PORTLAND OFF-ROAD CYCLING MASTER PLAN

Task 3.2

Assessment of Off-Road Cycling Impacts and Benefits

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Overview

Development of the Portland Off-Road Cycling Master Plan requires understanding the impacts and benefits of off-road cycling. This document presents a survey of studies of these impacts and benefits, related to:

- The environment (e.g. wildlife, vegetation, soil, and water resources, including streams and wetlands)
- The health and safety of park and trail users, including user conflicts and perceived nuisance activity
- The City's economic activity and tourism.

This document summarizes the research findings for each subject area and identifies some limitations and gaps in the research.

This survey will inform the site suitability criteria and site feasibility assessment as well as the development of best management practices and policy recommendations in the Master Plan.

Impacts on the Environment

This section focuses on the environmental impacts of off-road cycling. Where available, research specific to off-road cycling is presented. In some cases, broader research on recreational trails is also presented. This section follows a commonly used framework in the literature that breaks these impacts into four main categories:

- Soil – soil erosion, compaction and water runoff.
- Vegetation – plant health, structure, diversity and composition.
- Wildlife – mortality, habitat disturbance and behavioral stress.
- Water – water quality and alterations to aquatic and riparian habitats.

The review also summarizes the available research on off-road cycling impacts relative to other outdoor recreational activities such as hiking and horseback riding.

The body of published research on the environmental impacts of off-road cycling is limited compared to the research on recreational activities such as hiking (Marion and Wimpey 2007, Davies and Newsome 2009, Pickering and others 2010). Research has focused on soil erosion and related impacts, with a secondary focus on vegetation impacts such as trampling. In one of the more recent literature reviews, Quinn and Chernoff (2010) found no published research specifically on the impacts of off-road cycling on water resources. As noted by several authors, more study on the timing, duration, intensity and spatial distribution of various types of recreational activities would be useful.

Most research on the environmental impacts of off-road cycling focuses on cross-country cycling, with limited published research covering other off-road cycling disciplines such as freeride, downhill, dirt jumps and bike parks. Such research would improve understanding of the environmental effects of the other styles and make comparisons between them possible. However, some facilities such as bike parks could be assumed to have similar impacts to other intensive recreational facilities such as playgrounds or sport courts.

Based on this research, the Portland Off-road Cycling Master Plan proposes a suite of best management practices intend to avoid, minimize, and/or mitigate potential negative impacts and maximize potential benefits. As the body of research is not comprehensive and may evolve over time, the best management practices include monitoring and adaptive management of sites to address unintended impacts. These best management practices can be found in the *Survey of Design, Planning and Management Best Practices for Off-Road Cycling Facilities*, available under separate cover.

Impacts on Soils

KEY FINDINGS

- The available data indicate that off-road cycling, when limited to established trails, has a similar impact on soils to hiking, and a lower impact than horseback riding.
- Frequency of unpermitted off-trail activity by mountain bikes was the greatest cause of adverse soil and vegetation impacts.
- Trail design and landscape factors may have more potential to affect soils than the nature of the trail activity.
- Trails slopes of 12% to 15% are a threshold for significant increases in soil impacts.
- Trails with slopes greater than 12% are strongly correlated with significant increase in impacts to soil and vegetation.
- Cross-slope trails have lower erosion and runoff potential than fall line trails.

According to Marion and Wimpey (2007), the creation and use of trails for recreational activities results in soil disturbance via compaction, muddiness, displacement, and erosion. Soil is generally displaced from the tread center of a trail to the sides, building up soils on the uphill side and compounding drainage problems. Sediment can be carried directly into watercourses, creating impacts to aquatic systems.

The available data indicate that off-road cycling, when limited to established trails, has a similar impact on soils to hiking, and a lower impact than horseback riding. Biking trails that encourage high numbers of users (such as may occur for competitions) may raise the impact levels significantly.

One of the earliest studies of the environmental impacts of off-road cycling was conducted by Wilson and Seney (1994) and focused on soils. The authors studied the potential erosive impacts (water runoff and sediment yield) of four different user types (horses, hikers, mountain bikes and motorcycles) on a national forest trail network in Montana. They found that horses produced significantly larger quantities of sediment compared to hikers, off-road bicycles, and motorcycles. While acknowledging limitations with the study's methodology, the authors concluded that both horses and hikers had a greater erosive potential than wheeled activities such as off-road bicycles and motorcycles, and this impact was most pronounced on wet soils and when going downhill. Other studies cited by the authors found that hikers and horses tend to loosen soil when descending a steep trail because greater forces are applied when decelerating and moving down a steep trail.

Several later studies have assessed soil impacts, including soil erosion, displacement, and compaction (Thurston (1998), Thurston and Reader (2001), Chiu and Kriwoken (2003), Marion and Olive (2006), White and others (2006)). Under the conditions tested, these studies generally found no significant

difference in the effects on soils between off-road cycling and hiking, with White also noting the greater damage that may be caused by horses.

However, several studies have found that the landscape characteristics of a trail can be significant determinants of the extent of soil degradation. For example, trail slope is a key factor influencing the potential impacts to soil and vegetation on recreational trails (Wilson and Seney 1994, Bjorkman 1998, Goeft and Alder 2001, Morlock and others 2006). Marion and Wimpey (2007) found that erosion rates on trails with 0-6 percent and 7-15 percent grades were similar, while erosion on trails with grades greater than 16 percent were significantly higher. Some studies (Marion and Wimpey 2007, Marion and Olive 2006) identified a 15% slope as a threshold for significant increases in soil impacts, while Morlock and others (2006) found that slopes greater than 12% were strongly correlated with higher degradation of soil and vegetation. Cross-slope trails have lower erosion and runoff potential than fall line trails (Marion and Wimpey 2007, Marion and Olive 2006, White and others 2006).

Variables such as soil composition, shade and moisture also influence the potential erosion and compaction impacts from recreational activities, including off-road cycling (Marion and Olive 2006, Morlock and others 2006, Marion and Leung 2001, Bjorkman 1998). These studies suggest that trail design and landscape factors may have more potential to affect soils than the nature of the trail activity.

From their studies in the Southwest U.S., Morlock and others (2006) noted that the frequency of unpermitted off-trail activity by mountain bikes was the greatest cause of adverse soil and vegetation impacts. The authors noted that for the 31 trails studied, there were 106 unpermitted off-trail, or "demand" routes identified. They concluded that the ecological impact of unpermitted off-trail routes was the primary argument for limiting mountain biking access to public lands. In related research in Perth, Australia, Newsome and Davies noted a similar management concern related to unpermitted off-trail mountain bike impacts (Pickering and others 2010).

Impacts on Vegetation

KEY FINDINGS:

- All trail-based recreational activities have the potential to negatively impact vegetation, especially on unestablished trails.
- Most impacts occur with initial trail construction and use, with a diminishing increase in impact associated with increasing use over time.
- Vegetation trampling/removal and soil erosion/compaction are closely linked impacts.
- Removal of vegetation is an inherent consequence in trail construction but that accelerated soil erosion becomes the primary impact once vegetation is lost.

All trail-based recreational activities have the potential to negatively impact vegetation, especially on unestablished or demand trails. Marion and Wimpey (2007) found that the action of crushing or treading upon vegetation, either by foot, hoof, or tire, contributes to a wide range of vegetation impacts, including damage to plant leaves, stems, and roots, reduction in vegetation height, change in the composition of species, and loss of plants and vegetative cover. Most impact occurs with initial or low use, with a diminishing increase in impact associated with increasing levels of traffic.

Vegetation trampling/removal and soil erosion/compaction are closely linked impacts, as soil compaction can restrict plant water and nutrient uptake and limit root penetration. As such, these impacts are often studied together. Several of these joint studies are noted in the preceding section on soils. Wilson and Seney (1994) found that removal of vegetation is an inherent consequence in trail construction but that accelerated soil erosion becomes the primary impact once vegetation is lost.

Research on the specific impacts of off-road cycling on vegetation is limited, and more focused vegetation studies are recommended in the literature. Researchers recommend management practices that focus on impact avoidance, particularly in areas of rare plants and sensitive habitats, and the use of low impact trail construction practices.

Marion and Wimpey (2007) found only one study specifically addressing vegetation effects associated with off-road cycling. This was the Thurston and Reader (2001) study described below. Most of the other research on vegetation addresses impacts from the construction and use of recreational trails in general, without differentiating uses.

Thurston and Reader (2001) constructed an experiment wherein mountain biking and hiking were applied to adjacent, previously undisturbed sample plots in Boyne Valley Provincial Park in Ontario. The authors set up two identical lanes of travel over natural vegetation in a deciduous forest. Hikers and bicyclists were then allowed to travel the lanes, at five different intensity levels. The researchers then measured changes in plant stem density, species richness, and soil exposure before, shortly after, and a year after treatment.

In general, recreational use of the lane of travel resulted in 100% removal of vegetation, and up to 54% increase in exposed soil. The authors' key findings included: "First, impacts on vegetation and soil increased with biking and hiking activity. Second, the impacts of biking and hiking measured here were not significantly different. Third, impacts did not extend beyond 30cm of the trail centerline" (Thurston and Reader, 2001, p.405). One limitation of the study noted by Pickering and others (2010) was that the experiment methodology may only reflect "optimal" riding behavior.

Studies have found that recreational activity contributes appreciably to the loss in vegetation and native biodiversity, but that additional study is needed to assess the scale of the issue and distinguish between different types of recreational use. (Quinn and Chernoff 2010) A recent thesis by Pankiw (2011) studied the effects of varying degrees of long-term recreational trail use on vegetation communities in Ontario, Canada. The author found that trail-influenced environments experienced significant shifts in composition and reductions in species diversity. If conserving species diversity is a major concern,

managers should consider either closing trails or concentrating their use since spatial impacts are large and changes to composition inevitable.

The spread of invasive plant species has been documented for hikers and equestrians through the spread of seed that attaches to shoes, clothing, animal coats and hooves, and particularly dung. Quinn and Chernoff (2010) and Pickering and others (2010) found no published studies specifically addressing the dispersal potential of mountain biking. This is another research gap identified by researchers.

Several researchers have noted that additional studies differentiating between the effects of various types of recreational use on vegetation and native biodiversity would be helpful.

Impacts on Wildlife

KEY FINDINGS:

- Wildlife disturbance can extend much further into natural landscapes than other forms of trail impacts, which tend to be limited to the narrow trail corridor.
- The research on wildlife impacts focuses on a limited set of bird and mammal species, and the results appear to differ depending on the species studied.
- For some species, disturbance from mountain biking trail use on foraging and nesting behavior may be minimal, but fragmentation and alteration of habitat by mountain biking trails may reduce quality of nesting habitat.
- Wildlife impacts can be reduced by ensuring that trails avoid sensitive or critical wildlife habitats, including riparian corridors and wetlands.
- Additional studies of the impacts on wildlife habitat, including special status habitats and rare plant and animal communities are needed. There also is a gap in information on the cumulative impacts of recreational activities in natural areas, both urban and rural.

The research on the impacts of trails on wildlife focuses on a limited set of bird and mammal species. The research results appear to differ depending on the species studied. Additional studies of the impacts on wildlife habitat, including special status habitats such as interior forest or rare plant and animal communities, are needed. There also is a large gap in information on the cumulative impacts of recreational activities in natural areas, both urban and rural.

Marion and Wimpey (2007) note that while most forms of trail impacts tend to be limited to the narrow trail corridor, wildlife disturbance can extend further into natural landscapes. Recreational activities can cause stress and alter wildlife behavior, modify wildlife habitat, and directly injure or kill wildlife through collision.

The research on the off-road cycling impacts on wildlife addresses particular species of birds and large mammals. For example, Taylor and Knight (2003), studied the response of bison, mule deer, and pronghorn antelope to hikers and mountain bikers in Antelope Island State Park, Utah. They compared alert distance, flight distance, and distance moved by each species. The authors did not find a significant difference between hikers and mountain bikers with respect to the reaction of any of the three species to their presence. Papouchis and others (2001) studied the behavioral responses of desert bighorn sheep to disturbance by hikers, mountain bikers, and vehicles in Canyonlands National Park. The authors found that sheep fled from hikers in more than half of the human/sheep interactions, but had a significantly lower flight response to vehicles and mountain bikers. The stronger reaction to hikers was attributed to more off-trail hiking and direct approaches to the sheep.

Naylor and others (2009) reached a different conclusion studying female elk in Starkey Experimental Forest and Range in northeast Oregon. During control periods in this study, elk fed and rested with little time spent traveling. The authors found that while travel time increased in response to all recreational disturbance, horseback riding and hiking elicited lower travel times than mountain biking and all-terrain vehicle riding. Both mountain biking and hiking were shown to reduce resting time for elk.

Davis and others (2010) studied the foraging and nesting behavior, territory size, and nest success of Golden-cheeked Warblers, a federally endangered species that breeds exclusively in the mature juniper woodlands of central Texas. The authors conducted the study along trails at two mountain biking sites and two "non-biking" control sites where all recreational activities were restricted. The authors found that nest abandonment was three times greater in biking areas than non-biking areas. They conducted behavioral observations and found that the disturbance from mountain biking trail use on foraging and nesting behavior appeared to be minimal, but fragmentation and alteration of habitat by mountain biking trails may reduce quality of nesting habitat. They concluded that conservation efforts that curtail construction of new mountain biking trails in Golden-cheeked Warbler habitat and reduce the amount of forest open edge habitat created by existing mountain biking trails should promote recovery objectives for the species.

In a study along the Boise River in Idaho, Spahr (1990) assessed the flushing distances of bald eagles when exposed to actual and simulated walkers, joggers, fishermen, bicyclists, and vehicles. The author found that walkers were the most disturbing to eagles, and bicyclists, followed closely by fishermen, were the next most disturbing. Eagles were most likely to flush when recreationists approached slowly or stopped to observe them, and were less alarmed when bicyclists or vehicles passed quickly at constant speeds.

In their discussion of management implications, Marion and Wimpey (2007) suggest that wildlife impacts can be minimized by ensuring that trails avoid sensitive or critical wildlife habitats, including those of rare species, and riparian and wetland areas. Specifically for Portland, the City's Natural Resource Inventory (NRI) notes functional riparian widths (each side of stream) for wildlife including willow flycatcher (123'), frogs and salamanders (100'), deer (200'), smaller mammals (214-297'), birds (246-656'), beaver (300'), geotropically migratory birds (328'), pileated woodpecker (450'), and general wildlife habitat (100-600').

Impacts on Water Resources

KEY FINDINGS:

- Trails can introduce soils, nutrients, and pathogens, increase water turbidity and sedimentation, alter patterns of surface water drainage, and divert water sources that serve important ecological functions.
- Very little research exists on the specific impacts of off-road cycling on water resources.
- However, several references – both local and national – provide useful guidelines for planning, design and management of trails near these sensitive resource areas.

According to Marion and Wimpey (2007), trail-related impacts to water resources can include the introduction of soils, nutrients, and pathogenic organisms (e.g., Giardia), and altered patterns of surface water drainage. Eroded soil that enters water bodies increase water turbidity and cause sedimentation that can affect aquatic organisms. Salmon, trout and other fish lay their eggs in gravels on the bottom of streams, and sediments can smother those eggs, reducing reproductive success. Sedimentation can also harm invertebrate organisms, which serve as food for fish and other organisms. Trails can intercept and divert water from seeps or springs, which serve important ecological functions.

Current research has not specifically addressed the effects of off-road cycling on water resources, including streams, wetlands and riparian areas. However, other studies on trail-related impacts and design and management strategies can be instructive. Marion and Wimpey (2007) recommend avoiding placing trails in close proximity to water resources, including riparian or wetland areas. Where stream crossings are necessary, the stream should be carefully scouted to determine the most sustainable crossing location, and low impact crossings such as bridges may be warranted. Design and management strategies to limit soil loss from trails are recommended (Marion and Wimpey 2007). Local handbooks, such as Metro's *Green Trails: Guidelines for Environmentally Friendly Trails* (2004), provide useful guidance to planning and design of trails near sensitive water resource areas.

Impacts on Human Health and Safety

KEY FINDINGS

- Participation in outdoor recreation, including off-road cycling, can improve participants' physical and mental health. A positive recreational experience can inspire more use and benefit.
- Bicycling is a top gateway activity that results in an increase in outdoor activity.
- The frequency of injuries in mountain biking is comparable to that in other outdoor sports and the majority of injuries are minor. Riding within one's ability level, using properly maintained bicycles, and wearing helmets and other protective equipment can reduce the risk and severity of injuries.
- Actual and perceived conflicts between different user groups, such as off-road cyclists and hikers, is a potential impact of shared-use trails. Trail education and awareness reduces perceived and actual conflicts between user groups.
- Off-road cycling trails, along with other site improvements, have been successfully used to reduce or eliminate nuisance activities on public properties. Such uses can contribute to real or perceived health and safety threats.

Human Health

There is a large body of research in the United States that links physical activity and active outdoor recreation, such as off-road cycling, to improved physical and mental well-being (Outdoor Foundation, 2011; RTSG Neuroscience Consultants and Specialized Bicycles, 2013). In Multnomah County, 21% of adults are obese, 13% get no leisure-time physical activity, and the average resident reports 4 days of poor mental health in the past month (County Health Rankings, 2016).

Physical activity

Physical activity, at any level, has been shown to improve both physical health and quality of life. Off-road cycling provides all of the three main kinds of physical activity, aerobic, muscle strengthening, and bone strengthening, and each have associated health benefits.

In children and teens, physical activity can improve bone health, cardiovascular and muscular fitness, reduce body fat and the risk of overweight or obesity, and reduce rates of illness and recovery time.

Impacts among adults include lowered risks of early death, heart disease, stroke, high blood pressure, diabetes, depression, and certain types of cancer. For most health outcomes, benefits increase as the amount of physical activity increases through higher intensity, frequency, or duration. All types of people can experience benefits from physical activity, including children and adults, people of various racial and ethnic backgrounds, and people with various disabilities (Office of Disease Prevention and Health Promotion, 2008 and Godbey 2009).

There is limited research specifically on the physical activity-related benefits of off-road cycling. However, the National Interscholastic Cycling Association's (NICA) 2013 Participation Study polled hundreds of student-athletes, parents and coaches, and found that participation in the NICA high school mountain biking program led to improved youth fitness. Nearly all (96%) of survey respondents reported that their health and physical fitness improved because of their participation in the league. The NICA survey also found that student-athletes inspired their parents and siblings to start riding. Similarly, the Outdoor Foundation (2011) found that bicycling is a top "gateway" activity, resulting in participants being more likely to participate in another outdoor activity.

Mental Health

Outdoor recreation, particularly in natural spaces, has also been shown to reduce acute and chronic stress, reduce symptoms of depression, and improve mental health. There is a statistically significant reduction in stress through the use of urban green spaces, regardless of the person's age, sex, or socioeconomic status (Godbey, 2009).

There is limited research that focuses specifically on the impact of off-road cycling on mental health. RTSG Neuroscience Consultants and Specialized Bicycles (2013) studied the effect of bicycling on youth Attention Deficit Hyperactivity Disorder (ADHD) in 54 students at two middle schools in Massachusetts. They found that cycling improves cognition, attention, mood, fitness and decreases impulsivity. Further, the study found that bicycling accelerates cognitive performance in the near term and long-term. Limitations of this study were that it did not evaluate the effect of *additional* exercise in the student's schedules, and also did not account for subjects' ADHD diagnosis percentages. While this study collaborated with Specialized Bicycles and was funded by the Specialized Foundation, its findings corroborate results found in other peer-reviewed studies (Foundation Acta Paediatrica, 2014; Gapin, J. 2010).

Safety

Mountain biking presents a risk of physical injury, though such risk is common to road cycling as well as many other recreational and competitive sports and activities (Gualrapp, et. al., 2001 and Pons-Villanueva, et. al., 2007). The frequency of injuries in mountain biking is comparable to that in other outdoor sports, and the majority of injuries are minor (Gaulrapp et. al., 2001). Various studies have found overall injury rates of approximately 1.0 to 1.5 injuries per 1,000 hours of participation (Gaulrapp

et. al., 2001 and Aitken et. al, 2011). Rates are higher during participation in competitive events, increasing to 3.7 injuries per 1000 hours participation for cross-country events and 4.3 injuries per 1000 hours participation in downhill events (Carmont, 2008). Minor injuries, including soft-tissue abrasions, lacerations and contusions, represent the most common mountain biking injuries (60-75% of all injuries) (Carmont, 2008 and Gaulrapp, et. al. 2001). One in ten injuries is severe enough to require a hospital visit (Gaulrapp et. al., 2001). While more serious injuries, including fractures and injuries to the head and neck, can occur, most injuries are minor and can be minimized through safety precautions.

The main risk factors for injury include excessive speed, loss of control or traction, mechanical problems, inappropriate or improperly adjusted equipment, competitive activity, and riding beyond the physical ability, fitness level, or experience of the rider (Carmont, 2008 and Aleman and Meyers, 2012).

To reduce risk of injury, Carmont (2008) recommends that riders should be well trained, ride within the level of their capability, and learn to dismount safely. Riders should also wear a helmet, padded gloves and shorts, and use a well-maintained bicycle. Such safety precautions have been shown to reduce injury rates and severity. Furthermore, Aleman and Meyers (2012) recommend education about off-road cycling safety, including bike suitability, maintenance, and equipment, proper riding technique, and attentive behavior to reduce the risk of injury.

Data regarding the use of helmets in off-road cycling in the Portland-area is not available. However a survey of college students in the southeastern United States found a higher likelihood of helmet use when riding on mountain bike terrain than on city roads (17% to 12%). (Ross et.al. 2010) Of note is the low overall level of helmet use among the study's population. In Portland, 81% of people wear helmets when riding on City streets (Portland Bureau of Transportation, 2014), suggesting a relatively high likelihood of helmet use among area off-road cyclists.

Trail Experience and Social Interaction

Actual and perceived conflicts between different user groups, such as off-road cyclists and hikers, is a potential impact of shared-use trails, and is noted in research. Conflicts tend to occur when there is limited public land resources and a lack of policies and practices in place for the management of shared-use trails. (Ruff & Mellors; Schuett; Symmonds et al., 2000; Watson et al. as cited in Jellum, 2007) However, land managers may opt to concentrate trails and associated recreational use, in order to reduce overall environmental impacts (Roth, 2000).

Conflicts can be real or perceived and are often rooted in concerns over personal safety, variations in social norms and expectations, and concerns about environmental degradation (Jellum, 2007). Common causes of perceived or actual conflict include:

- *Safety*: There is limited recent research on the frequency of actual hazardous encounters between mountain bikers and other users. However, in a survey of forty land managers in the United States, Chavez et al. (1993) found only one case of reported walker injury. Similarly, Edger (1997) studied 300 accident records for trail users within the Marin Municipal Water District in Marin County, California, and found very few that resulted from biker-walker collisions. However,

Keller (1990) noted a number of problems from the reactions of horses to people riding bicycles (as cited in Cessford, 2003).

People riding bicycles off-road can be perceived as a hazard by hikers when "they are considered to be riding too fast for the conditions (e.g., on crowded, multiple-use trails); not slowing enough when approaching blind corners; or where they surprise people because they move quickly and quietly" (Moore, 1994; Cessford, 1995a as cited in Cessford, 2003). Additionally, some research has found that a pre-existing fear of an unsafe encounter (such as meeting a person on a bicycle travelling at high speeds or on a blind corner) can negatively impact hikers' recreational experience (Chavez, 1996a and Watson et al., 1991 as cited in Jellum, 2007).

- *Differences in physical attributes*: Users on shared-use trails can sometimes experience conflict because of differences in technology, speed, group size or other physical characteristics. In these cases, conflict may be asymmetrical, or one-directional. For example, trail users generally dislike uses that are faster or more mechanized than their own (Federal Highway Administration, 1994).

- *Differences in social values or norms*: According to Cessford (2002), conflicts between users may result from a lack of trail user etiquette that interferes with another user's enjoyment. Such actions could include rudeness or lack of or inappropriate yielding of right-of-way – including failure to announce passing or passing too closely. Cessford (2002) also cites a variety of other potential social conflicts, including "social values such as different lifestyles (i.e., socioeconomic differences), attitudes toward place attachment (i.e., sense of belonging or attachment to a place based on repeat visits or knowledge about a place) (Backlund & Williams, 2003; Clark, 2004), different recreation goals, or motivational differences (i.e., wildlife viewing, socializing, solitude, exercise) (Bjorkman, 1996; Watson et al.)".

- *Concerns over carrying capacity:* Jellum (2007) cites perceptions that a trail's "biophysical (i.e., overuse diminishing environmental integrity) or social (i.e., experience interrupted by lack of solitude or increased noise levels)" carrying capacity has been exceeded as a potential source of conflict.

- *"Last settler syndrome"* – According to the Federal Highway Administration (1994), trail managers often find that traditional trail users often express resentment toward newcomers. This dynamic can be exacerbated in situations where one user group has had long-standing access or has built and/or maintained trails, leading to a sense of ownership over the trails. Mountain bikers, who participate in a recreational activity that has gained popularity relatively recently, may often be considered newcomers in trail situations. However, this dynamic may manifest in situations where mountain biking trails are considered for either opening to other users or closure to mountain biking.

- *Concerns about resource degradation:* According to research cited in Jellum (2007), user concerns about potential environmental degradation can results in conflicts. Such conflicts increase when there is a visual sign of potential damage (i.e. tire tracks, horse tracks, or footprints in mud; trail widening; or damaged vegetation) and can be exacerbated by poor trail design and/or increased use

(Cessford, 2003; White, Waskey, Brodehl, & Foti, 2006 as cited in Jellum. 2007).

- *Familiarity with off-road cycling*: Hikers' experience when encountering people on bicycles may be influenced by the hiker's familiarity and experience in such situations (Chavez et al., 1993; Bannister et al., 1992; Horn, 1994; Woehrstein, 1998, 2001 as cited in Cessford, 2003). Cessford (2002) examined the perceptions that hikers have towards mountain bikers and found that that hikers who actually encountered a mountain biker had more positive opinions toward mountain bikers than those hikers who did not encounter mountain bikers, suggesting conflict was more perceived than actually encountered. However, Chavez et al. (1993) observed that the hiker's with an established negative attitude towards people on bicycles maintained this perception, despite a three-fold increase in mountain bike use over two years and minimal actual safety issues (Cessford, 2003).

  Jellum (2007) studied the use and perceptions of hikers and mountain bikers using the Middle Fork Trail System outside of Seattle, Washington. This research found that a majority (63%) of mountain bikers using the trail also participate in hiking, while only a limited number of hikers (11%) using the trail also participate in mountain biking. As such, hikers may be generally unfamiliar with the mountain biking experience, which may contribute to their experience and perception of shared-use trail environments.

There are multiple ways that trail designers and land managers can address real or perceived safety concerns. Mann and Absher (2008) suggest that communication strategies are more effective than enforcing trail width based regulations for mountain bikers (e.g. bikes only allowed on trails >6') at addressing potential conflicts, as communication can address underlying concerns about safety, social norms, and environmental impacts. Similarly, Cessford (2002) states that infrastructure and programs that increase education and awareness between user groups (i.e. signage, volunteer trail patrols) reduces negative perceptions. Additionally, trail design and maintenance techniques, such as improving sight lines and controlling speed, are widely accepted as best management practices to promote positive social interaction and reduce conflict (Webber, 2007).

Nuisance uses

Across the country, there are examples where new trail and park development has replaced nuisance uses, ranging from littering to criminal activity. Such uses can contribute to real or perceived health and safety threats. Off-road cycling examples in the Pacific Northwest include the City of Seattle's Colonnade Bike Park and Cheasty Greenspace Trails Project, both of which are intended to provide new off-road cycling and recreational experiences and replace the previous nuisance uses with positive, family-friendly outdoor activities. The Seattle Colonnade Bike Park is located below the I-5 freeway in urban Seattle. The site was formerly filled with garbage and noxious weeds and impacted by illegal camping. (Seattle Parks & Recreation) The Cheasty Greenspace project includes the restoration of a 43-acre remnant forest in south Seattle. The Greenspace suffered from invasive plants and garbage dumping and was home to multiple illegal encampments. Work will be done in stages, and include the construction of mountain biking trails, as part of a pilot effort that will assess the impacts of restoration and recreational trails on the environment and community. (Cheasty Greenspace)

Impacts on Economic Activity and Tourism

The League of American Bicyclists rates Portland as a Platinum Level Bike Friendly Community, the highest rating available, for "providing safe accommodation and facilities for bicyclists and encouraging residents to bike for transportation and recreation." Accompanying this rating is a recommendation to "ensure better access to city parks and recreation areas for off-road riding." Infrastructure and programs to provide and promote safe biking coupled with a population mindful of reducing use of fossil fuels and oriented to outdoor activities has resulted in a significant number of bicyclists in Portland, including off-road cyclists. Bicycling contributes to the state and local economy through the manufacture and sales of bicycle-related products and services, and expenditures by people travelling to cycle. The availability of bicycling infrastructure and facilities also serve to draw new residents and businesses.

KEY FINDINGS

A survey of studies of the economic impacts of bicycling at the national, state and local levels provide an estimate of the value of off-road cycling to Oregon and the Portland area, and insights into the economic benefits of increasing access to off-road facilities.

- The growing bicycling industry in Portland contributes nearly $134 million to the local economy. The majority of Portland bicycle-related businesses cite availability of bicycle infrastructure, including off-road cycling facilities, as important to the growth of the industry and their ability to attract top industry talent.
- People traveling to bicycle off-road spend $28 million annually throughout Oregon.
- With an average expenditure of $125 per trip for day off-road cycling trips and $732 per trip for overnight off-road cycling trips, there is opportunity for increases in travel-related revenues in Portland with increased availability of off-road cycling facilities.

Statewide Bicycling Industry

A 2014 report for Travel Oregon (Runyon) estimates the economic value of the entire bicycle industry to the state as creating nearly 2,700 jobs and contributing nearly $84 million in wages and $440 million in sales to the state economy.

Statewide	Number of Businesses	Number of Jobs	Wages and Salaries (millions)	Sales (millions)
Manufacturing	89	609	$24	$117.7
Retail/Service	405	1718	$51.8	$300.3
Other (distribution, tour operation, events)	48	319	$8	$22.7
Total	**542**	**2646**	**$83.8**	**$440**

Approximately 22% of products sold by manufacturers and 77% of retail products and services are sold locally, contributing to their local economy.

The report also found that of the 542 Oregon bicycle-related businesses, a majority are located in the greater Portland Metro area, providing 75% of all bicycle-related manufacturing jobs and nearly 50% of all bicycle-related sales jobs in the state.

The report did not attempt to break out contributions of road cycling versus off-road cycling. Southwick (2013) estimated the total number of cyclists in Oregon as 888,655, and the total number of off-road cyclists in Oregon is estimated as 484,369 (see Statewide and Portland Area Off-Road Cycling Tourism, page 4), indicating a significant portion of the economic benefit of the bicycling industry in Oregon can be attributed to off-road cycling.

Portland Bicycling Industry

The Portland region includes more than 800 companies, both large and small, producing products for the athletic and outdoor industry (Impresa, 2010). It is not the home of any of the major bicycle brands, but has a growing bicycle manufacturing and retail sector. Ibsen (2015) investigates the role of bicycle-related businesses in Portland's economy, including manufacturing, retail sales, distribution and service of bicycles, parts and related gear. Since 2002, the number of bicycle-related businesses in Portland has increased from 22 to 217. The direct effects of these businesses, the result of initial purchases made by customers, is estimated to support 1469 jobs for a combined income of $39.4 million, and total sales of $296.2 million.

Portland sector	Number of Businesses	Number of Jobs	Wages and Salaries (millions)	Sales (millions)
Manufacturing	78	464	$14.7	$129.9
Retail	100	797	$20.3	$36.6
Wholesale/distribution	8	49	$1.6	$108
Service	31	160	$2.8	$30.7
Total	**217**	**1469**	**$39.4**	**$296.2**

Considering the percentages of sales that remain local from the 2014 statewide report (22% of manufacturer's sales, 77% of retail sales), $28.4 million of Portland manufacturer's sales revenues and $51.8 million of retail and service sales revenues remain in Portland.

The ripple effects of Portland's bicycle-related businesses, the measure of how sales affect other industries providing supplies and support and wages paid by those industries, is additive to the direct impacts to estimate the total economic contribution. The total number of jobs generated by the Portland bicycle industry is 2312 for a combined income of $82.8 million. The Total Value Added to the local economy, consisting of wages and salaries, property income and business tax revenue, is $133.7 million.

	Number of Jobs	Wages and Salaries (millions)	Total Value Added to Portland Economy (millions)
Direct effect	1469	$39.4	$64
Ripple effect	842	$45.5	$69.7
Total	**2312**	**$82.8**	**$133.7**

Off-road bicycles, parts, equipment and gear represent some percentage of sales of most Portland bicycle-related businesses. The report did not provide a detailed breakdown across all the businesses participating in the study, but of those that directly contributed sales data, manufacturers estimated off-road equipment to comprise from 15% to 70% of their sales, and retailers estimated 30% to 65% of their sales. Portland also has one retail establishment that sells and services off-road bicycles exclusively.

Bicycle Tourism

National and Statewide Bicycle-Related Tourism

The Outdoor Industry Association (OIA), a trade association for the outdoor recreation industry, produces periodic reports estimating the number of participants in a variety of outdoor activities, and the economic value of the industry at national and state levels. Their *Active Outdoor Recreation Economy Report* of 2006 reported that nationally, 60 million adults bicycle, and one in five over the age of 16 ride off-road. The 2015 *Outdoor Recreation Participation Topline* report shows some decline in

road cycling but significant increases in off-road ridership in the prior three years: mountain biking and BMX riding has increased by 6% and 16.2% respectively, while participation in road riding has dropped by 5%.

National Bicycling Activity	Number of Participants	% Change over 3 Years
Road riding	39,725,000	-5%
Mountain biking	8,044,000	+6%
BMX riding	2,350,000	+16.2%

The Topline report also found that 17.2 million youth (21.2% of all U.S. youth) bicycle, averaging 67.2 cycling outings/cyclist annually, for a total of 1.2 billion cycling outings. 26.8 million adults (12.8% of all adults) bicycle, averaging 54.3 cycling outings/cyclist annually, for a total of 1.5 billion cycling outings.

The total annual, national spending on bicycling in 2011 was over $81 billion: $10.5 billion on gear and accessories, and $70.8 billion on trip-related sales (Southwick, 2012). By OIA estimates, there are 888,655 bicyclists in Oregon. Over 17 million day trips and 1.7 million overnight trips to cycle in Oregon resulted in nearly $6 billion in trip-related sales (Southwick, 2013).

Off-Road Bicycling Tourism at Destinations Areas

Outdoor recreation including off-road cycling is a major economic driver for some communities surrounded by expanses of public lands. In a 2000 study, the trails outside Moab, UT, a major destination for mountain biking, were estimated to generate $1.3 million in economic value to this tiny city of just over 5000 residents (Chakrabarty, 2000). The trail system in Jackson Hole, WY is estimated to generate $18.5 million in expenditures (Kaliszewski, 2011), mostly by tourists, and mountain bicycling activities in Whistler, British Columbia generate $34.4 million (Canadian dollars) in expenditures (Western Canada Mountain Bike Tourism Association, 2007).

Oakridge, Oregon, a former timber-based city 35 miles southeast of Eugene in the Cascade Mountains, has seen significant economic benefit from the development of an extensive trail system nearby. A University of Oregon study (Meltzer, 2014) estimated annual spending by mountain bikers in Oakridge at $2.5 to $5 million, accounting for 5% of the city's total economy.

Statewide and Portland Area Off-Road Cycling Tourism

The economic value of bicycle-related tourism is a function of the number of cyclists, the number and types of travel trips (day or overnight) taken and their regional destinations. A specific study of off-road cycling travel trips to and within the Portland Metro area has not been completed, but a number of studies assessing general bicycling-related travel in Oregon coupled with estimates of the proportion of off-road cyclists provides some insights into the Portland area tourism value.

The Oregon Parks and Recreation Department investigated demand for a range of state park activities. The *Oregon Resident Outdoor Recreation Demand Analysis* found through a 2011 survey that Oregon residents cycled unpaved surfaces on nearly 15 million occasions. 40% of those cycling experiences (6

million) were in Multnomah County. 12.2% of the state population and 11.4% of Multnomah County population participated in these cycling experiences. Based on 2014 population estimates by the US Census Bureau, nearly 500,000 Oregon residents and 90,000 Multnomah County residents are off-road cyclists.

	Population	% Total Population	% Off-Road Cyclists	# Off-Road Cyclists
Oregon	3,970,239	100	12.2	484,369
Multnomah County	776,712	19.6	11.4	88,545

Oregon Non-Motorized Trail Participation and Priorities, also prepared by the Oregon Parks and Recreation Department, reported the number of activity days for unpaved surface cycling in Multnomah County is the highest in the state. Oregon residents cycled on unpaved surfaces in Multnomah County on 2.5 million occasions, nearly five times the rate in Deschutes County, a destination for off-road cycling. The report also notes that in the Portland region, 47% of 'singletrack cyclists' see additional trails in the region as a priority.

Oregon Parks and Recreation estimates for statewide travel expenditures by Oregon residents participating in singletrack cycling, including direct and ripple effect spending, is $82 million annually. Expenditures for day trips include food, fuel, park fees and other services, and total $57 million. Overnight trips, which additionally include hotel or camping expenditures, total $25 million.

Travel Expenditures for Off-Road Cycling Trips in Oregon by Oregon Residents:

	Expenditures for Day Trips (millions)	**Expenditures for Overnight Trips** (millions)	**Total Expenditures** (millions)
Local trips	$45	$3	$48
Non-Local trips	$12	$22	$34
Total	**$57**	**$25**	**$82**

While the report did not break out travel expenditures for singletrack cyclists by region, a rough estimate can be made based on the region's population. Using 2014 US Census estimates, Multnomah County comprises 19.6% of the total Oregon population. Assuming Multnomah County residents travel to cycle off-road in the same proportion as residents statewide, Multnomah County residents spend over $16 million annually on off-road cycling trips.

Travel Expenditures for Off-Road Cycling Trips in Oregon by Multnomah County Residents:

	Expenditures (millions)		
	Day Trips	**Overnight Trips**	**Total**
Statewide	$57	$25	**$82**
Multnomah County *(at 19.6% of statewide figure)*	$11	$4.9	**$16**

Travel Oregon commissioned a study on the value of bicycling-related travel to the state. *The Economic Significance of Bicycle-Related Travel in Oregon* evaluated the amount spent by travelers who participated in bicycle-related activities while traveling to and throughout Oregon in 2012 (Runyon, 2013). Activities included bicycle racing events, organized tours, day road riding, bicycle touring, day mountain bike riding, and other organized bicycling events. "Travel" was defined as 50 miles or more of one-way travel to cycle. The annual expenditures by all bike travelers statewide is estimated to total $400 million, or $1.2 million per day.

Service	Expenditures (millions)
Accommodations and food services	$174.6
Groceries	$53.5
Fuel	$71.5
Event fees	$1.9
Repairs, gear, clothing	$27.9
Overall	**$400 annual, $1.2/day**

These annual expenditures support 4600 jobs, generating $102 million in earnings, $18 million in tax revenue.

In the Portland Metro region, annual expenditures by all bike travelers are estimated to total $89 million.

Day trip	Overnight trip	Total
$33 million	$56 million	$89 million

These local annual expenditures support 700 jobs, generating $18 million in earnings and $4.1 million in tax revenue.

The report estimates a total of 1,151,000 bicycle-related trips in Oregon in 2012: 748,000 day trips and 403,000 overnight trips. Of all Oregon bicycle-related trips in 2012, 80,000 were for day mountain biking: 51,000 for day trips, 29,000 for overnight trips. Day and overnight mountain bike trips were approximately 7% of both all day trips and all overnight trips. The average expenditure per mountain bike party was $125 per day trip, $732 for overnight trips (over 3.4 nights).

Statewide, 2012 annual expenditures for off-road cycling-related travel totaled nearly $28 million: $64 million for day trips and $21.5 million for overnight trips.

Service	Day trip	Overnight trip	Total
Accommodations	-	$5,590,000	$5,590,000
Restaurants/bars	$2,235,000	$4,761,000	$6,996,000
Groceries	$793,000	$3,096,000	$3,889,000
Fuel/parking	$2,168,000	$3,986,000	$6,153,000
Repairs, gear, clothing	$440,000	$1,727,000	$2,167,000
Event fees	$552,000	$716,000	$1,268,000

Recreation and entertainment	$48,000	$462,000	$510,000
Other retail	$152,000	$922,000	$1,074,000
Airfare	-	$289,000	$289,000
Total	**$6,388,000**	**$21,549,000**	**$27,937,000**

In the Portland Metro region in 2012, there were 287,000 bicycle-related trips: 227,000 day trips and 60,000 overnight trips. Assuming the same proportion of statewide trips attributable to mountain biking, there were 20,090 mountain biking trips in the Portland Metro region: 15,890 day trips and 4,200 overnight trips.

Estimates of expenditures for mountain bikes trips in the Portland Metro region are therefore over $5 million: nearly $2 million attributed to day trips and over $3 million for overnight trips.

	Trips	Expenditures
Day Trips	15,890 @ $125/trip	$1,986,250
Overnight Trips	4200 @ $732/trip	$3,074,400
Total	**20,090**	**$5,060,650**

This estimate is considerably lower than the $16 million in total trip expenditures by Multnomah County residents derived from the Oregon Parks and Recreation Department's study. A study to directly analyze the tourism impacts of off-road cycling in Oregon has not been completed.

Bicycle Racing

Organized bicycle races also generate local revenue through event venue rentals and hospitality services for racers travelling to participate in events. *The Economic Significance of Bicycle-Related Travel in Oregon* report included racers travelling for events in their analysis of travel-related expenditures, but did not evaluate the local revenues of event venues. A 2013 study from Linfield College (McNamee, et al, 2013) evaluated local expenditures by off-road cyclists at three race events: two 1-day events in Bend, OR, and one 3-day event in Oakridge, OR. The study found that 65% of the participants came from outside Oregon and included travelers from outside the US. The two Bend events generated a total of $918,200 in sales, and the Oakridge event generated $1.69 million in sales.

The Oregon Bicycle Racing Association (OBRA) offers the largest cyclo-cross racing series in the U.S., with many of the events held in Portland. In addition to smaller weekend and evening races, the Cross-Crusade series draws thousands of competitors and spectators to events around the state. In 2014, three Cross-Crusade events were held in Portland, two in North Portland at the Portland International Raceway (PIR) and one two-day event in Southwest Portland at Alpenrose. 50 to 57 percent of the Cross-Crusade participants were Portland residents, with the remainder travelling from the region, Oregon and from outside the US.

OBRA also sponsors a range of mountain biking events: Short Track Cross Country; Cross Country; Endurance; Downhill; Super-Downhill; and Enduro. Only Short Track Cross County events are held in

Portland in addition to the cyclo-cross events. 62 to 70 percent of the Short Track participants are Portland residents, and nearly one-third travel to Portland to race.

More than half (9143) of the statewide cyclo-cross participants and the majority (2836) of Short Track Cross Country participants in 2014 competed in Portland.

	Number of Events	Participants
Cyclo-cross		
Statewide	51	18,070
Portland area (35 miles)	32	471
Portland	20	9143
Short Track XC		
Statewide	14	3100
Portland	8	2836
Other Off-road events		
Statewide	26	3831
Portland	0	0
Totals	151	37,451

Many of the cyclo-cross events and all of the Short Track Cross Country races in Portland are held at PIR. In 2014, there were 6122 participants in off-road events generating $12,300 in rental revenue for PIR.

	Number of Off-Road Events	Number of Participants	PIR Rental Income for Off-Road Events
Cyclo-cross	6	3286	$8,700
Short Track XC	8	2836	$3,600
Total	**14**	**6122**	**$12,300**

While venue rental income is one small portion of revenue generated by off-road racing events, the number of participants statewide is an indicator of demand for race facilities and the potential for benefits to the local economy through travel expenditures with increased access to race facilities.

Quality of Life Aspects of Access to Bicycling

The natural amenities available to the Portland region provide a draw to new residents, contribute to the satisfaction of current residents, and factor into employers' decisions to locate their businesses. The availability of infrastructure for bicycling in and around Portland, the number of people who bicycle here and Portland's Bike-Friendly rating are regularly cited by real estate services, businesses and lists featuring reasons to move to Portland. It may not be possible to quantify the economic benefit to the region attributable to the accessibility of bicycling facilities, but there is an impact.

In developing *The Economic Impact of the Bicycle Industry in Portland* report, survey questions were posed to bicycle-related business owners in Portland. Participants indicated they see a clear causality between the provision of bicycle infrastructure and Portland's rating and reputation as a bike-friendly

city with the success of the local bicycle industry and the ability to draw top talent. Of those businesses responding, 80% agreed this reputation was part of the reason for establishing their business in Portland. 75% identified access to a good network of off-road, unpaved cycling facilities as important to growth of the local industry, and 95.8% stated Portland does not have that now.

The Jackson Hole study cited earlier surveyed trail users and found overwhelming agreement that availability of well-maintained trail systems are important for making travel decisions and to quality of life at home.

A 2004 study in North Carolina (North Carolina University) found investment in bicycling infrastructure had an array of benefits for residents and tourism. The Northern Outer Banks of North Carolina hosts an extensive system of bicycling facilities, mostly paved, and a high level of bicycling activity. In addition to finding bicycling infrastructure is a strong draw for visitors and the revenues they generate, they found the economic benefit of investment in bicycling facilities outweighs the costs. In their case, the annual economic benefits of cycling is nine times the initial cost of construction of the facilities. Less quantifiable benefits were found to be:

- Enhanced property values near bicycling trails
- Reduced healthcare costs resulting from increased opportunities for healthful exercise
- Increased safety of the transportation system for all

The vital economy of a region is linked directly to quality of life benefits. Recreational opportunities including parks and trails contribute to a high quality of life, which in turn attracts new businesses and residents as well as retaining existing residents.

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