking entrenched habits. A 2017 study performed a longitudinal assessment following participants of a two-week "keys for e-bike" demo period in Switzerland. This study found that after a year, habitual association with car transport had weakened substantially among study participants who purchased an e-bike and those who did not [167]. This study suggests that prolonged exposure to alternative forms of transportation can decrease the habitual nature of relying on cars for transport.

This potential modal shift toward e-bikes is encouraging, as the reductions in CO2 can be significant. A 2019 white paper assessed these potential impacts. The study employed a CO2 reduction model based on transport modal share in the Portland, Ore., metro area, hypothesizing that a 5% modal share of e-bikes in the city would reduce CO2 by 307 tons/day and 112,049 tons/year. With a 15% modal share of e-bikes, these numbers would increase to 921 tons/day and 336,147 tons of CO2/year. At the 15% level, there would be an 11% decrease in CO2 emissions from transportation per day. When looking at an individual level, the study found cars to emit 274 g of CO2 per person mile, 140 g CO2/person mile for public transit, and only 4.9 g CO2/person mile for e-bikes. As more utilities switch to renewables or electricity generation, the associated CO2 emissions from e-bike charging (and the charging of other e-vehicles) may decrease [168].

In Boulder County, transportation accounts for 30% of county-wide emissions [169]. In 2017, Boulder County residents drove 15.2 miles/day/person [170]. If e-bikes were to increase in modal share and the miles driven per person per day were to decrease, the emissions reductions and associated public health benefits could be significant.

These numbers reinforce previous research that concluded that significant emissions savings result from an individual changing his/her primary mode of transportation from a car to public transportation or e-biking [171]. It is important to note, however, that these potential climate change benefits would result from using e-bikes for commuting. Although this review intends to highlight that transportation possibility, it must be noted that using an e-bike for purely recreation or exercise purposes instead of commuting may introduce more carbon into the system. An exception is if an eMTB rider were to e-bike to the trailhead instead of using a car for transport. When an e-bike is used solely for transportation, the result is carbon-neutral [172].

Although e-bikes have a relatively low carbon footprint, 4.9 g of CO2 /person mile, conventional bikes have a footprint of 0 g CO2 /person mile [173]. In effect, when e-bikes are used recreationally, either as a potential substitute for a conventional bike or as a standalone purchase, they are introducing CO2. Although not a significant amount, it is essential to consider this effect and be aware of the full picture of e-bike impacts. To this end, the potential ecological effects of e-bikes are explored in the following section.

f. E-bikes and Potential Ecological Impacts

The previous section on climate change mitigation from e-bikes primarily focused on their urban use. However, e-bikes, including electric mountain trail bikes (eMTBs), may have associated environmental impacts as a result of both their production and use. Looking to the Chinese market, current figures estimate that 95% of e-bikes (of which many are possible "e-scooters") use lead-acid batteries. These batteries are primarily responsible for the demand of lead-mining in recent years throughout the country [174], and the subsequent disposal or recycling of said batteries are believed to be a significant source of environmental pollution and pose significant human health risks [175]. Given the environmental and health impacts associated with lead batteries, lithium-ion or li-on batteries have emerged as a vehicle-enhancing and healthier choice for e-bikes [176]. E-bike manufacturers in Europe already employ these batteries almost exclusively [177], and other emerging or transitioning e-bike markets (the United States and China, respectively) are expected to follow suit. Such a shift may bear its own environmental impacts; however, unlike the electric vehicle market, the link between demand and production of e-bikes using li-on has not been empirically connected to adverse environmental impacts.

As with all batteries, lithium-ion batteries have a limited life-span. Although estimates differ, as reported by battery manufacturers, and can be increased or decreased depending upon the charging behavior of the rider, most e-bike batteries are expected to last around three years or 1,000 charge cycles [178]. The life-cycle and production of e-bike batteries should be considered when assessing their role in broader sustainability goals.

eMTBs on trails

For land managers, research surrounding the effects of e-bikes on natural surface trails is of particular interest. Since e-bikes are classified by some as motorized vehicles, research on motorized and non-motorized effects is salient. This research comes from the field of recreation ecology or "the study of the environmental consequences of outdoor recreation activities and their effective management" [179] (p. 1). Included in this research are the effects of trampling and visitor use on vegetation, soil, aquatic environments, and wildlife. Each of these uses is affected by the amount and type of use, timing and seasonality, environmental conditions, and spatial aspects [180].

A global review of literature on the ecological impacts of recreation revealed that land-based recreation has a substantial adverse effect on mammal and bird species, but a minimal effect on aquatic species [181]. These effects include decreased species richness or diversity; decreased occurrence, survival, or reproduction; decreased foraging, increased vigilance, and other behaviors thought to be a negative reflection of anthropogenic disturbances; and physiological conditions believed to be associated with disturbance effects; i.e., decreased weight and increased stress. Long-term recreation activities (activities lasting multiple years in a specific area) revealed the most significant effect, suggesting that repeated human disturbances can have a cumulative effect on wildlife. Counter to public perception, non-motorized activities had more evidence for a negative effect on recreation than motorized activities, with effects observed 1.2 more frequently. One reason for this conclusion is that motorized activities are more predictable than non-motorized activities in terms of trail use and noise.

This study contradicts previous research that suggests more significant potential for ecological impacts from motorized use because of the ability to travel greater distances, tackle more terrain at higher speeds, and add noise pollution in the area [182]. A 2004 study compared the disturbance levels of hiking, horse riding, mountain biking, and ATV use on deer and elk populations in Oregon. Measuring the farthest distance from each animal, researchers found that ATVs disturbed both deer and elk from over 1,350 meters away, while mountain bikes, horse riders, and hikers were observed at 750, 550, and 400 meters, respectively. Overall, this study suggests that motorized recreation users have more significant impacts on wildlife. Given that e-bikes are very similar to conventional bikes in terms of noise, trail impact, and speed, it is fair to say that their impact on wildlife habitats would be similar to other non-motorized bicycles [183].

This study considered only the effects of motorized-vs.-non-motorized recreation on wildlife. The study did not explore the effects of soil compaction, vegetation loss, or other trail degradation by recreation type. Previous research has found motorized uses to have negative impacts when compared to similar non-motorized activities. However, "motorized uses" in this research mainly considered ATV's, dirt bikes, and other large off-roading vehicles [184]. Notably, these motorized uses do not consider e-bikes. To date, there has been only one study that documented the differences in trail impacts from conventional mountain bikes and eMTBs. The study explicitly states that its scope was limited, being a small- scale field study; therefore, no broad conclusions should be drawn from the interpretation of the data. That said, the study did find that all trail users affect the surrounding environment, especially when the trails are poorly constructed. Some differences were observed at grade changes and turn between class 1 eMTB and mountain bikes. However, the study found that soil displacement from eMTB and mountain bikes was not significantly different between the two but was significantly different from motorcycles. These differences were expected because of eMTBs increased ability to accelerate and use speed through turns. The motorcycle's differences persist because of its relatively higher mass and throttle function, which allows for much greater acceleration and speed [185].

Despite these findings, public concerns about potential trail degradation caused by eMTBs persist. A 2017 study conducted in Fruita, Colo., found crowding, potential user conflict, and trail damage as participants' top concerns following the potential opening of popular mountain biking areas to eMTBs. In the same study, however, trail users who participated in the study's demo addressed another top environmental concern of e-bike allowance: noise pollution. These trail users acknowledged how quiet the e-bikes were when demoed and saw similar trail impacts as created by conventional mountain bikes [186]. This fact suggests that public perception surrounding e-bikes' environmental impact may be at odds with observed effects. Given the limitations of the 2015 Oregon study and the conflicting findings of the 2017 Fruita study, more research is needed to evaluate both the social and physical impacts of eMTBs on trails.

g. Conclusion

The associated costs and benefits of e-bikes include numerous social, economic, and ecological factors in both the transportation and recreation space. The main takeaways from this chapter are:

- When disaggregated by trip type, age, gender, and physical ability, e-bike use varies substantially. Most notably, older riders or those with physical limitations are more likely to use an e-bike for recreational purposes. Younger riders, on the other hand, tend to use e-bikes for commuting purposes. This observation suggests that younger riders are using e-bikes to replace regular trips, while older riders may find more value in their recreational abilities on an e-bike.
- Research to date on the impact of e-bikes on cycling and car use suggests that e-bikes may facilitate more frequent cycling and trips of greater distance. In North America, Australia, and China, e-bikes are used as a replacement for some car trips or to increase/prolong recreation opportunities despite age or mobility disabilities.
- Owning an e-bike can reduce other barriers to cycling, including challenging topography and weather, while still being limited by the comparatively high cost of ownership, maintenance, and storage, heaviness, and fear of theft.
- E-bikes make riders feel safer and more confident navigating urban spaces, though riders display the same risky biking behavior as conventional cyclists. In addition, on trails, e-bikes can more easily surpass other cyclists, hikers, or equestrians, raising concerns about their safety and trail etiquette.
- Ecologically, some evidence suggests that their trail impacts (erosion, noise pollution, effects on wildlife) are no different from conventional bikes, but e-bike batteries may exacerbate problems associated with battery production and disposal. In addition, although they emit more CO^2 than conventional bicycles, the potential emissions reductions from e-bikes could be significant if widely adopted.
- Concerns about e-bikes mirror concerns about conventional bikes.

In summary, e-bikes allow more riders to pursue cycling for recreation or commuting with relatively few observed impacts. Despite this fact, public perceptions of e-bikes remain well aligned with decade-old concerns of conventional bicycles, including speed, safety and noise disturbance. More research is needed on both fronts, including trail-impact studies in a variety of conditions, life-cycle analyses of e-bike batteries, speed, and associated safety impacts, and the potential for expanded opportunities for people living with disabilities.

Chapter 6: Recreation Management

Perhaps one of the most essential and challenging responsibilities of a land manager is achieving the elusive and precarious balance between optimizing visitor use experiences while protecting intrinsic ecological values. One must foster an environment that sits between a free-for-all and a "police-state wilderness," between absolute autonomy and the enforcement of mandatory permits and visitor use regulations [187]. Implicit in this struggle is blending education and information efforts with use allocation and rationing [188]. With the emergence of e-bikes, managing public lands has become even more complicated. This chapter will explore the numerous ways land managers have grappled with these issues and the prescriptions empirical research can offer.

a. Management classifications

In recreation management literature, there are two significant classifications of management strategies [189]. The first classification considers recreation opportunities/spaces and visitors as either a fixed or dynamic supply. For instance, when considering a fixed supply of recreation opportunities, a land manager may limit demand through restrictions that aim to reduce the number of visitors. Conversely, a land manager may assume that the same number of visitors will come each year (a fixed demand) and thus attempt to modify the resource base (by creating more trails, etc.) in order to reduce adverse impacts and increase the durability of the landscape [190].

A second classification schema categorizes actual management practices, including direct and indirect management [191]. Direct practices directly influence visitor behavior. An example of direct management includes restricting off-trail hiking through ranger enforcement and fee/fine systems. By contrast, indirect management practices "attempt to influence the decision factors upon which visitors base their behavior" (p. 275). An indirect approach could include an educational campaign about the fragility of alpine or riparian ecosystems and the individual visitor's direct role in his/her long-term health. Some studies point to indirect management as the more effective because of low associated costs of enforcement and visitor preference [192]. Others tout direct management prescriptions as more effective since they regulate those users who may ignore indirect management tactics [193]. Finally, a contingent of researchers claim that managing along a spectrum of indirect to direct may be the most effective scheme [194], and a combination of the two—indirect and direct management—may complement each other.

These two management classifications include attempts to mitigate recreation conflict. Considering the supply and demand of visitation and recreation opportunities, a land manager can attempt to reduce crowding and thereby reduce potential conflict. Direct or indirect management practices attempt to influence user behavior and therefore create a more hospitable recreation space for all users. Both classification types are helpful frameworks from which to analyze and make decisions regarding use management tools: information and education and use allocation and rationing [195]. Each of these tools will be discussed in further detail in the following sections.

b. Information and Education

Information and education are considered an indirect management approach designed to "persuade visitors to adopt behaviors that are compatible with recreation management objectives, usually to reduce the ecological and experiential impacts of outdoor recreation." Large-scale examples of these approaches include the Leave No Trace (LNT) campaign and the Global Code of Ethics for Tourism. The research within information and education management has primarily examined four main categories

1. Influencing recreation patterns
2. Enhancing visitor knowledge
3. Influencing attitudes towards management policies
4. Addressing depreciative behavior (littering and vandalism)

Examples of practical information and education tactics include interpretive programs regarding guidelines and regulations given today’s users, education campaigns using compelling programs within a designated area, bulletin boards at trailheads, and workshops or special programs for recreation groups [196]. Such tactics try to influence behavioral change in regard to on-trail behavior, knowledge of the area, attitudes towards management policies, and depreciative behaviors [197].

c. Use Allocation and Rationing

Since its inception in the 1960s, the use rationing and allocation tool has been viewed as controversial, as its prescription counters the primary objective of public lands, which is to secure access for all people. Most commonly, use allocation and rationing are grouped into five management practices—reservation systems, lotteries, first-come-first-serve, merit, and pricing. These tactics were historically used in urban fringe areas and are currently employed in some aspects of the National Park and USFS system, where outdoor recreation conflict intensity is most significant because of limited space, dense populations, and a greater diversity of outdoor recreation [198].

To effectively and fairly administer rationing and allocation, recommendations include emphasizing the social and environmental impacts of use instead of the amount of use since some activities may be more resource-intensive or damaging than others [199]. It is also recommended that use rationing and allocation methods be the last resort for land managers and that the decision to implement any such regulations be grounded in well-sourced and accurate information. This recommendation is especially important as new regulations could affect users and the landscape in unintended ways. A final recommendation includes implementing a combination of use-allocation so that the needs and restraints (both monetary and temporal) of multiple users are being considered. This last consideration suggests the importance of fairness in all decision-making within public land agencies. Actions must be perceived as efficient and equitable to calm public discontentment and build support.

Such support can be garnered through adherence to "distributive justice" or the "idea whereby individuals obtain what they ought to have based on criteria of fairness" [200] (p. 296). This concept of distributive justice is understood within four dimensions: equality, equity, need, and efficiency [201].

- Equality affirms that every person has equal rights to access.
- Equity, in its early definition, describes the equal distribution of benefits to those who have earned them through various investments (time, money, effort, etc.) — in the modern conception, achieving equity guarantees that access is not determined by forms of discrimination and oppression including race, class, culture, and gender [202].

- Need suggests that these benefits be distributed to individuals based on unmet needs or competitive advantage.
- Efficiency considers that benefits should be given to those who place the highest value (social or environmental) on them [203].

Another series of studies identifies eight potential dimensions of equity and applies them to a broad spectrum of outdoor recreation services/activities. These dimensions are categorized into compensatory, equality, demand, and market reasons for allocating benefits [204]. Either conceptualization or distributive justice can be a helpful theoretical tool when using demographic information to determine use allocation and rationing.

Carrying Capacity and Recreation Management

Most research on use limits and the subsequent applications of use allocation and rationing has been concerned with crowding in wilderness areas. This topic has long been of particular concern for land managers since over-crowding can have significant social and ecological impacts. The rationale for limiting use is based upon two principles: protecting the biophysical resources and protecting the visitor experience. As an attempt to enumerate the absolute limit of visitors that an ecosystem can sustain [205], the notion of carrying capacity was adopted from the ecological sciences into recreation management. This application of carrying capacity falls within human dimensions research and examines how many visitors an area can accommodate without degradation to the physical environment and while maintaining a high level of satisfaction for visitors [206].

As the questions of carrying capacity and use rationing and allocation relate to tourism, many researchers see carrying capacity as a flawed concept and predicated on unethical and self-validating beliefs [207]. Carrying capacity is tricky to define and quite challenging to quantify.

Coupled with the fact that the relationship between impacts and use level is not predictable, attempting to make management decisions premised on these two observed factors alone will yield insufficient and largely inaccurate results.

In the words of the authors:

> *"Ultimately, the notion of carrying capacity implicitly assumes that human-environmental systems are stable – how else could a number that can be sustained over time be developed? Instead, such systems are highly dynamic – even non-linearly dynamic, and capacities would vary under different environmental and social conditions. Thus, designating a carrying capacity could only occur under the assumption that systems are static. If systems are dynamic, then multiple capacities over time would have to be estimated, as well as the state of the system predicted"* [208] *(p. 383).*

For these reasons, researchers recommend that land managers identify acceptable outputs from tourism development—including desirable social and biophysical conditions—and then develop management plans that commit to establishing and maintaining strict standards of quality. This strategy will be more effective and efficient than relying on the numeric estimates of carrying capacity. However, this type of regulation does nothing to quell potential public perception of overcrowding, even when managers are adhering to their guidelines. Changing such opinions would be better accomplished following information and education tactics [209]. A related field of management tools—spatial and temporal strategies—will be described in the following section.

Spatial and Temporal Strategies of Management

According to the recreation activity space consumption sphere, activities can concern each other in three ways, dependent upon the resource use they demand: compatible, partially compatible, and incompatible. Compatible activities include fly-fishing and nature-watching, partially compatible involve non-motorized boats and fishermen, while hiking and mountain biking are often considered incompatible activities. Incompatible activities require single-use resource allocations, which, in effect, detract from user experience when the resource is shared [210]. Through direct regulation of where visitors may go, how long they may stay and when they may enter the area, management can attain the desired intensity of use for a particular site. Implicit in these techniques is a trade-off between the loss in the recreationist’s freedom of choice and the gain in ability of the site to more nearly meet visitor needs and objectives [211].

Similar to the way the intent of reducing the number of people within a specific area of use is at the core of use-allocation, rationing and carrying capacity designations, spatial strategies attempt to contain visitor impacts within acceptable limits, both on the environment and with interaction with each other, often heeding the compatibility of activities. Four main strategies exist within the recreation literature, each of which is enumerated below [212].

1. Spatial segregation: a strategy that shields sensitive environments from any human contact or from conflicting forms of recreation from each other
    a. Zoning: the designation of users (within the same group or multiple groups) within a particular space
    b. Closure: a zero-tolerance policy that completely eliminates visitor usage of the area.
2. Spatial containment: a strategy that funnels all visitors into an established or designated area with the intention of minimizing the aggregate impact on the landscape.
3. Spatial dispersal: attempts to minimize permanent resource impacts or visitor conflict by reducing the frequency and intensity of use via spreading visitors across a landscape.
4. Spatial configuration: a strategy that creates spatially distinct facilities to reduce negative impacts of visitor behavior and use patterns

Examples of these strategies in practice include designated bike, hiking, or equestrian trails and trail-closures, national recreation areas within a wilderness area, multiple entrance points for a trail system or rotation of trail closures, and spreading facilities for recreation across a municipality, respectively. Taken together or separately, these strategies can be useful in a concentrated setting, but also spatially distinct areas [213]

Across the Front Range of Colorado, spatial segregation has been a tool used by land managers to limit the amount of interface and, hopefully, conflict between user groups with competing goals and motivations, such as hikers and mountain-bikers. Such actions have been empirically cataloged in other parts of the country as direct responses to overcrowding and the observed displacement of sensitive visitors [214]. For more information on federal and state regulations, please see the appendix. One study suggested that residents living in or around a park (in this instance, Acadia National Park) or another recreation area may display more displacement coping mechanisms than other tourists, given their tendencies for place attachment and local knowledge of the area. As discussed in Chapter 3, this place attachment may give rise to NIMBY reactions if the local trail users believe their trails are being altered in some way. Given this knowledge of coping as a result of perceived crowding or conflict, a thorough and community-engaged planning process is recommended. Specifically, one that incorporates public participation geographic information systems (PPGIS) is considered a best practice for creating and managing the best park experiences [215]. In this process, spatial strategies can be used to ameliorate perceptions of crowding, conflict between visitors, and environmental impacts while reducing displacement of local residents or frequent visitors.

Temporal management has been used as a recreation management tool to reduce the skew of visitors to an area over time. These peaks of visitation can happen yearly (such as on holidays) or on a daily scale (lunch time or after work). Peak visitations are also more likely to happen in areas closer to high-density urban areas regularly throughout the year, while alpine recreation areas tend to experience peak visitation during the summer months [216]. The management demands of this peaking phenomenon include providing facilities that can accommodate peak demand and regulating crowding so as not to diminish visitor experience and prevent damage to flora and fauna of the area [217]. Examples of temporal management in practice include closing trails entirely on specific days or requiring closures toward particular groups on specific days. For instance, Betasso Preserve within the Boulder County Parks and Open Space System has hiker-only days. This system enables both users of the areas, hikers and mountain bikers, to enjoy days crowding is minimized. This version of temporal management attempts to reduce the documented phenomena associated with crowding, including displacement of individuals, conflict, and environmental impacts [218]. As another example, Boulder County Parks and Open Space closes its properties from sunrise to sunset. This strategy reduces the responsibilities of park rangers and temporal opportunities for conflict. (QUESTION: should it be from sunset to sunrise??)

d. Relating Research and Management

Sustainable Trails

Each of the strategies described above references the intent to instate management prescriptions that give the best possible opportunities for trails that both allow public access and concentrate impacts into a specific corridor. According to *The eMTB Land Manager Handbook*, this desire is synonymous with creating sustainable trails or a trail that “allows users to enjoy an area with minimal impact to the natural and cultural resources and requires only modest maintenance [219]. Trail sustainability is usually conceived as having three dimensions:

environmental, social, and economical.

- Environmental sustainability includes creating trails that enable minimal impacts, such as erosion, soil compaction, etc.
- Social sustainability aims to balance the number of people who can access the trail by providing an exceptional trial experience. To do so, land managers can create three distinct types of trails, single-use, multi-use, and preferred-use.
    - Single-use trails allow only a single user type, which can create targeted user experiences (such as technical single-track) and disperse traffic.
    - Multi-use trails allow two or more user-groups trail access. This trail type has the potential to accommodate the broadest array of users, build trail communities, support most visitors, and be the most cost-and-resource efficient.
    - Preferred-use trails allow two or more user-types access but are specifically designed to primarily accommodate only one of them. For example, a trail may entertain both cyclists and trail-runners but can be designed with cyclist-specific elements, such as technical descents or flowy single-track.
- Economic sustainability depends upon assurance of funding for trail maintenance and improvements over the trail's expected lifetime [220].

Sustainable Trails and E-bikes

Given the potentially higher travel speeds of e-bikes as compared with conventional bikes, especially on uphill sections, People for Bikes recommends designating descending-direction trails as a way to mitigate user conflicts. Directional travel reduces user interactions, reducing the speed differential, and mitigating adverse effects [221]. If this trail design is done in conjunction with other facets of sustainable trails, the design may work to increase the social sustainability of the area, given the reduction of trail conflicts.

e. Conclusion

In this chapter, indirect and direct, information and education, use-allocation and rationing, and spatial management strategies were discussed. This chapter sought to give an overview of how researchers and land management agencies have navigated the management questions surrounding this emerging technology. The main takeaways from this research relating to e-bike management are:

- Crowding is a concern on public lands across the United States. Spatial and temporal management strategies may be an effective means to alter visitor recreation patterns and thereby disperse visitor use, alleviate recreation conflict, and minimize environmental impacts.
- Local allowance of e-bikes differs at the state and local levels across the country. Several land management agencies have conducted pilot studies to analyze the potential effects of e-bikes within their jurisdiction. With such pilot studies, reports show community engagement to be a vital part of the process.
- Recommendations for e-bike management on trails range from descending direction trails to speed limits to restrictions on trail-width for e-bike use. Each of the regulations may increase trail sustainability and minimize conflict.
- Information and education management strategies may be useful when implementing e-bike regulations and for improving on-trail etiquette for all trail users.
- Public participation geographic information systems (PPGIS) may be another helpful tool when determining how e-bikes are affecting a recreation area since they allow for public input on changes in conflict, displacement, and environmental impacts.
- Given the recent introduction of e-bikes into the outdoor recreation space, there is a paucity of research on e-bike management prescriptions. To further research in this field, we suggest follow-up studies from management agencies that have already decided upon the e-bike question in conjunction with empirical research that explores the efficacy of traditional management practices on e-bikes

Chapter 7: E-Bike Regulations on Federal, State, and Local Lands

This chapter will provide a brief overview of e-bike classification and regulation at the federal, state, and local levels on public lands, roadways, and bike paths. For further reference to any jurisdiction discussed below, please see the Appendix.

a. Federal Regulations of E-bikes

Low-Speed Electric Bicycles

Federal regulations governing e-bikes were set in 2002 by HB 727, which designated a low-speed electric bicycle as "A two- or three-wheeled vehicle with fully operable pedals and an electric motor of fewer than 750 watts (1 h.p.), whose maximum speed on a paved level surface, when powered solely by such a motor while ridden by an operator who weighs 170 pounds, is less than 20 mph" [222]. The designation of the 20 mph speed limit for e-bikes distinguishes them from motorcycles, mopeds, or other motor vehicles. As such, under the Consumer Product Safety Commission, e-bikes must meet the same safety standards as required for conventional bicycles. This law (15 USC 2085) allows for e-bikes to be pedal-assist (class 1) and throttle assist (class 2); however, it explicitly states that both styles of e-bikes must travel under 20 mph when propelled by the motor alone. An e-bike may travel above these speeds, as is the case with class 3 at 28 mph, but only from a combination of human and motor power. This standard and the subsequent regulations affect only the manufacturing and sale of the e-bike at the federal level. The designation of where e-bikes are allowed, however, falls under the state domain, giving local jurisdictions the right to restrict or allow e-bikes on streets and bikeways [223].

Other Power-Driven Mobility Devices (OPDMD)

Under an interpretation of ADA, e-bikes may be used as an OPDMD on certain public lands, along with electric wheelchairs, golf carts, and other devices that provide mobility assistance. This use allows people living with mobility challenges the right to access the same lands as every other person unless the area has been specifically designated as unsuitable for OPDMD use. However, this interpretation of the ADA is not uniform across U.S. land agencies (as discussed below); therefore, the list of accepted devices for use as an OPDMD may differ dependent on the trail or path location [224].

Regulation by the Department of the Interior (DOI)

A recent order by the Trump Administration will change all regulations currently in place on land regulated by the Department of the Interior (DOI). Secretary Order 3376 was signed on August 29, 2019, by U.S. Secretary of the Interior David Bernhardt, directing all DOI lands to maintain a consistent regulation of e-bikes and increase recreation opportunities for all people by exempting e-bikes from the definition of motorized vehicles [225]. Under the new proposed policy, class 1, 2, and 3 e-bikes are allowed everywhere conventional bikes can go on all National Park Service, National Wildlife Refuge, Bureau of Land Management, and Bureau of Reclamation lands. Each agency has 30 days from August 30, 2019, to develop a public proposal guiding implementation [226]. The law also states that local land managers have the authority to exclude e-bikes from certain bike facilities.

A summary of prior and current e-bike regulations for each of the agencies under the DOI is outlined below.

National Parks Service (NPS)

The August 2019 e-bike policy will allow e-bikes on all park roads, paved or hardened trails, motorized-use areas, and administrative roads where conventional bikes are currently allowed. However, the order mandates that the e-bike rider must be pedaling to use the electric-assist function except in areas where there is public motor vehicle traffic. In other words, class 2 e-bikes may only use the throttle function while in traffic, and not on bike trails or paths.

This policy followed a trio of decisions by Acadia, Arches, and Canyonlands National Parks (in Maine and Utah respectively) to restrict e-bikes from areas currently open to bicycle traffic. It is not clear whether these three National Parks will be able to maintain these prohibitions or if they will have to reverse their decisions following Order 3376 [227]. The order has been met with pushback from regulators and the public, who are frustrated with the lack of public process before the decision. In addition, this change may reinvigorate a fear held by a subset of the mountain biking community who worry that eMTB introduction on public lands and an associated increase in demands on federal agencies will roll back hard-won mountain-bike access in similar areas [228].

E-bikes are currently allowed on paved roads within U.S. National Parks and have grown in popularity, particularly within urban parks. E-bikes as a commuting tool are also encouraged for NPS staff in and around the park. This current use complies with NPS policy that regulates e-bikes as motorized vehicles, restricting them to roads where conventional bicycles and other cars are allowed. Per federally established rules, e-bikes are classified as such since they have an engine and are not exclusively human-powered. For this regulation to change in any park location, the superintendent of the park would be required to undergo a thorough cost-benefit review process that considers the NPS criteria of “appropriate use” for the vehicle in the designated space. These criteria include:

- Consistency with applicable laws, regulations, and policies
- Consistency with existing park plans for public use and resource management
- The actual and potential effects on park resources and values
- The total costs to the Park Service
- Whether the public interest will be served [229]

In regards to accessibility within the park system, NPS defines assistive devices as mobility aids that can be used both indoors and outdoors. This designation allows electric wheelchairs on all trails but does not permit e-bikes, since the latter is acceptable only for outdoor use.

In the 2018 NPS Active Transportation Guidebook, NPS acknowledges the benefits of e-bikes in increased access, utility, and emissions reduction. The handbook suggests that land managers for specific parks determine e-bike use on a trail-by-trail basis by considering surrounding resource characteristics, trail use volume, trail type and width, speed and safety, and soil conditions [230].

<u>Bureau of Land Management (BLM)</u>

Following the August 2019 Secretary Order 3376, e-bikes are no longer classified as motorized vehicles; however, local jurisdictions have authority as to where they are allowed, including BLM managed properties [231].

Prior to Order 3376, the BLM considered e-bikes as motorized vehicles under CFR

8340.5. They were prohibited on non-motorized trails, and thus allowed only on roads that permit cars, dirt bikes, and ATVs [232]. However, e-bikes are now allowed wherever conventional bikes are allowed [233].

National Wilderness Preservation System

Wilderness areas are closed off to conventional bikes, as areas must be considered “untrammeled” to received wilderness protections under the Wilderness Act. As such, e-bikes are not allowed in wilderness areas [234].

Regulation by the Department of Agriculture

United States Forest Service (USFS)

Under the Travel Management Rule (TMR), the USFS defines motor vehicles as “any vehicle which is self-propelled, other than: (1) a vehicle operated on rails; and (2) any wheelchair or mobility device, including one that is battery-powered, that is designed solely for use by a mobility-impaired person for locomotion, and that is suitable for use in an indoor pedestrian area.” 36 CFR 212.1[235]. Under this classification schema, e-bikes do not qualify as an Other Power-Driven Mobility Device (OPDMD) given that they are self-powered, not solely designed for use by a person with a mobility impairment and are not suitable for indoor use as a mobility tool. As such, under the TMR, e-bikes are regulated as motor vehicles and are subsequently allowed only on roads, trails, and other lands that have been recognized for motorized use.

Administrative units and ranger districts may introduce new opportunities for riding e-bikes as they update their motor vehicle use map (MVUM). However, any changes to management require environmental analysis and public participation prior to changes [236].

Special Permits – Ski Areas

E-bikes are currently allowed on the summer trail systems in multiple ski areas across the country. Such allowance is because of the ski area's special-use permit with the USFS, in which the leased land can allow e-bikes despite being on USFS lands. These trails often include lift-serviced downhill mountain bike parks as well as other trail networks for a diverse set of riders. Ski areas that currently allow e-bikes include Mammoth Mountain, Calif.; Steamboat Springs; and Purgatory Resort, Copper Mountain, Breckenridge, Keystone, Colo [237].

b. State Regulations of E-bikes

At the state level, e-bike laws are variable. About two-thirds of states have "model" or "acceptable" legislation (as designated by the Bicycle Product Suppliers Association and People for Bikes) on the books. "Model" legislation regulates e-bikes within the three-class tier system, whereas "acceptable" regulates e-bikes as a bicycle. The final one-third have no working legal classification or regulation surrounding e-bikes and their use. Such legislation mainly includes regulation of e-bikes on roadways and segregated pedestrian paths or greenways. Concerning e-bikes on trails and public lands, e-bikes are allowed in state parks across Colorado, Delaware, Florida, Louisiana, Missouri, Minnesota, North Dakota, New Mexico, and Utah in areas where bicycles are allowed [238]. In California, class 1 and 2 e-bikes are allowed everywhere where conventional bikes are so long as they have not been explicitly prohibited.

Similarly, Pennsylvania recently revised its guidelines, allowing for class 1 e-bike allowance on State Forest trails anywhere that a conventional bike is allowed. Wyoming State Parks is considering a similar policy and planning a pilot program to evaluate the effects of allowing class 2 e-bikes as well. Similar to Colorado, several of these states have also allowed for local jurisdictions the right to restrict e-bike use within cities and counties [239]. For more detailed information on other U.S. states, please see the appendix.

c. Colorado State Regulations of E-bikes

In Colorado, e-bikes are considered bicycles so long as they have two or three wheels, fully operable pedals, and an electric motor that does not exceed 750 watts. E-bikes are exempt from motor vehicle requirements, including license and registration. E-bikes must conform to the three-tier classification system and be labeled as such with the top assisted speed and motor wattage. Any updates or alterations to the original e-bike must be met with an updated label.

Class 1 and 2 e-bikes are allowed on the same pedestrian paths as conventional bicycles. Class 3 e-bikes can only be ridden on pedestrian paths if it is within a street or highway or permitted by the local jurisdiction. However, local jurisdictions have the authority to prohibit any and all e-bike use on bicycle or pedestrian paths at their discretion [240]. These alterations are summarized in Table 7.1 below

Table 7.1 E-bike allowance by trail type in several jurisdictions within Colorado

Jurisdiction	**Type of Trail/Area Where E-bikes are Allowed**			
	Natural Surface[1]	Improved Surface[2]	Paved	Motorized Use
U.S. Forest Service				I, II, III
U.S. Forest Service Special Use Permit	I, II			
Bureau of Land Management	I, II, III			I, II, III
National Park Service	I, II, III		I, II	I, II, III
Colorado Department of Transportation			I, II, III	
Colorado Parks and Wildlife	I, II		I, II	I, II
Boulder County Parks and Open Space*		I, II		
City of Boulder Multi-use Paths*			I, II	
City of Boulder Open Space and Mountain Parks				
City of Fort Collins*			I, II	
City of Durango Parks & Recreation*			I, II	
City of Grand Junction*			I, II	
Jefferson County Open Space*	I	I	I, II	
Larimer County Department of Natural Resources			I, II	
Roaring Fork Transportation Authority			I	
Summit County Open Space & Trails			I	
Eagle County Trails			I, II	
Village of Snowmass Transportation			I	
Town of Aspen Transportation			I, II, III	

*Pilot study conducted prior to management decision
[1]Natural Surface = Dirt trails with ongoing management
[2]Improved Surface = Crusher fines/gravel trail with ongoing management
I = Class 1 e-bike, II =Class 2 e-bike, III = Class 3 e-bike

Colorado Department of Transportation (CDOT)

CDOT has not adopted a formal policy following the 2017 state law change. CDOT has followed the prescription that e-bikes are allowed everywhere bicycles are allowed and haven't specified regions in which they are not. In the case of the US 36 bikeway, the path crosses five different local jurisdictions, each of which is responsible for setting its own policy and maintenance. To date, no involved jurisdiction has banned e-bike use on its section of the bikeway [241].

Colorado Parks and Wildlife (CPW) [242]

- E-bike use on CPW lands
  - Class 1 and 2 e-bikes are allowed the same access as road bikes and mountain bikes, while class 3 e-bikes are allowed only on roadways and in designated bike lanes.
- E-bike use on State Park Lands
  - Class 1 and 3 e-bikes are allowed on roadways, designated bikes lanes, multi-use trails, and other areas (e.g., campgrounds) that are open to non-motorized biking.
  - Class 3 e-bikes are allowed only on roadways and designated bikes lanes
- E-bike use on State Wildlife Areas
  - E-bikes are allowed on designated roads and within designated camping areas where motorized vehicles are allowed. They are prohibited in all other areas.
- E-bike use on State Trust Lands
  - E-bikes are allowed only on designated roads and when being used for hunting, fishing, and wildlife viewing.

d. Colorado Local Regulations of E-bikes

Following the state law change in 2017, local jurisdictions across Colorado have grappled with how to regulate e-bikes on their lands. Several communities have held pilot periods or community meetings, allowing for public comment and opinions. These public comment periods have been productive since each jurisdiction faces different constituents, land management ideologies, and trail systems. These confounding factors alter the way in which e-bikes fit into their broader recreation and community ideals. These effects are described below in several notable counties and communities across Colorado. Also included below are the basic demographics of the funding partners of this literature review, summarized in Table 7.2.

Table 7.2: Landscape overview of trail demographics for Boulder County 2019 e-bike pilot project funding partners[243]

Jurisdiction	Annual Visitation (Millions)	Conserved Acres	Public Access Acres	Total Trail Miles	Improved Surface & Crush-or-Fine Trails (Miles)	Paved Trails (Miles)	Natural Surface Trails (Miles)	Defintions of Passive Recreation (Y/N)	E-bike Pilot Study/Public Engagement Method
Boulder County POS	1.65	104,911	40,377	116	48.5	N/A	67.6	Y[1]	2019 Pilot Study w/ surveys, lit. review
City of Boulder OSMP	6.3	46,364	33,485	158	N/A	N/A	158	N[2]	2020 Proposed Review
Larimer County DNR	1.7	51,000	30,600	99	N/A	5-6	90+	N	Online Survey
City of Fort Collins NAD	unknown	36,650	35,644	124.6	N/A	20.6	104	N[3]	Pilot Study w/ Surveys, Education & Outreach

1. Boulder County POS: Passive recreation, referred to in the *Open Space Element* policies, is traditionally defined as non-motorized outdoor recreation with minimal impact on the land, water, or other resources that create opportunities to be close to nature, enjoy the open space features, and have a high degree of interaction with the natural environment. Further, • Passive recreation requires no rules of play or installation of equipment or facilities, except for trails and associated improvements. • Passive recreation includes activities such as hiking, snowshoeing, cross-country skiing, photography, bird-watching, or other nature observation or study. • If specifically designated, passive recreation may include bicycling, horseback riding, dog walking, boating, fishing, or riding e-bikes. • Though passive recreation is traditionally non-motorized, the sustainability and inclusion benefits of electrical-assist modes align with Boulder County's mission and goals. Such modes may be considered for designated use if: • Travel speeds are comparable to non-motorized modes, or are dependent on the user's condition, skill, terrain, trail conditions, and weather, and Noise is no greater than that generated by non-motorized modes or other permitted uses, and Potential trail damage is no greater than that caused by similar non-motorized modes or other permitted uses and can be mitigated through management actions such as trail closures, and Potential impacts to land, water, other resources, and visitors are no greater than those caused by similar non-motorized modes or other permitted uses.
2. City of Boulder OSMP: Passive recreation is identified as a purpose of OSMP, among other things, in the Boulder City Charter. Although the City Charter never precisely defines passives recreation, it does mention several "passive" recreational activities, including hiking, nature study, and photography. Three other recreational activities are listed in the City Charter as appropriate passive recreation under certain conditions--bicycling, fishing, and horseback riding.
3. City of Fort Collins NAD: NAD does not have a formal definition of "passive recreation." However, it is traditionally interpreted as activities including hiking, bird watching, photography and the like.

Boulder County Parks and Open Space (BCPOS). In December 2018, Boulder County Commissioners approved a one-year pilot study to allow e-bikes on specific county open space trails on the plains starting January 1, 2019. During the pilot period, staff studied visitor and trail impacts of e-bikes on county trails through an intercept survey, speed observation study, phone survey, trail evaluation, and this literature review. The goals of this pilot study included investigating demographics, use patterns, visitor use impacts, and trail impacts related to e-bikes. This information informed the November 2019 policy decision to allow class 1 and class 2 e-bikes on most trails in the plains where regular bicycles are allowed.

Boulder County Speed Observation Results:

Speed observations were recorded starting in June until mid-September. During this period, a total of 504 speed observations were taken, with 491 conventional bikes and 12 e-bikes. There were 2 recumbent bikes observed and a single one-wheeled skateboard; however, their speeds were omitted from the speed analysis. Given that total e-bike observations were a fraction of the overall speed observations, at just12 total e-bike observations, this data should not be broadly interpreted, nor should it be used as evidence for a speed differential between conventional bikes and e-bikes. When incorporating these conclusions into policy recommendations, it is imperative that the limitations of this data be considered.

- **Average Speed by Bike Type:** The average speed for all bikes was 14.8 mph. The average e-bike speed was 13.8 mph, while the average conventional bike speed was 14.9 mph.
- **Average Uphill and Downhill Speeds by Bike Type:** For uphill speeds, conventional bikes were 12.9 mph, while e-bikes were 13.8 mph. For downhill speeds, conventional bikes were 15 mph, while e-bikes were 13.5 mph.
- **Speed Observations on US 36 Bikeway:** The average speed for conventional bikes was 15.7 mph, while e-bikes were 16.9 mph.

City of Boulder Open Space and Mountain Parks (OSMP). In 2014, the City of Boulder passed an ordinance allowing e-bikes on paved, multi-use paths within the city. The ordinance does not allow e-bike use on OSMP trails per the City Charter, which limits trail-use to non-motorized, passive recreation and, therefore, excludes the use of e-bikes given their motorized status. In addition, the ordinance mandated that the management responsibilities for all underlying OSMP trail segments dispersed within the city's multi-use path network be transferred to the City Transportation Department and Greenways program. The City of Boulder anticipates reviewing its e-bike policy on OSMP lands in 2020 [244].

Larimer County Department of Natural Resources (LCDNR). LCDNR allows class 1 and 2 e-bikes on paved trails under its jurisdiction. These trails traverse five to six miles through three of the 10 county open spaces designed to allow a higher level of use and also connect other regional trail corridors. LCDNR does not allow motorized use, including e-bikes of any class, on its park and open space natural surface trails. Following the state's new regulation, LCDNR does not currently have a definition of passive recreation within its guiding document [245].

City of Fort Collins Natural Areas Department (NAD). On April 19, 2019, the City of Fort Collins City Council approved a one-year e-bike pilot program allowing e-bikes on paved trails beginning May 1, 2019. The impetus for the pilot was prompted by the rising popularity of e-bikes and the 2017 state law that allowed e-bikes on trails statewide unless otherwise restricted by a local jurisdiction. The pilot program does not allow e-bikes on any unpaved trails and permits only class 1 and 2 e-bikes on paved trails within the city. Throughout the pilot, the city plans to conduct extensive community outreach, education. and evaluation. This decision was endorsed by several city committees and unhindered by an informal definition of passive recreation on NAD's trail system [246].

Jefferson County (Jeffco) Open Space. Following a 2018 pilot period that involved extensive community outreach, including surveys, demo-days, and collaboration with local bicycle organizations, Open Space adopted a permanent policy allowing class 1 e-bikes on all Open Space managed lands and class 1 and 2 e-bikes on all paved trails under its jurisdiction [247]. Anecdotally, Jeffco managers have encountered very little pushback from its trail users over this change and have qualified e-bike introduction and subsequent propagation as a current non-issue.

Roaring Fork Transportation Authority (RFTA). In 2018, Pitkin County Open Space and Trails worked in conjunction with RFTA to conduct a one-month public process project gathering public opinions about e-bike allowance on 42 miles of paved trails within the Rio Grande Trail network from New Castle to Aspen. The project included electronic and paper surveys and comment cards regarding class 1 and 2 e-bikes. The project partners also hosted community demo events for community members to ask questions, fill out surveys, and test out e-bikes [248]. Following the public comments period, class 1 and 2 e-bikes are allowed on the Rio Grande Trail between Two Rivers Park in Glenwood Springs and the Pitkin County line at Emma Road in Basalt. Only class 1 e-bikes are allowed from Emma Road to Aspen, thus the entirety of the trail system [249]. The Rio Grande Trail does maintain a 20-mph speed limit for all bikes and mandates that all cyclists ride single file.

Eagle County. Eagle County allows e-bikes per the prescription of Colorado state law [250]. Within Eagle County, the town of Vail allows e-bikes on certain recreation paths for a six-month trial period that started on July 12, 2019. During the trial period, class 1 and 2 e-bikes with motors of 500 watts or less are allowed. E-bikes may be operated only by those age 16 and older. In addition, the town has identified several "blackout zones," or areas where e-bikes must disengage their pedal or throttle-assist function. These zones include sections of trails within and immediately outside of the town center. The trial period was enacted in order to accommodate several bike rental companies that operate during the summer tourism season and to encourage the use of sustainable transportation by Vail guests and residents [251].

Summit County. Summit County is not currently considering eMTB use on natural surface trails. These restricted areas have been designated for non-motorized use and include trails under the jurisdiction of Summit County, the town of Breckenridge, and the Forest Service. However, class 1 eMTB's are allowed on the Recpath, Frisco Peninsula Recreation Area, and all roads open to other motorized uses. Additionally, class 1 eMTB's are allowed on trails at Copper Mountain, Breckenridge, and Keystone Ski Areas.

This decision follows a public engagement period in which the Summit County Board of Commissioners and the Open Space & Trails Department gathered public input via open houses and an online survey, which included more than 1,000 responses. The final decision from all community input codified class 1 e-bikes as acceptable, while class 2 and 3 are prohibited.

Summit County allows class 1 e-bikes to be allowed as an OPDMD and adheres to the following regulations: (the e-bike) “has a maximum power-driven speed equal or less than 20 mph, is no wider than 36 inches, and has brakes that enable the operator to make the wheels skid on the dry, level and clean pavement. No Other Power-Driven Mobility Devices (OPDMD) may be used, including but not limited to any gas or combustible fuel-powered devices, ATV’s, golf carts, or motorcycles. Wheelchairs and manually- powered mobility aids are allowed.” [252].

Towns of Durango and Grand Junction. Following a one-year pilot study in the Town of Durango, e-bikes are allowed on paved trails. The decision came after Durango’s Parks and Recreation Department didn’t receive a single negative public comment regarding e-bike presence. Durango allows class 1 and 2 e-bikes on paved trails but restricts class 3 to roadways and designated bike lanes. The town has indicated that it will explore the possibility of opening the non-paved trails to e-bikes in the future [253].

Similarly, the City of Grand Junction will allow class 1 and 2 e-bikes on its paved trails. This decision follows a year of public outreach that included extensive conversations among local bike groups, the public, and government officials [254].

e. Notable Local Regulations Across the Country

Maricopa County, Ariz., and Santa Clara County, Calif., currently allow class 1 and 2 e-bikes wherever bicycles are allowed, while other jurisdictions, such as Boise, Idaho, and the encompassing Ada County, regulate class 1 and 2 as conventional bikes, but allow only class 1e-bikes on a 125-mile path system respectively [255]. Park City, Utah, allows e-bikes on all paved multi-use trails as well as soft-surface trails wider than five feet. The city also mandates a 15-mph speed limit for all trail-users.

f. Conclusion: Local Jurisdictional Change and Follow-up Research

- Agencies at all levels are currently at their most receptive to user, visitor, and community demand. However, there must be concentrated public demand if there is to be an impetus for revised regulations [256].

- As of this writing, the roll-out of these policies across the country hasn't been empirically documented, and the existing evidence of how these communities are receiving e-bikes is anecdotal.
- Class 1 e-bikes are generally considered the most akin to a conventional bicycle, and therefore, the most generally accepted. It is also evident that the agencies or municipalities that have allowed e-bikes on paths or trails have done so with accessibility and congestion-reduction in mind.
- Several Colorado agencies, including City of Boulder, Jefferson County, Boulder County, Grand Junction, Durango, and the City of Fort Collins, also used pilot studies as a means of engaging the public and trying on policies before they are implemented [257].

Chapter 8: Conclusion

Since e-bikes have entered the outdoor recreation scene, there have been both early adopters of the technology and those who are adamantly opposed to widespread use. For each side, there are multiple reasons behind their attitudes concerning e-bikes, including perceptions of speed and safety, their influence on accessibility/crowding, and their impact on the trails themselves.

Jacob and Schreyer's theoretical model of conflict highlights the asymmetrical nature of the conflict between trail users, citing that one group of trail users has negative attitudes toward another group, while the reverse isn't always true. In the research surrounding how this model affects relationships among bikers, e-bikers, and pedestrians, it appears that pedestrians maintain a similar relationship to e-bikes as they do to conventional bikes, frequently citing concerns about the speed, safety, and on-trail etiquette of e-bikes. This relationship demonstrates an asymmetrical conflict. Whether this attitude is perceived or reflects actual conflict is up for debate. Proposed remedies include several types of education and outreach, use allocation and rationing, and behavior enforcement options that may alleviate potential conflict.

Education and outreach campaigns that focus on etiquette and on-trail behavior may help to reduce situations in which a cyclist or e-biker is perceived as displaying inconsiderate or risky behavior toward another trail user. In the same vein, hikers, runners, and walkers may benefit from learning how to change their behavior while hiking in groups, with music, or with dogs, thereby minimizing their role in conflict scenarios. As another education option, e-bike demos have the potential to inform and possibly change users' perceptions of the e-bikes themselves and their place on the road.

Use allocation and rationing management tactics, including spatial and temporal strategies, such as biker- or hiker-only days and single-use trails, may be another option to reduce potential conflict points. However, these strategies may be resource-intensive because of higher levels of enforcement required to maintain spatial and temporal segregation. In addition, shifting an area from multi-use to single-use may require the building and management of additional trail miles.

As another option, enforcing behavior may reduce conflict between users. Instituting a courtesy speed limit may self-regulate users to travel at safe speeds for trail conditions.

Maintaining a suggested speed for all users may reduce the speed differential between the two bike types. Even if the limit isn't enforced, the presence of an expectation for bike speeds may slow down users. As to research on the riding behavior of e-bikes compared to conventional bikes, there isn't a clear consensus of whether or not e-bikes travel at faster average speeds. This approach of using speed signs has proven successful for the City of Fort Collins, which adopted it shortly after Boulder County started its pilot study. As to research on road types, some studies found e-bikes to be faster on roads but slower on paths, and others found their speeds to be largely comparable.

Another commonly cited concern regarding e-bikes is the perception that they will increase crowding. Current research shows that most early e-bike adopters were already regular cyclists, suggesting that e-bikes are not appealing exclusively to an entirely new user group. In addition, outdoor recreation as a whole, especially along the Front Range of Colorado, is gaining popularity. It is likely that crowding as a result of this increase will occur regardless of whether e-bikes are allowed in select areas. Given the inevitable increase of trail users, it is recommended that managing for increased annual visitation rather than restricting the use of a select group of users is more practical and equitable.

As for maintaining equitable trail opportunities, one of the most frequently addressed benefits of allowing e-bikes is the increased access to trails. Since e-bikes allow more inclusive populations to ride farther and up steep inclines, more people can enjoy the biking experience. An increased number of e-bikes may also benefit the transportation sphere through reduced road congestion and emissions. E-bikes may also reduce the adverse effects of weather, aid in rider confidence while navigating roadways and intersections, and enable families and/or friends to ride together regardless of physical ability or age.

In terms of impact to trails, one study analyzed potential differences in trail impacts between mountain bikes, eMTBs, and dirt bikes. Although the study was conducted in a very specific environmental setting, the results suggest that eMTB's and mountain bikes have similar trail impacts, both of which are far less damaging than the impacts from dirt bikes. Research results on ecological impacts are mixed. According to recreation ecology research, most forms of recreation have a disruptive and potentially harmful impact on wildlife. Some evidence suggests that motorized recreation has a higher impact (e.g., the distance at which motorized uses are found to cause disturbance is smaller compared to non-motorized recreation). Other research suggests that motorized recreation causes less disturbance because vehicles move through an area more quickly and their travel behavior is more predictable (they are more likely to stay on trail compared to non-motorized modes), with the result that wildlife may be more able to adjust to them; however, motorized users may also penetrate farther into back-country areas, thus distributing impacts over a larger area. Research also suggests that non-motorized users have more frequent occurrences with wildlife than motorized uses, which could result in more impacts. Furthermore, exposure to long-term recreation activities (greater than one year) has a substantial impact on abundance, suggesting that repeated human disturbances can have a cumulative effect on wildlife.

A final consideration when analyzing the results of empirical research and pilot studies is whether or not the findings are specific to e-bikes or if they apply to conventional bikes as well. This notion is perhaps most important when evaluating the results of pilot studies in areas in which the market penetration of bikes compared to e-bikes is significantly different, in which case trail users may project their perception of conventional bike behavior onto e-bikes. Given that NIMBY and emerging technology research demonstrates likely resistance to change following the introduction of a new technology or management prescription, especially if it is in a neighborhood or local area, it is vital to understand who is resistant to change. With that understanding, land managers can make more informed, equitable decisions on how to balance the benefits of e-bikes vs. the costs, and how to communicate effectively about e-bikes with constituents.

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