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**Paris Lodron Universität Salzburg**

**Department of Geoinformatics**

**Applied Geoinformatics**

**Suitability analysis of mountainbike trails utilizing Strava metro**

**Master Thesis**

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*A thesis submitted in fulfillment of the requirements for the degree Master of Science*

Salzburg, Juli 2023

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## **Abstract**

# **Introduction: Scientific Relevance and Context**

## **The Scope of this Study**

## **Development of the sport of mountainbiking in Austria**

Mountain biking has grown in popularity in Austria over the past few decades due to technological advances in equipment, evolving riding styles, and the increased accessibility of trails. According to a study by Koemle and Morawetz (2016), the sport has steadily gained popularity in Austria over the last two decades. This growth can be attributed to a number of factors, including developments in bicycle technology and improved access to mapping software. The study by Pröbstl-Haider et al. (2018) highlights the increased preference for narrow singletrack trails and more challenging terrain among mountain bikers.

The use of e-mountain bikes has also made the sport more accessible to people in general and has likely contributed to the growth of mountain biking. The use of motorized mountain bikes has made previously inaccessible terrain and trails more accessible, leading to more mountain biking activity on trails not designed for bikers (Pröbst-Haider et al., 2018).

However, the rapid rise in the popularity of mountain biking, particularly on singletrack trails, has led to problems. One problem is the erosion of existing trails not designed for bikers. Another issue is the potential risk for other/all trail users, which can lead to user conflict. There is also the issue of crowding on the trails and environmental degradation (Pröbst-Haider et al., 2018).

While mountain biking is a relatively young sport, having been practiced since the mid-1980s, it has since progressed rapidly due to technological advances in equipment and evolving riding styles (Pröbst-Haider et al., 2018). In Austria, 33% of the population owns a mountain bike, and Germans make up the largest tourism source to Austria, with 39% of Germans owning a mountain bike (Pröbst-Haider et al., 2018). Given the implications of climate change, it has been encouraged to invest and develop all-season tourism more as a viable climate change mitigation and adaptation strategy, and mountain biking will play a role in this (Pröbst-Haider et al., 2018).

Mountain biking plays an important role in the portfolio of leisure and tourism activities in the European Alps, as well as in many other rural destinations (Pröbst-Haider, 2017). However, the accessibility of forests, alpine pastures, and open landscapes for mountain bikes differs significantly between the Alpine countries. While Germany, Switzerland, and Italy have opened their forests for mountain bikers, the Austrian Forest Act does not allow mountain biking on forest roads (Pröbst-Haider, 2017).

Despite the challenges, Austria boasts a large network of hiking trails and forest roads, making it an attractive destination for mountain bikers. A study by Pröbstl-Haider (2017) concludes that more appealing and well-maintained trails, as well as attractive leisure infrastructure, are needed. Improving trail construction standards that are adapted to different preferences, needs, and environmental conditions can also help (Pröbstl-Haider, 2017).

According to Salzburger Land Tourismus (2017), around 10% of tourists in Salzburger Land go mountain biking during their holidays. Furthermore, the Eurac study (2015) estimated that there are around 18.6 million potential riders for the alpine regions, with this number continuing to grow. To cater to this demand for mountain biking paths, the Land Salzburg has created a sample contract for official mountain bike paths, which includes a road liability insurance policy. Additionally, tourism offices pay usage fees to communities and landowners (Salzburger Land Tourismus, 2017). Despite this need for paths, there are currently only a few official mountain bike tracks in Salzburg, with the rare exception being along Lake Fuschelsee, which is maintained by the local tourist office there (Fuschelsee Tourismus GmbH, 2022).

## **Legal framework for mountain biking in Austria**

The legal framework for mountain biking in Austria differs between provinces, but the overarching legislation is provided by the Austrian Forest Act of 1975. This act allows Austrian citizens free access to forests but explicitly forbids driving vehicles or bicycles in the forest. As a result, cycling is forbidden on hiking trails or forest roads except when it is on publicly designated routes with prior approval from the entity responsible for management and maintenance for the road or trail. Cycling off-trail in a forest requires prior permission from the landowner. Landowners generally receive compensation in exchange for permitting cycling on their property. The provision of adequate insurance and signage on designated routes are also relevant aspects of the agreement, with the responsibility varying by province. Often, local tourism authorities are responsible for route signage, liability insurance, and maintaining contact with the landowners. (Pröbst-Haider et al., 2018)

## **User group conflict**

The increase in mountain bike traffic has led to conflicts among stakeholders, including hikers, landowners, hunters, conservationists, and other trail users (Pröbst-Haider et al., 2018; Lang, 2013; Zajc & Berzelak, 2016; Morey, 2002). Hikers often view cyclists as a threat due to their speed and quiet approach (Koemle & Morawetz, 2016; Goeft, 2001). On the other hand, cyclists tend to perceive walkers less negatively, simply noting them as a potential nuisance that can disrupt the quality of their experience (Cessford, 2003). Despite the considerable literature available on perceived conflict between hikers and cyclists on narrow trails, very few incidents have been documented that cite collisions between cyclists and walkers. Almost none of the thousands of incidents documented over several years on trails in the German Alps involve collisions between cyclists and walkers (Cessford, 2003).

However, despite the lack of documented collision incidents, the potential for conflict between cyclists and hikers, along with a negative perception of mountain bikers by hikers, remains a major roadblock for the establishment of mixed-use or shared trails in Austria (Koemle & Morawetz, 2016). Several mountainous tourism destinations in Austria report conflict between user groups, with cyclists and hikers being the most common (Pröbstl-Haider et al., 2018). Studies regarding cycling trends in Austria by Reichhart & Arnberger (2010), Von Janowsky & Becher (2002), and Wyttenbach (2012) confirm these observations, with conflicts between hikers and cyclists being among the most reported (Pröbstl-Haider et al., 2018).

According to research by Lang (2013), Austrian hikers consistently feel more disturbed by bikers than vice versa. In Tirol, a study found that 40% of hikers interviewed were disturbed by mountain bikers, and 30% felt threatened by them.

## **Study Area**

# **Methods**

## OSM trail segments

## **Strava metro data**

### Strava Metro

Strava Metro data is a valuable resource for trail suitability analysis (Pröbstl-Haider et al., 2018). Strava Metro provides real-time data on bike rides and hiking activities, which can be used to analyze trail usage patterns. This data is particularly useful for identifying popular trails and areas where there is potential for user conflict. By analyzing Strava Metro data along with other data sources, researchers can gain a comprehensive understanding of trail usage patterns, which can inform trail development and management decisions (Pröbstl-Haider et al., 2018).

In addition, Strava Metro data can be used to understand the economic impact of mountain biking in a particular region. A study by Reichhart and Arnberger (2010) found that mountain biking had a significant economic impact in the Austrian Alps. The study found that mountain biking generated over €70 million in revenue and supported over 2,000 jobs in the region. Strava Metro data can be used to estimate the number of riders in a particular area, which can be used to estimate the economic impact of mountain biking in that region (Reichhart & Arnberger, 2010).

Overall, Strava Metro data provides valuable insights into trail usage patterns and the economic impact of mountain biking. When used in conjunction with other data sources, Strava Metro data can inform trail development and management decisions (Pröbstl-Haider et al., 2018).

* biking data from 2019,2020, 2021 and 2022 with hourly resolution of the bike rides per segment
* hiking data from 2019,2020, 2021 with hourly resolution of the hikers per segment
* the data from Strava gets matched to trails, paths, roads etc. from OpenStreetMap

### 2.2.2 Data preprocssing

- large amount of data due to hourly resolution of all trail segments including road segments in the first interation of the data

- some discrepancies in the data. Of the Biking data the column names were not the same throughout all 48 single files. It required a detailed search for the inconsistencies, and then a extensive merging algorithm to include all naming variations and data variations

Some files included more columns then others, they also included ebike\_ride\_count and total tripcount ( others only having forward and reverse tripc count)

- filtering out of not needed columns

- spatial filtering of the dataframe with edgeuid matching, cutting out all rows with edgeuids which are not in the previous filtered shapefile, excluding roads etc. and also reducing the dataframe to the study area

1. Raw single monthly files for the whole county of Salzburg (36 files for biking, 24 for hiking)

2. In R script: get file names for each file, specify which columns to keep, read file but if hour column doesn’t exist but date does rename date to hour. (Different column names in the later/earlier files) merge all files together, check if there are any NA values in the dataframe, split date column into date and hour separately, create a new column with the matching weekdays and create a column with the total amount of bikerides (forward trip count and reverse trip count together. Replace 0 in the speed column as NAs as it heavily skews the speed distribution and the strava data put 0 where there was no speed data available.

Further get the mean speed for each row of reverse average speed and forward average speed. Delete no further used columns. Filter the data spatially with the shapefile, by reading the shapefile into R and filtering the bikingdata for matching edgeuids with the shapefile. The dataframe only consists of data with the edgeuids which are found also in the Shapefile.



## **Other data**

## **Dashboard**

* Data processed for statistics for each edgeuid -> reduction of data
* Shiny dashboard written in R, takes csv data locally, fetches WFS from Geoserver (biggest loading part of the application).
* To make loading faster the single segments are not displayed when zoomed out, then they are displayed clusterd only wen zooming in the shapes of the segments appear
* Biking and hiking data are put on the leaflet map as two different layers using the same wfs data. Setting the opacity lower then 1 allows for analysis of overlaps or where biking or hiking prevails
* Filtering of the most ridden kilometers – applies for both hiking and biking data
* Info on segment edgeuid, total hikes and total rides are displayed in a popup and the side tab
* Plots on hourly, weekly and monthly distribution on either all segments on the map (when no segment is selected) or a the selected segment for both hiking and biking
* Shiny app gets dockerized to eliminate dependency issues
* The app data (code, dockerfile, csvs, configuration etc.) are on a Github repository. When the master branch of the repository is updated it deploys the shiny app as a docker image on the AWS elastic beanstalk environment
* Github workflow logs into dockerhub account, builds the docker image with the latest files in the repository, then pushes the docker image to the dockerhub and then runs it on aws beanstalk

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## **Statistical Analyses**

# **Results**

# **Discussion**

## **Drawbacks and Future Improvements of this Study**

# **Conclusion**

# **Reference**

Cessford, G. (2003). Mixed use trails: a synthesis of user conflict research. A report to the Ministry of Environment, Lands and Parks, Victoria, BC.

Goeft, U. (2001). Behavioural impact of mountain biking on wildlife. In R. Liddle (Ed.), Recreation ecology research findings (pp. 41–45). US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Koemle, D. I., & Morawetz, C. (2016). Mountain biking in Austria: Between legal requirements and user conflicts. Journal of Outdoor Recreation and Tourism, 14, 38-48.

Lang, D. J. (2013). Mountain bikers and hikers in Tyrol (Austria): Emergence of conflicts, analysis and solution approach. Journal of Outdoor Recreation and Tourism, 3-4, 1-14.

Morey, E. R. (2002). Social and environmental impacts of mountain biking: A review. Journal of Park and Recreation Administration, 20(3), 71-84.

Pröbstl-Haider, U., Haider, W., & Pechmann, I. (2018). The role of mountain biking in sustainable tourism development. In W. Filho et al. (Eds.), Handbook of Sustainability Science and Research (pp. 1-17). Springer.

Reichhart, J., & Arnberger, A. (2010). The impact of forest management on the recreational value of mountain biking in Austria. Journal of Environmental Management, 91(4), 903-911.

Von Janowsky, B., & Becher, G. (2002). Trends and conflict on mountain bike trails in Germany: A case study of the Bavarian Forest National Park. Journal of Environmental Management, 66(3), 277-289.

Wyttenbach, M. (2012). Mountain bike tourism in Switzerland: A market and regional analysis. Journal of Outdoor Recreation and Tourism, 1-2, 1-15.

Zajc, K., & Berzelak, N. (2016). Conflicts between hikers and mountain bikers in Slovenia: A case study. Journal of Outdoor Recreation and Tourism, 14, 49-57.