



Cartography M.Sc.

Master thesis

Visualizing Decision-Relevant Map Layers to Support Travel Planning

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2021

Visualizing Decision-Relevant Map Layers to Support Travel Planning

submitted for the academic degree of Master of Science (M.Sc.)
conducted at the Department of Aerospace and Geodesy
Technical University of Munich

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Statement of Authorship

Herewith I declare that I am the sole author of the submitted Master's thesis entitled:
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Literal or analogous citations are clearly marked as such.

Munich, 14.10.2021

Nina Ioseliani

Acknowledgments

This thesis marks the end of a long, exciting, and challenging time in my life.

First and foremost, I would like to express my deepest gratitude and appreciation to my supervisor and the coordinator of this Master Programme, M.Sc. Juliane Cron. Thank you for your extraordinary support, encouragement, insights, valuable comments, and weekly meetings, which inspired me to work. Thank you for always guiding me in the right direction.

I would also like to thank my external supervisor Dennis Heine for the valuable feedback and remarks through the research process of this master thesis.

I want to express my gratitude to my reviewer M.Eng. Andrea Binn for her useful critiques and recommendations during my research proposal and mid-term presentation.

I would also like to extend my thanks to all the 60 participants for taking the time to participate in my user study. You were a great help to my work.

I want to thank all the lecturers for this wonderful experience. Special thanks to my beloved cartographers for making the study days full of joy.

Huge thanks to my family and friends for their endless love and support.

This work would not have been possible without the everlasting, caring support I received during all this time from my husband. Thank you so much!

Abstract

Travel planning is a complex, multi-faceted decision-making process that can be supported with different web applications existing nowadays. To plan a trip, a traveller often uses multiple sources and switches from one application to another.

Maps perform a valuable function and are involved throughout the whole travel process. Many aspects influence tourists' travel decisions. The same person may use various strategies to plan a trip. This presents challenges for the design of usable and effective decision-support tools. This master thesis contributes to a startup's project that builds a novel decision support system in the context of sports travel (e.g., surfing/kitesurfing, skiing, hiking, mountaineering, etc.). The thesis aims to facilitate users' decision-making process while planning a trip using a web-based mapping application focusing on one type of outdoor sport, hiking. The study contributes insights on what information can be relevant for making travel-related decisions and proposes how map layers and map elements can be visualized in different zoom levels. A prototype showing how decision-relevant map layers can be visualized was implemented.

The prototype's visualizations were divided into three zoom levels: so-called "Global level", "Local level", and "Spot level" and compared on three different basemaps: customized basemap, terrain, and satellite. The visualizations on the global and local levels are the system's recommendations and top 10 hiking trails within the recommended areas. The visualizations corresponding to the spot level are clusters of available hiking trails based on a difficulty level, individual hiking trails, and points of interest. Besides, an itinerary with all selected items by the user is visualized by days and available on all zoom levels.

A user test was conducted in order to evaluate how the proposed design works and in which ways such a system can support travel planning. While the user study with 60 participants produced predominantly positive results, the conducted user test gave ideas on how to improve the proposed visualization of decision-relevant map layers further.

The most needed refinement can be to add a legend to the interface or choose another more intuitive color scheme to visualize less recommended and not recommended countries or regions on the global and local levels. Further research might go into the necessity of showing the systems' recommendations on the local level based on geographical areas instead of administrative units to make it more hiking-relevant. The important refinement can be using a qualitative color scheme to visualize different days of the itinerary. In addition, a path of a hiking trail along with other point items (like restaurants) in the itinerary can be visualized. It is necessary to consider adding the relief to the canvas basemap since most participants preferred to see the terrain basemap on all zoom levels.

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List of Abbreviations

<i>API</i>	Application Programming Interface
<i>CSS</i>	Cascading Style Sheets
<i>GeoJSON</i>	Geographic JavaScript Object Notation
<i>HTML</i>	HyperText Markup Language
<i>JSON</i>	JavaScript Object Notation
<i>UI</i>	User Interface
<i>WGS</i>	World Geodetic System

1 Introduction

1.1 Motivation and Problem Statement

Travel planning is a complex, multi-faceted decision-making process consisting of choosing a destination, tourism products, and services related to the destination (attractions, accommodations, and activities) with the help of different web or mobile applications and tools (Ricci & Del Missier, 2004).

There are many aspects that influence tourists' travel decisions as well as many different stages that may occur in tourists' travel choices. According to Woodside and Lysonski (1989), a plethora of traveler characteristics (like age, lifestyle, income, previous destination experience, personal preferences, etc.), marketing aspects (like product design, pricing, advertising, etc.), destination awareness, or situational aspects can influence travel choices. Moreover, maps may be used by tourists in the decision-making stage to visualize and imagine potential destinations since they can include useful information about weather, terrain, accommodation, or attractions to visit. Besides, maps are used to assist with navigation and orientation. Thus, maps perform a valuable function and are involved throughout the whole travel decision process.

Consequently, a travel plan can have different structures and contents, and various strategies can be used to prepare it. For example, travelers can start searching from a specific destination and then choose particular activities within this destination or vice versa. Other travelers may use digital maps to search for specific travel components during the trip, while some may prefer to use maps in the trip-planning phase. Thus, the same person may use various strategies depending on the context (e.g., travel purpose, travel length, distance to the destination, and travel group composition). This leads to challenges for the design of usable and effective decision-support tools that include maps.

This master thesis contributes to a startup's company project that builds a novel decision support system in the context of sports travel (e.g., surfing/kitesurfing, skiing, hiking, mountaineering). This system wants to help travelers to decide with ease on a smartphone or a desktop application, 1) where to travel for a specific sport, 2) when to travel, and 3) what to do during a trip as well as to plan an itinerary.

Within the scope of this project, the thesis aims to facilitate users' decision-making process while planning a trip using a web-based mapping application that is intended to work on a desktop using a standards-compliant browser. The mapping tool should be the core component of the decision support system but has not been attentively researched before. For the thesis, the topic is focused on one type of sports travel, hiking, and on two types of user personas (explained in detail in Chapter 3.2).

1.2 Research Objective and Research Questions

The main objective of the thesis is to define, visualize and evaluate decision-relevant map layers of a web-based application. The main objective is split into two sub-objectives. The sub-objectives correspond to two main phases of the research.

I. Data phase: Sub-objective I

Defining and designing the data acquisition process.

Within the sub-objective I, the following research questions will be answered:

- I-a) What is the decision-relevant information for a decision support system for travellers focusing on hiking activity?
- I-b) What APIs are available and relevant for a decision support system focusing on hiking activity, and what criteria do the APIs have to fulfill?

II. Visualization and evaluation phase: Sub-objective II

Visualizing and evaluating decision-relevant web map layers.

Within the sub-objective II, the following research questions will be answered:

- II-a) What web mapping applications exist, and how do they support travellers' decisions?
- II-b) How are the decision-relevant map layers visualized in the existing web mapping applications?
- II-c) What decision-relevant information should be visualized in different zoom levels?
- II-d) How should the map elements be designed to support the traveller best?

The hypothesis guiding this research is that a careful selection and appropriate visualization of decision-relevant map layers in a web-based application will support travellers in their (hiking-related) decisions.

1.3 Innovations Intended

This work intends to combine existing cartographic methods of visualizing decision-relevant information from different data sources on the web maps in an innovative way to support users' travel-related decisions in a more intuitive way.

1.4 Outline of the Thesis

The thesis is divided into six chapters. In the first chapter, motivation and the problem statement are given, research objectives and questions are defined. The second chapter provides an overview of the general concept of the startup's decision support system. The main cartographic design principles for web maps are reviewed. The third chapter introduces the methodology on how the decision-relevant map layers of the web application for a decision support system for outdoor activities may look and feel. The main stages of the

methodology are defining user personas and decision-relevant information, data collection, evaluation of relevant APIs, the visualization concept of decision-relevant map layers for the decision support system, and methods of the user research. The fourth chapter presents the implementation and evaluation stages of the prototype. The results of the evaluation are presented and discussed in the fifth chapter. The thesis concludes with key findings and an outlook on future research that may be useful for continuing work on this subject.

2 State of the Art

This chapter provides an overview of the general concept of the startup's decision support system. A review of cartographic design principles for web maps is included. Afterward, a review of existing web mapping products supporting travel-related decisions is presented.

2.1 General Concept of the Startup's Decision Support System

The core of the product of the startup company is a recommender system showing recommended areas and ranked items related to a favorite outdoor activity (e.g., hiking, climbing, kitesurfing). The product is based on a recommendation algorithm that provides a list of recommended areas and ranked items depending on selected filters. For example, the user wants to spend holidays in June in Europe and is looking for a hiking trip. The best area for hiking in Europe in June might be the Alps. The recommender system will suggest regions in the Alps. Then, the best trail in the Alps might be the Via Claudia Augusta. These rankings should show next to the items, and the best options should be easily visually accessible to the user. Next, the user can select items relevant to the Via Claudia Augusta, e.g., hotels to stay at and restaurants to eat. It is important to note that this recommendation algorithm is not the focus of the thesis and will not be integrated into the prototype. The system's recommendations will be simulated since the thesis is mainly concerned with presenting the results of the recommender system. Besides the recommender system, the main idea of the startup is to show areas, subareas, groups of items (e.g., groups of hiking trails), and individual items (one hiking trail, one restaurant, or one hotel) depending on zoom levels. The zoom level is an integer which is the resolution of the current view on the web map. The zoom levels are between 0 (the entire world is shown on the map) and 21+. The zoom levels are grouped into three categories: "Global level", "Local level", and "Spot level". The overview of these levels, what is covered, and what should be visualized is shown in Table 2.1.

Category	What is covered	What should be visualized
Global level (lower zoom levels)	Entire areas (continents, countries)	Recommended areas based on the degree of "goodness or badness" and ranked items (e.g., top 10 options)
Local level (intermediate zoom levels)	Subareas (regions, subregions)	Recommended subareas based on the degree of "goodness or badness" and ranked items (e.g., top 10 options)
Spot level (higher zoom levels)	Items within subareas and details on a selected item	Recommended and available groups of items (e.g., groups of hiking trails) and individual items (e.g., hiking trails, hotels, restaurants) based on specific criteria (e.g., the difficulty level of hiking trails). The items can be saved to an itinerary.

Table 2.1: The overview of the "Global level", "Local level", and "Spot level".

As it can be seen in Table 2.1, the lower zoom levels correspond to the "Global level", intermediate zoom levels correspond to the "Local level", and higher zoom levels correspond

to the “Spot level”. They show entire areas, subareas, and items, respectively. The areas and subareas are recommended by the system based on the degree of “goodness” or “badness”. It means how “good” or “bad” an area is according to specific criteria. If the area is “good” (meets the criteria), then it is recommended by the system. If the area does not fully meet the criteria, it is less recommended by the system. If the area is “bad” (does not meet the criteria), it is not recommended by the system. Besides, the system recommends ranked items based on specific criteria (e.g., top 10 hiking trails in Europe or top 10 hiking trails in Bavaria). In addition, the system provides groups of items and individual items based on specific criteria. The user can save selected individual items such as hiking trails, hotels, and restaurants to an itinerary. The itinerary is an additional feature of the system. The user can see the saved items as a list in the itinerary and on the map.

These were all ideas mentioned by the startup at the thesis start. The decision support system showing all three levels, and the recommendations were not available. Therefore, the web mapping module (prototype of the decision support system) had to be conceptualized and realized. The purposes of the map module (all three levels combined) are:

- Support users to find travel destinations.
- Allow users to access recommendations of the system.
- Allow users to access rankings of items and areas (“top 10 options”).
- Allow users a quick overview of available items organized by location.
- Support users to find spots, places to sleep, eat, and services.
- Allow users to explore and navigate (the data about) each option.

The application is not intended to feature its own navigation and routing option. An own navigation module will not be developed since similar services exist and will be used to navigate (e.g., every item should carry a link “navigate here,” which opens the user’s favorite navigation service). The startup provided the basic user interface of the application. The left sidebar and the right sidebar were implemented by the startup based on React JavaScript libraries using the TypeScript programming language. The screenshot of the interface is shown in Figure 2.1. The right sidebar is supposed to reveal details on selected items. The left sidebar is supposed to show the itinerary and the list of items displayed on the map.

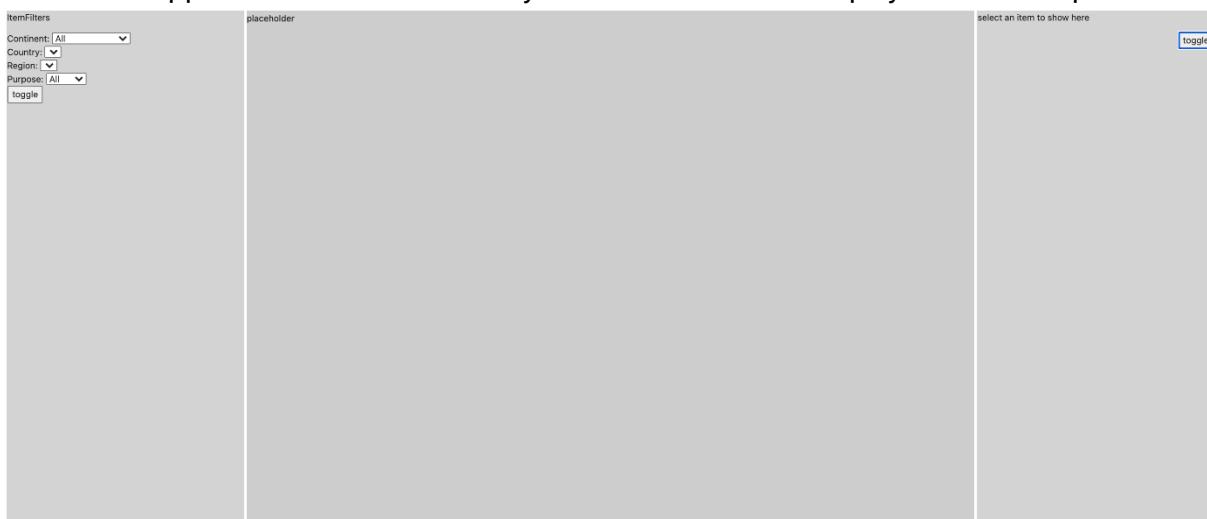


Figure 2.1: The screenshot of the initial user interface provided by the startup.

Thus, based on information provided by the startup, the general concept of the web application was defined (see Table 2.2). The user can use the web application while planning a new trip (pre-destination decision making) or next days during a trip (in-destination decision-making). The application facilitates the users' decisions on where to travel for a hiking trip, when to travel, what to do during the trip, and planning an itinerary.

Decisions	Pre-destination decision-making (planning a new trip)	In-destination decision-making (planning next days during a trip)
Where to go	Choose a destination for a trip.	Find the next travel destination.
When to go	Choose seasons or months better for this destination (e.g., summer, June, or July).	Choose places which are better in the next few days, e.g., depending on the weather forecast.
What to do	Start to plan a trip in advance, select items in a chosen destination.	Choose items (hiking trails, huts to resupply, accommodation to sleep) already in a chosen destination.
	Itinerary with all selected items visualized on a map (e.g., five days, 13 items selected for the trip: five hiking trails, three hotels, five restaurants).	

Table 2.2: The general concept of the web application.

Furthermore, the startup conducted user research related to use cases of such a decision support system and provided excerpts of the questionnaire. The findings have been reviewed and used to define the profile of user personas (see Chapter 3.2).

2.2. Cartographic Design Principles for Web Maps

In this subchapter, considerable design principles for web maps will be discussed, the nature of cartographic communication and data visualization will be touched on.

2.2.1 Web Map Design and Composition

Web maps are composed of different elements, some of which are required, and some differ depending on the map's purpose. These elements are organized based on levels of visual hierarchy and include map layers with different types of content. The composition of a typical web mapping application has the following structure:

1. A vector layer with a static basemap.
2. A raster layer with a topographic or thematic overlay (static or optional).
3. A raster layer with interactive thematic map layers.

Moreover, web maps are often equipped with interactive elements to help user to know more about the map layers (e.g., controls (pan, zoom, and rotate), informational popups, slider bars).

However, map legend is often ignored on general web maps despite the symbology cannot always be easily understood and self-explanatory (Kiefer, 2015). Thus, the creation of a good web map requires the inclusion of several visual levels, meaningful basemaps, and intuitive controls for map interaction into a coherent layout.

2.2.2 Cartographic Communication

Cartographic communication can be defined as the transfer of information from cartographer to map user by means of the map (Guelke, 2011). A fundamental objective of cartography is to enhance a map users' understanding of reality by placing information in appropriate contexts and efficiently communicating the information by cartographic methods of generalization and visualization (Kriz, 2009).

Massive increases in data sizes make it necessary to enable users to explore complex datasets in an intuitive and flexible manner. The way people perceive and interact with visualizations can strongly influence their understanding of the data as well as the usefulness of a visualization system in general (Zudilova-Seinstra et al., 2010).

Visual data exploration is crucial to discovering knowledge and information. There are many visual design guidelines, but the basic principles were described by Shneiderman (1996) and termed "visual information seeking mantra". It states the following: "overview first, zoom and filter, then details-on-demand".

Thus, the general process of visual data exploration happens in three stages:

1. Overview – obtaining an overview of the entire data collection.
2. Zoom and filter – zooming in to interesting items and filtering out uninteresting items.
3. Details-on-demand – selecting an item or group of items and obtaining details when needed.

According to Keim (2005), the "visual information seeking mantra" is as follows: first, the user gets an overview of all the data and identifies interesting patterns in the data and concentrates on one or a few of them. Then, the user wants to further analyze the patterns and needs to drill down to access details of the data. Applied to web maps, the user can perform the described process efficiently by using the zoom and pan interactivity and pop-up functionalities provided by a web mapping application. Nevertheless, when applying these functionalities without proper knowledge, it may lead to a confusing and misunderstood map (Kiefer, 2015). In order to avoid it, a cartographer's responsibility is to ensure that a web map is designed in a way that spatial information is delivered in a correct and understandable manner.

2.2.3 Visual Variables of Cartographic Symbols

When designing a web map, it is important to consider the technical limitations such as screen size and resolution. Thus, the design of web maps needs extra attention (Kraak & Ormeling, 2013). Various techniques exist to create clear and intuitive maps and emphasize specific data characteristics to be mapped. In 1983, the French cartographer Bertin developed the basic concept of visual variables. He proposed six categories of visual variables: shape, size, color hue, color value, color intensity, and texture (grain). These visual variables can be applied to make one symbol different from another (Kraak & Ormeling, 2013). Since then, it has been elaborated upon by other authors. Morrison (1974) stated to include

two additional variables used in the cartographic design: color saturation (color purity or intensity produced by the variety of light composing it) and arrangement (the layout of graphic marks constituting a map symbol). Moreover, MacEachren (1995) identified three additional visual variables for the web software design: crispness (sharpness of the map symbol's boundary), resolution (spatial precision at which the symbol is displayed), and transparency (the amount of graphic blending between a map symbol and the background or underlying map symbols). The overview of visual variables and their syntactic are presented in Figure 2.2.

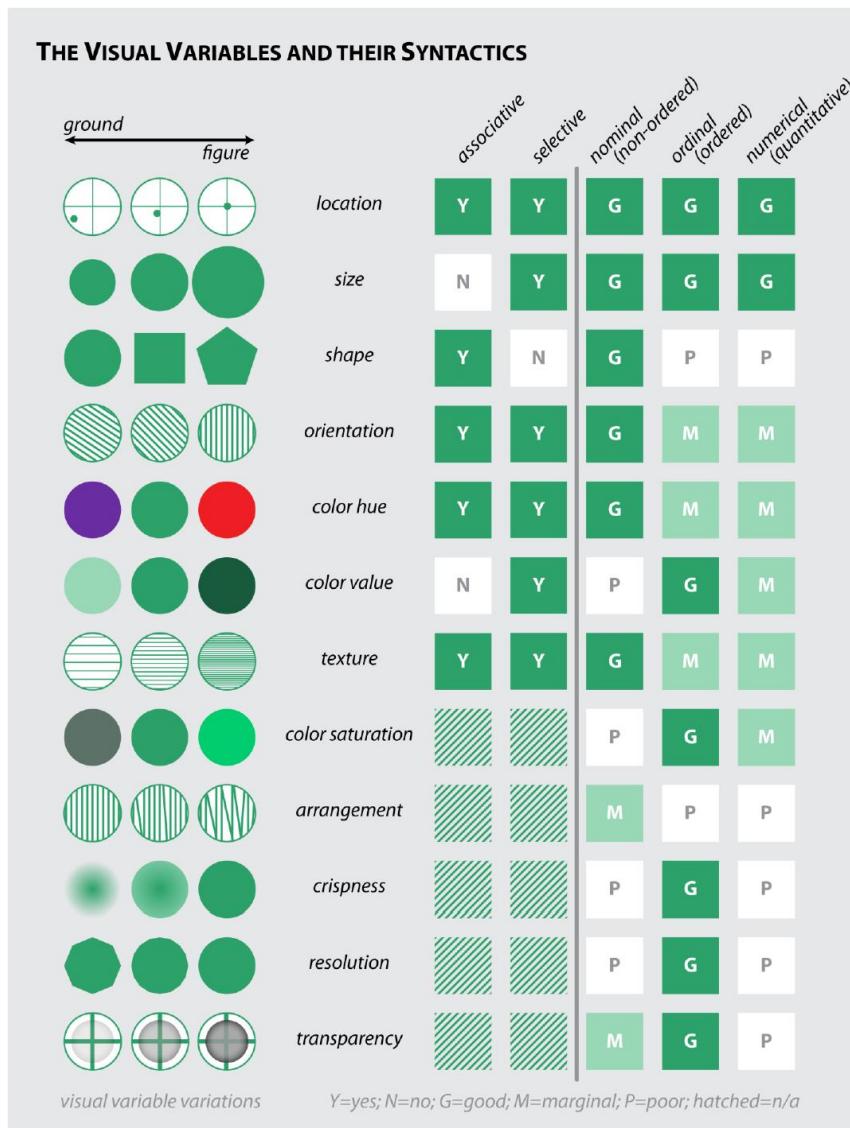


Figure 2.2: The visual variables and their syntactics.

Note. From "Visual Variables" by R. Roth, 2017, The International Encyclopedia of Geography, p.7. (<https://doi.org/10.1002/9781118786352.wbieg0761>).

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It shows examples of a point symbol for each visual variable. Moreover, the visual variables can be used to encode information about the line and area features. They can be used to improve the aesthetic quality of the map (Roth, 2017). Thus, understanding visual variables are essential for knowing how the different types of maps work and how the choice of symbols implies or does not imply patterns, groups, order, and quantity. The proper use of the visual

variables is crucial for the proper communication of thematic data and designing an efficient and understandable map.

2.2.4 Cartographic Symbol Design for Web Maps

A map consists of point symbols (zero-dimensional), line symbols (one-dimensional), area symbols (two-dimensional), and text. The symbols can vary in their appearance and have different sizes, shapes, and color. The overview of common visual variables for point, line, and area symbols is presented in Figure 2.3.

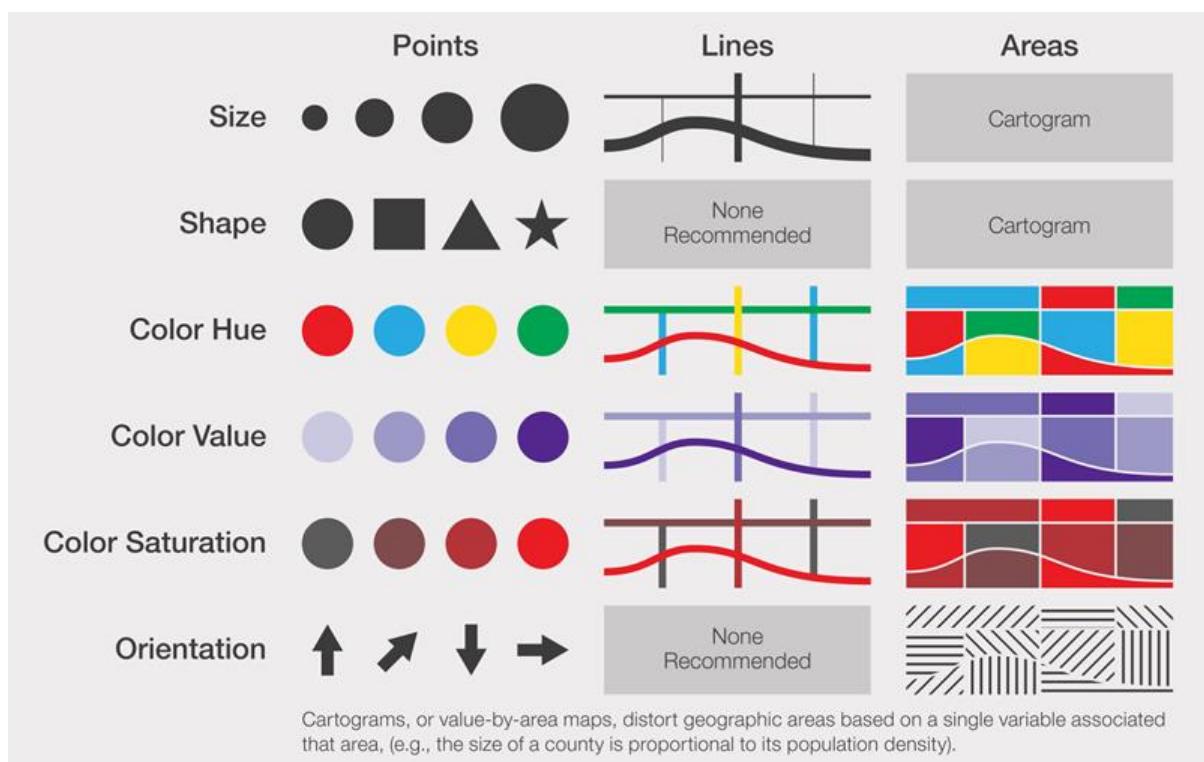


Figure 2.3: Common visual variables for point, line, and area phenomena.

Note. From "Symbolization and the Visual Variables" by T. White, 2017, The Geographic Information Science & Technology Body of Knowledge (2nd Quarter 2017 Edition), John P. Wilson (<https://doi.org/10.22224/gistbok/2017.2.3>).

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Point symbols

Point symbols have several different uses on maps. Examples include a depiction of geographic features that occupy a minimal area on the map; representation of data referring to a geographic unit; providing "shorthand" information, e.g., an array of symbols next to a town on a tourist map to show the tourist facilities available. Three categories of point symbols can be presented on maps: pictorial, geometric (abstract), associative, and alphanumeric (Brown & Kraak, 2003).

Pictorial point symbols are designed to resemble its referent directly. They are easy to understand for inexperienced map readers, even without a legend. However, the problem in

designing the pictorial symbols for web maps is a need to visualize the important characteristics of the object within a small area and a limited number of screen pixels. The pictorial symbols are used to represent qualitative data. In comparison with traditional paper maps, these symbols may be more prominent on the web maps to improve legibility. Therefore, designing such symbols can be tedious. Geometric point symbols are designed with little or no resemblance to its referent. Moreover, the same symbol can mean different features on different maps. Thus, in most cases, the geometric symbols should be interpreted in a legend. In comparison with pictorial symbols, geometric symbols can be relatively small, easily varied in size to present quantities, whereas the shape and color can convey qualitative information. The point symbols are considered associative when the combination of geometric or pictorial characteristics is used to form a shape associated with the referent (Divjak et al., 2020). Alphanumeric point symbols use letters or numbers. Although this type of symbol has some disadvantages, such as the fact that distribution patterns may not be immediately obvious and a legend is required to understand their meaning, they are found on many maps. Especially for web maps, they have to be made relatively large to be effective.

Line Symbols

Line symbols are used to indicate connectivity or flow, equal values along a line, and boundaries between unlike areas (MacEachren, 1979). Line symbols on topographic maps are used to represent features such as roads, railways, and contour lines. In thematic maps, they can be applied to depict the ocean currents, trade flows, or average temperature. Line symbols are differentiated depending on their form (e.g., solid line versus dotted line), color, and width. When designing thin and/or highly curved line symbols, it is important to consider that some specific graphic variables such as orientation and/or texture are not recommended, primarily because of the limited web capabilities. Since web objects have to be defined as areas, it is inconvenient to handle thin and elongated shapes of lines as interactive web objects.

Area Symbols

Area symbols are used to present area-based information. Visual variables used for area symbols are color, value, saturation, and orientation. Most web design software has tools to apply these variables to area symbols. In combination, these visual variables can be applied to create some complex area patterns. It can be used to enhance the semantic meaning of the symbol (e.g., green tree symbols indicate forest areas), to reduce confusion between symbols, to emphasize the figure-ground relationship, or to facilitate the aesthetic impression of the map. The correct use of visual variables besides the simple color and value can make a web map more interesting. However, this often leads to an increase in file size and slower downloads. On web maps, area symbols can work very well as web objects since they are relatively large (Brown & Kraak, 2003).

Combination of Symbols

Map design is not only the design of the individual symbols. It assumes the simultaneous display of all information on the map. This is a simple intellectual process, composing a series of steps that web mapping should logically follow, starting with analyzing the type of information that needs to be presented. Following these steps, it is possible to design a functional map taking into account an overall layout. Making the map more interesting and

exciting to look at while still keeping to the cartographic principles and adding extra artistic efforts is unnecessary (Brown & Kraak, 2003).

2.2.5 Colors on Web Maps

Selecting an effective color scheme is one of the most critical steps in designing an effective web map. As described above, colors play a crucial role in the theory of visual variables. The visual perception of objects is a powerful sense as human beings. It is only natural to use this fact to highlight objects and guide the reader's attention in the right direction. However, unintuitive use of colors is likely to cause misinterpretation and confusion. It is important to consider the fact that the map reader has no direct control over how the image displays on a screen. It depends on the specific configuration and settings. This is why web map designers frequently adopt a cautious approach and consider the minimum configuration and lowest settings (Kraak & Ormeling, 2013).

There are three color properties such as hue, value, and saturation. Hue refers to what we assume by color. The pure hues are easy to recognize, e.g., blue, red, green, yellow. The value defines how light or dark the color hue is. When white is added to a color hue, it is called a tint. When black is added, it is a shade. Saturation refers to the brightness of a hue. Colors that are pure and not mixed like primary colors have the highest saturation. The primary colors are red, green, and blue. And other colors are created from the primary colors. Secondary colors represent a mix of cyan, magenta, and yellow, including the changes in value and saturation. Monochromatic colors are created with the value or saturation of a single hue, and they are best for presenting thematic data. Achromatic colors have greyscale colors with white, black, or grey values in between. Achromatic colors can look powerful and engaging on web maps since users expect a plethora of different colors and do not find them (Muehlenhaus, 2013).

It is important to note the simultaneous contrast on web maps. Simultaneous contrast is when two or more objects of the same color are displayed with different values because of the colors around them. It often happens on aerial imageries with different color variations.

Some color rules that can be applied to the web maps are:

- Less color variation is more powerful, which helps the user to better interpret what is displayed. In most cases, it is better to use neutral (white, black, grey scaled colors) of a basemap in order to symbolize important data with other colors to catch the user's attention.
- Different colors have different meanings to different people. Colors are associated with various feelings and emotions, which vary depending on culture, traditions, or experiences. That is why it is best to choose a color scheme based on the intended audience.

2.2.6 Web Typography

Text on web maps cannot be omitted since it can express information such as geographic names, elevation values, etc., which is not possible with any other symbols. Text greatly

affects the look and feel of maps. Inappropriate selection and use of typographic variables, such as font size or font variable, can conflict with graphic variables, such as those used when designing cartographic symbols. Hence, the map typography and the design of map symbols cannot be separated from each other (Kraak & Ormeling, 2013).

According to Muehlenhaus (2013), the key concepts related to web typography are as follows:

- It is important to consider that not all fonts are available to all users. Different devices have different installed fonts. Therefore, it is best to use commonly used fonts.
- Never use more than two different fonts on a web map. All other font differences can be created by manipulating the properties of the applied font.
- Avoiding most serif fonts is crucial for web maps since it is difficult to read them on a screen. However, such fonts as Georgia are advisable in case it is directly designed for computer monitors.
- Consistent line weight and thickness with simple strokes help make the text more legible.

2.2.7 Icon Cluttering

According to Burigat and Chittaro (2008), unprocessed displaying of too many features can result in significant degradation of performance and an icon cluttering problem. It happens when too many icons are located on a small map space. Thus, symbols overlap each other, which may lead to a low level of map readability since the important map features can be hidden. This effect further emphasizes the importance of generalization and clustering strategy on cluttered maps since it is increasingly difficult for the user to precisely choose a particular marker when the neighboring icons are too close to each other.

2.2.8 Decluttering of Point Markers

As mentioned above, a wide range of available data which can be displayed on maps often leads to different problems. Therefore, cognitive overload, low application performance like a slow response to map interactions, or long loading times can cause a frustrating and unsatisfying user experience.

Huang and Gartner (2012) defined solutions to address the icon cluttering and one of those is icon aggregation (building clusters). Intelligent filtering methods can be applied in different situations, as the number of points of interest can be significantly reduced, and the user is enabled to find the desired results more efficiently and faster. The application of semantic filtering would be beneficial.

The situation can happen where multiple points of interest fall together, causing overlapping icons. In this case, the location of the icons either needs to be rearranged or the points of interest need to be aggregated and replaced by a placeholder symbol. Burigat and Chittaro (2008) defined the process of icon aggregation in the following way 'identify clusters of mutually overlapping icons and replace them with special aggregator icons [...]' . Such an

approach can help to declutter the map, and therefore, improve map legibility and free the map space without losing information.

2.3 Existing Web Mapping Products Supporting Travel-Related Decisions

There are different web mapping products that have partially similar purposes, functions and aim at supporting travellers and outdoor enthusiasts in their travel-related decisions during the travel process. Some of the visualizations of the map layers may be relevant for consideration and applied while developing the web mapping application focusing on hiking. Based on the results of the user research conducted by the startup, it was decided to choose the applications most often mentioned by participants: AllTrails, Komoot, FATMAP, Google Maps, and TripAdvisor. The overview of such web mapping products is presented in Table 2.3.

Web applications	Description
AllTrails ¹	A fitness and travel platform used in outdoor recreational activities such as hiking, mountain and road biking, rock climbing, camping and snow sports.
Komoot ²	A route planner and navigation app for outdoor activities. It is aimed specifically at cyclists, hikers, mountain bikers, and racing cyclists. It displays the route on the Leaflet-based map.
FATMAP ³	An outdoor adventure platform for both web and mobile. There are currently 20 activities such as hiking, rock climbing, trail running, mountain biking, freeride skiing. The main feature is using high-resolution 3D topographic maps with snow layers to check the snow depth and snow forecast.
Google Maps ⁴	A web mapping product developed at Google. It offers satellite imagery, aerial photography, street maps, 360° interactive panoramic views of streets, route planning for traveling by foot and cars.
TripAdvisor ⁵	A travel guidance platform that offers online hotel reservations, bookings for transportation, travel experiences, restaurants and includes user-generated content.

Table 2.3: Overview of some web mapping products supporting travel-related decisions.

The web map of AllTrails is based on Mapbox and OpenStreetMap. The scrollable left sidebar in the user interface displays the general information about a hiking trail, description, waypoints, tips, weather, ultraviolet index, daylight, reviews, and images (see Figure 2.4). The path of a hiking trail is colored in red. The markers of items (e.g., restaurants and hotels) have the same color. The hiking trails are clustered into single clusters of the same size. When the user hovers over the cluster, it shows all the trails within the cluster (see Figure 2.5). AllTrails offers a wide range of basemaps such as its own customized terrain basemap, road, satellite, terrain, world parks, and topographic basemaps. Additionally, it has different map overlays: distance markers, heatmap, weather, air quality, and light pollution.

¹ <https://www.alltrails.com/>

² <https://www.komoot.com/>

³ <https://fatmap.com/>

⁴ <https://www.google.com/maps>

⁵ <https://www.tripadvisor.com/>

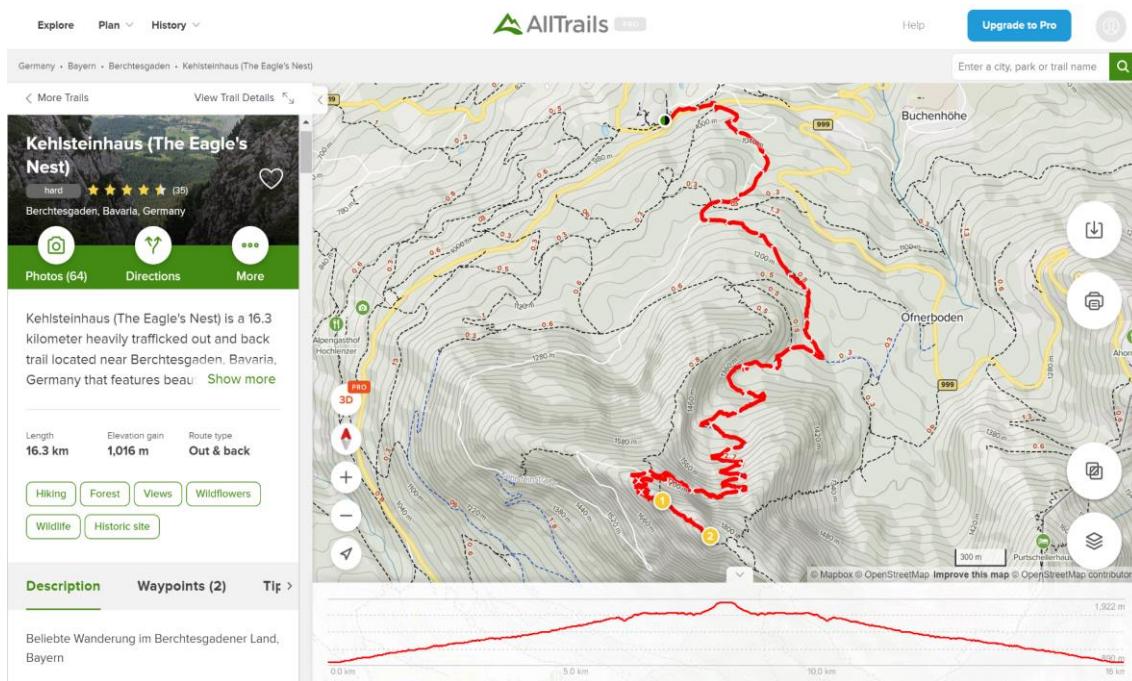


Figure 2.4: AllTrails map interface.

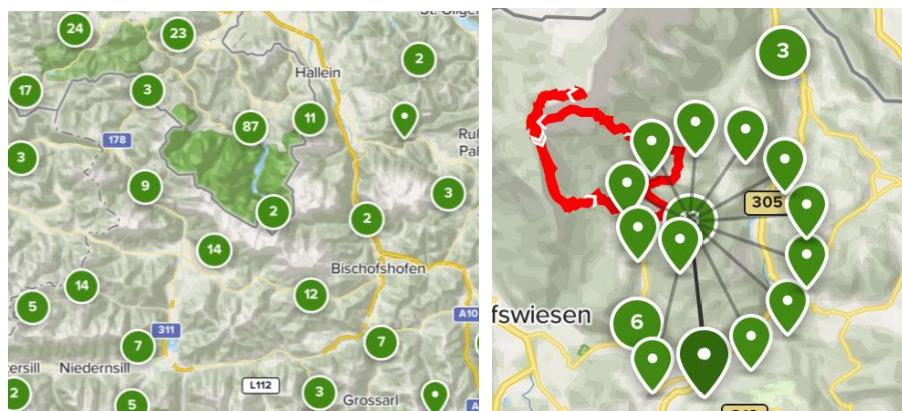


Figure 2.5: Example of clustering of hiking trails in different zoom levels.

The map of Komoot is based on Leaflet and OpenStreetMap. The scrollable left sidebar in the user interface displays general information about the trail, options to customize the trail, information about waypoints along the route with reviews from users, detailed view surface, tour profile, way type, and elevation analysis in the planning panel (see Figure 2.6). It offers some filtering options to show or hide different items, e.g., shops, Internet hot spots, ATMs, accommodation, parking, travels stations, bus stops. The path of a hiking trail is semi-transparent, colored in blue, and has a white outline. The markers of items (e.g., restaurants and accommodation) have the same color. The hiking trails are clustered into single clusters of the same size. When the user clicks on the cluster, the map zooms in, and it is divided into single trails (see Figure 2.7). There is no choice of basemaps.

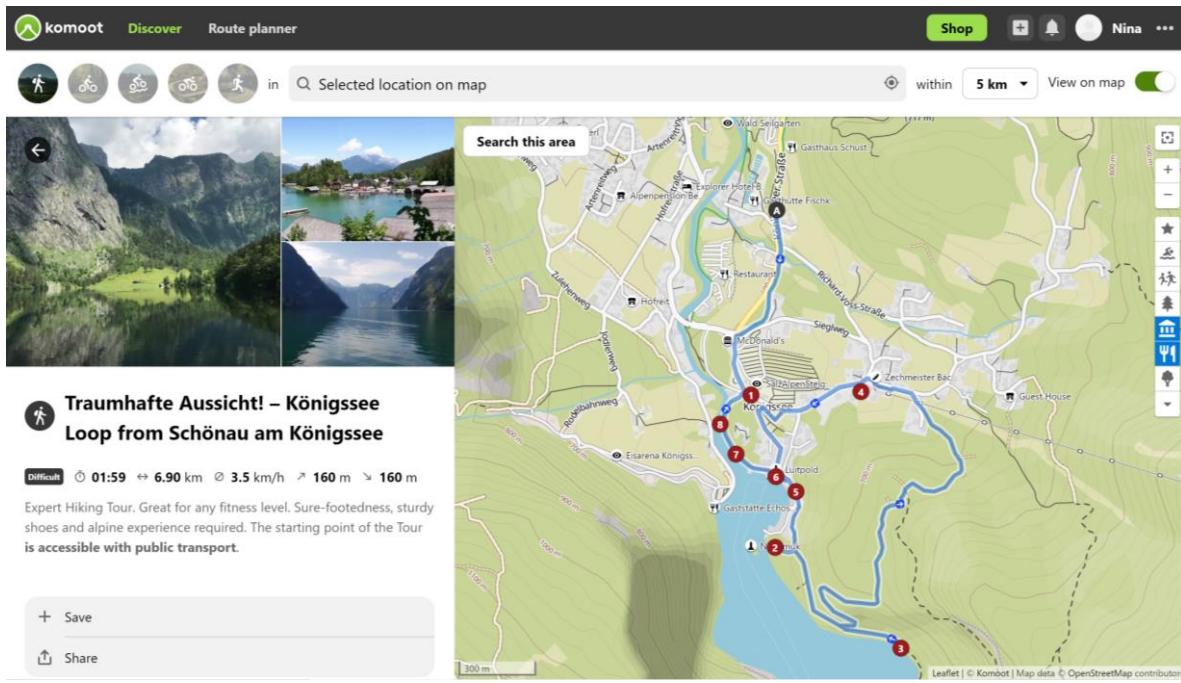


Figure 2.6: The Komoot's map interface.

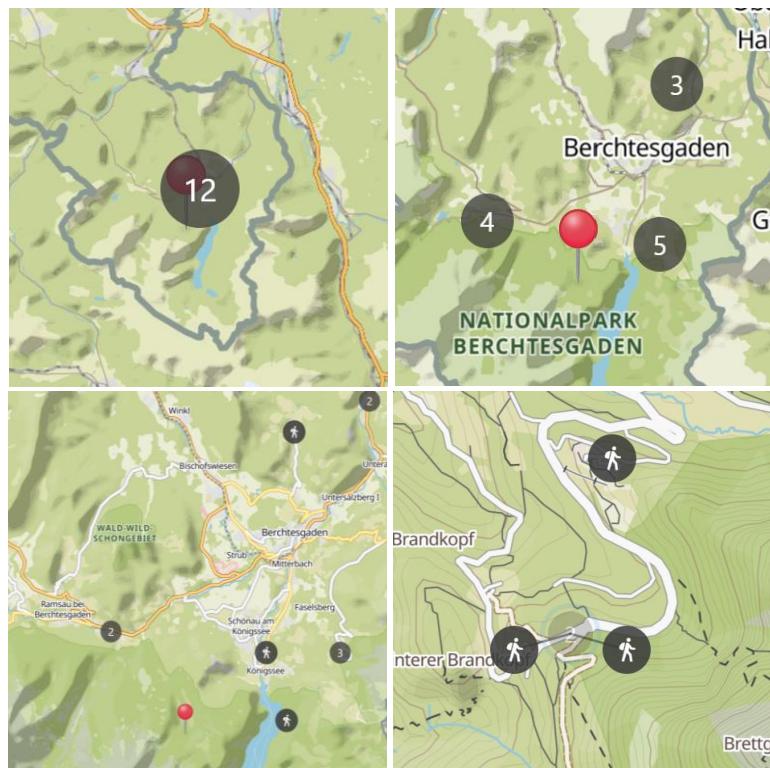


Figure 2.7: Example of clustering of hiking trails in different zoom levels.

FATMAP is based on its own high-resolution 3D topographic map. It displays such information about a hiking trail as estimated time, distance, elevation, slope shown at the bottom of the map (see Figure 2.8). It has a left sidebar with description, difficulty grade, estimated time, characteristics (e.g., dog-friendly, picturesque, road sections), level of exposure (some trail sections have exposed ledges or steep ascents/descents where falling could cause serious injury), remoteness (e.g., away from help but easily accessed), and recommended time of

year. The path of a hiking trail is bright green. FATMAP offers country-specific topographic maps for Great Britain, Switzerland, France, Germany, Austria, Spain, Norway, New Zealand, Sweden, and the USA. In addition, there is a wide range of overlays for the terrain basemap: avalanche, aspect, distance, elevation, flats, and gradient.

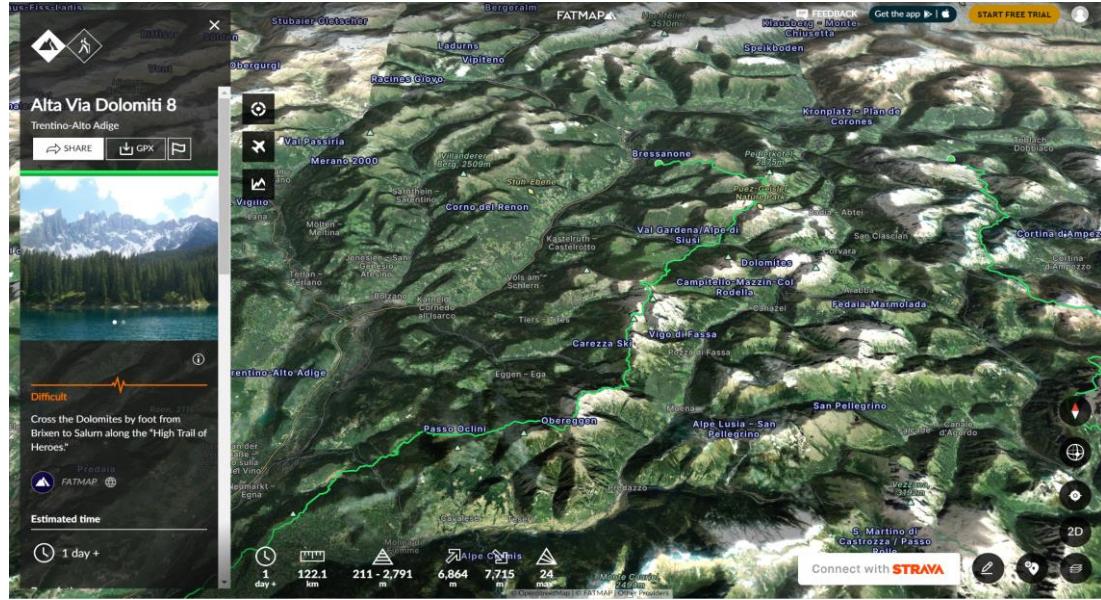


Figure 2.8: The interface of FATMAP.

Google Maps displays hikes as a single marker without a path (see Figure 2.9). The markers of hiking trails have the same color as other points of interest. When searching for a hiking trail, it shows photographs of the trailhead or the trail itself that users uploaded, ranking, reviews, recommendations of places to visit nearby. Google Maps provides the following basemaps layers: default, satellite, terrain, and such overlays as traffic, transit, street view, and biking.

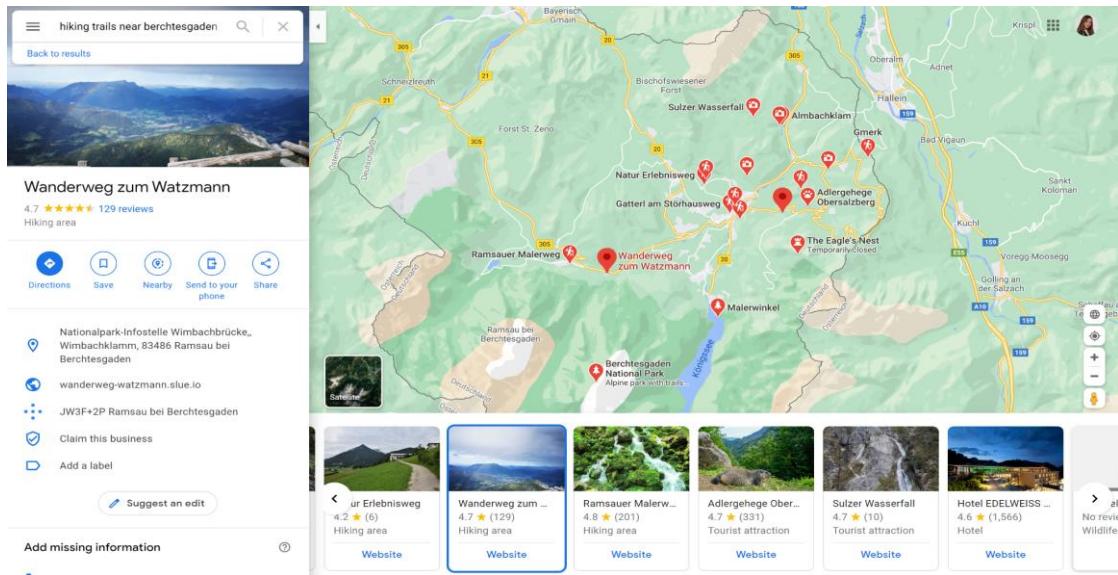


Figure 2.9: The interface of Google Maps.

TripAdvisor is based on Google Maps. Outdoor activities such as hiking belong to the category "Things to do". A hiking trail is shown on the map as a single marker without its path. The

colors of the markers in different categories vary. When choosing a particular hiking trail, it displays the items nearby (hotels, restaurants, things to do), photographs, and trail rating by clicking a pinpoint (see Figure 2.10).

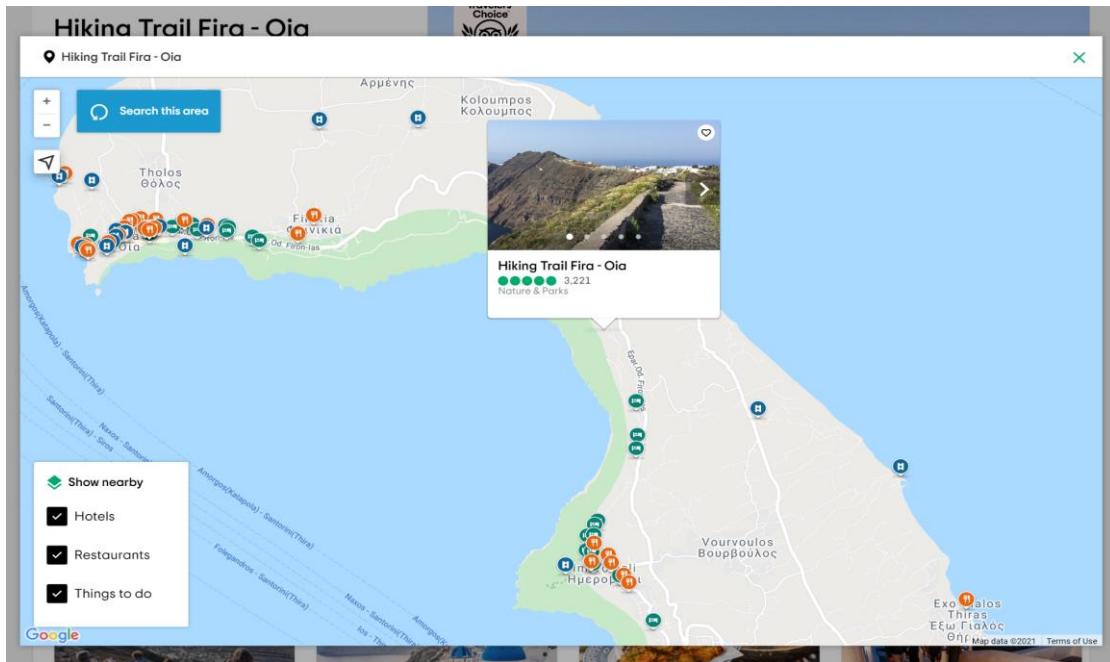


Figure 2.10: Example of TripAdvisor's web map.

Thus, the web mapping products visualize decision-relevant information differently. Though the applications focused on outdoor activities present more details about hiking trails on the map. Komoot and AllTrails aggregate hiking trails into clusters in different zoom levels. Komoot, AllTrails, and FATMAP visualize a hiking path on terrain or satellite basemap. AllTrails and FATMAP offer a wide range of basemaps and overlays relevant to outdoor activities. Google Maps also provides terrain and satellite layers but displays hiking trails as points of interest like TripAdvisor. However, the mentioned applications do not have the functionality of highlighting groups of areas relevant to this study.

3 Methodology

This chapter presents a methodology on how the decision-relevant map layers of the web application for a decision support system focusing on hiking may look and feel. This chapter describes the data, tools, and methods needed for data collection, visualization, and evaluation of a web application for the decision support system.

3.1 General Overview

The methodology comprises seven main stages. The general workflow of the methodology is presented in Figure 3.1.

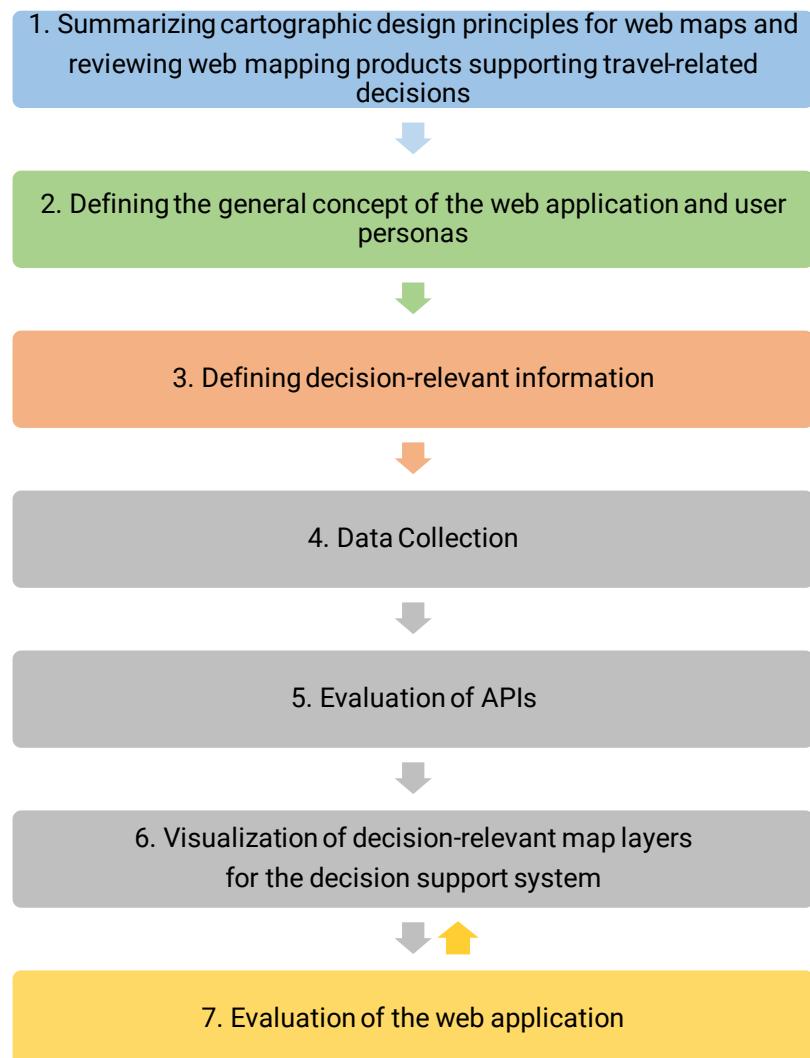


Figure 3.1: Workflow showing an overview of the methodology.

The first stage consists of the literature review on cartographic design principles for web maps and reviewing web mapping products supporting travel-related decisions. The second stage is defining the general concept of the web application and user personas. The third

stage includes defining decision-relevant information: decision-relevant map layers, places, and weather information. Then there is an implementation phase consisting of data collection (choosing tools and techniques), evaluation of selected APIs (Map APIs, Places APIs, and Weather APIs), and visualization of the decision-relevant map layers for the decision support system. After implementation, the next stage is evaluating the web application, including user study (choosing evaluation methods: thinking aloud, questionnaire, and expert interviews) and analyzing the results. Since the designing web application is user-centered, it is an iterative design process, and the implementation can continue until the evaluation results are satisfactory.

3.2 Defining User Personas

To create a product that should meet the needs of a diverse audience of users, it is necessary to design it for specific types of individuals with special needs. First, it is crucial to select the right individuals to whom the product is intended. Their needs can best reflect the needs of a broader set of key constituents. Then, it is necessary to prioritize these individuals to meet the needs of the important audience without compromising secondary users (Cooper et al., 2007). User personas are a powerful tool for communicating about different types of users and their needs. They help to define which users are the most important in the design. User personas represent a model of users not individual persons, and combined directly from observations of real people. Thus, based on the information provided by the startup and their analysis of the requirements', the following assumptions regarding goals, needs, and travel behavior of two primary user personas were made (see Figure 3.2 and Figure 3.3). The user personas' descriptions are needed to define what is the decision-relevant information, what features of the prototype should be developed, and what should be visualized. Moreover, the potential participants of the user study will be asked to imagine the roles of these two user personas considering their travel cases presented in Table 3.1.

Who	Anna	Roman
What	Searches for a long hiking trail for three days or three-day hiking trails	One day hiking trip
When	Trip is fixed to five days at the end of October	Trip is flexible and depends on the weather next week
	Chooses the region to hike based on best months/seasons (what is the most suitable in October)	Chooses day with the best weather on the next week
Where	Somewhere in Europe	Somewhere in Bavaria
	Prefers moderate and hard trails	Prefers easy or moderate trails, 4-6 hours long
Details	Needs overnight stays and places to eat along the trails	Wants to have lunch at a restaurant near a lake and to swim there afterward
	Uses public transport	Uses public transport

Table 3.1: Overview of the use cases.

User Persona 1

Anna, 33 y.o.



Bio

- Lives in Moscow
- Works at IT company
- Loves nature
- Regularly visits new places
- Spends her vacation abroad (in April and October)
- Fond of active sport tourism
- Hiker enthusiast

Travel Behaviour

- Plans trips in advance
- Likes to organize a travel plan and has a bucket list
- Explores new places and countries
- Rents a car
- Prefers living near or in the mountains
- Relies on reviews
- Likes to share her experience and recommendations on social media
- Experienced with traditional navigational tools

Brands

Goals and Needs

- Get a new hiking experience
- Find out options for places to hike, to stay, to eat along the route during the trip
- Create, plan and organize travel itineraries in a simple and flexible way
- Find out if the trail is a loop, or it is needed to backtrack or spot another vehicle
- Get info about accessible trails in early spring (if covered in snow) and autumn
- See when the sun is setting earlier (in fall) to plan accordingly and not be caught out after dark unexpectedly

Frustrations

- Using multiple websites to plan trails to hike, hotels, restaurants, and activities, to compare and choose the most suitable option

Figure 3.2: Description of User Persona 1.

User Persona 2

Roman, 22 y.o.



Bio

- Lives in Munich
- International student having a part-time job
- Hiker beginner
- Fond of road cycling
- Has long-distance travels twice a year after winter and summer semesters
- Twice a month has day trips with classmates around Bavaria

Travel Behaviour

- Does not prepare any exact plan before trips, only chooses a destination
- Travels only with one backpack
- Prefers wild camping
- Prefers to spend some days of his long vacations hiking, some days exploring sightseeing nearby
- Experienced with digital navigational tools

Brands

Goals and Needs

- Create plan and travel itineraries during trips
- Understand the terrain
- Choose the right trails for his fitness level
- Familiarize himself with a trail after having selected it (obtain a map of the area, review reports and data)
- Options to check bus stops/train stations at the endpoint of a hike (which finishes at different places)
- Get few hours before hike information about the weather on a spot (how to dress, what to pack)
- Look for and save to itinerary a good lunch spot (lake/peak with a view)
- Look for places to arrange a campsite

Frustrations

- How to find a better way in case of a wrong turn (possibility to check any intersecting trails)

Figure 3.3: Description of User Persona 2.

3.3 Defining the Decision-Relevant Information

Based on the assumptions regarding two main user personas and the general concept of the web application, the decision-relevant information was divided into three main groups:

1. Decision-relevant map layers
2. Decision-relevant places information
3. Decision-relevant weather information

The three groups will be explained in detail in the following subchapters.

3.3.1 Decision-Relevant Map Layers

Since the user personas have slightly different needs in a map, the web mapping application should offer a choice of different basemaps across the web application to meet their needs. The decision-relevant map layers were divided into two categories: basemaps and map overlays (see Table 3.1).

The defined basemaps important for the decision support system are customized general-purpose basemap, terrain, and satellite basemaps. A primary basemap is a customized general-purpose basemap designed to provide geographic context while highlighting the system's recommendations. It should provide a vector reference basemap with global coverage, neutral background style, hill shading, minimal colors, labels, and features to draw attention to the content. Terrain basemap is a topographic map with contour lines and elevation, including labels and roads across the globe. Satellite basemap displays global, high-resolution satellite imagery includes labels.

Map overlays can be overlaid on top of any basemap and provide additional information to support users making decisions for their trips. Unlike basemaps, multiple map overlays can be applied at once. The decision-relevant map overlays are countries boundaries and country subdivision, and weather overlays. Countries' boundaries and country subdivision are essential for visualizing the system's recommendations ("goodness" or "badness" of areas). Weather overlays are used to support the user decision-making process of planning the trips on particular days. They display real-time satellite temperature or precipitation weather data, historical weather data, or forecast weather over any basemap.

Category	Type	Details
Basemaps	Customized basemap	<ul style="list-style-type: none">• Neutral background• Minimal colors, labels, and features• Hill shading• Global coverage
	Terrain	<ul style="list-style-type: none">• Topographic data with contour lines and elevation• Labels• Roads• Global coverage
	Satellite	<ul style="list-style-type: none">• High-resolution satellite imagery• Includes labels• Global coverage

Map overlays	Countries' boundaries and country subdivision	<ul style="list-style-type: none"> • Geometry of boundaries with additional properties (e.g., names of countries)
	Weather overlays	<ul style="list-style-type: none"> • Forecast weather overlay (temperature and precipitation) • Current weather overlay (temperature and precipitation) • Historical weather overlay (temperature and precipitation)

Table 3.1: Decision-relevant map layers.

3.3.2 Decision-Relevant Places Information

Decision-relevant places information is the information about objects of interest that the user considers while making travel-related decisions. The decision-relevant places information was divided into seven categories such as accommodation, food and drink, local facilities, health, transport, tourism, hiking based on needs of the defined user personas. Each category contains objects and their detailed information (see Table 3.2).

Category	Objects	Details
Accommodation	Hotels, hostels, guest houses, motels, etc.	Name, location, address, opening hours, contact, website's link, rating, photo
Food and drink	Cafes, restaurants, bars, grocery stores, etc.	Name, location, address, opening hours, contact, website's link, rating, photo
Local facilities	Supermarkets, outdoor and sport shops, kiosks, parking lots, camping grounds, public toilets, public water fountains, ATMs, etc.	Name, location, address, contact, opening hours, website's link
Health	Ambulance stations, pharmacies, emergency rooms, etc.	Name, location, address, contact, opening hours, website's link
Transport	Train stations, bus stops, aerialways, etc.	Name, location, address
Tourism	<ul style="list-style-type: none"> • Tourist attractions (viewpoints, museums, galleries, castles, churches, monasteries, ruins, etc.) • Leisure facilities (playgrounds, swimming area, parks, gardens, etc.) 	Name, location, address, opening hours, contact, website's link, rating, photo
Hiking	Hiking trails	Location, route type, surface, elevation gain, length, difficulty, duration, rating, photos, description, waypoints, etc.

Table 3.2: Places decision-relevant information.

3.3.3 Decision-Relevant Weather Information

Besides weather overlays, decision-relevant weather information should include weather widgets displaying current weather, daily forecast, historical temperature and precipitation data. The important details can be temperature, atmospheric pressure, humidity, cloudiness, current ultraviolet index, wind speed, precipitation, and daylight hours.

3.4 Data Collection

To visualize decision-relevant map layers for the web mapping application, the decision-relevant information defined in Chapter 3.3 should be collected. This section presents the tools and techniques used to obtain the necessary data.

3.4.1 Data Collection Tools

A programming stack for developing a web application should be chosen based on how many useful libraries are supported and how many different use cases are covered by the standard solutions that can be found on the Internet. For this particular research, the stack was predetermined by the startup. It includes React, a free and open-source front-end JavaScript library for building user interfaces or UI components based on the TypeScript programming language and the standard stack. Python, a script programming language, is used to collect data from public APIs.

3.4.2 Data Collection Techniques

As defined in Chapter 3.2, different types of data should be obtained. There are three techniques on how to obtain the required data:

- Some data (e.g., hiking trails, weather overlays) can be obtained directly using APIs.
- In case an API has low performance, the data can be acquired using scripts to be collected from the public APIs and stored in the application database.
- Some data can be downloaded in the proper format on the Internet (e.g., from an open-source project on GitHub) and integrated into the application code.

3.5 Evaluation of APIs

In modern software development, developers often rely on existing frameworks, libraries, or software development toolkits providing existing code structures for reuse, not programming them from scratch. To access these and simplify app development, application programming interfaces are provided. While there may be many kinds of APIs, they all serve the same purpose of providing a programmatic user interface to a code module. As with any interface, some are more user-friendly than others, significantly impacting the final product.

Though there is a wide range of API products across all domains. However, there is no standardized methodology to evaluate an API product. The selection of an API depends heavily on business goals, preferences, project scope, and budget. APIs as a widespread issue have been evaluated in many different ways (Farooq & Zirkler, 2010), (Gerken et al., 2011). These studies provide some general guidelines for evaluating APIs. Peterson (2014) described criteria of evaluation for mapping APIs such as execution speed, length of code, cartographic functionality, map cost, etc. Some researchers analyzed the developer's behavior when selecting API products (Ayala et al., 2011). These studies concluded that developers follow informal or ad-hoc procedures to make an API product selection. Chikkala (2017) summarized selection criteria based on relevant research papers such as functionality, cost, support and maintenance, documentation quality, ease of customization, ease of implementation, licensing terms, etc.

Based on the research of papers mentioned above and the concept of the web application, own criteria for each required API are defined to compare existing API products and choose the suitable APIs for the decision support system.

3.5.1 Choosing Map API

A typical Map API (also known as Mapping API) includes features for geocoding, reverse geocoding, geolocation, directions, and navigation, touch-screen interaction, different types of maps (e.g., terrain or satellite), and customizable control objects. There are various Map APIs for the user-driven web. The most used are the APIs of Google Maps, OpenStreetMap, and Mapbox. Other Map APIs available to app developers are HERE Maps API, TomTom Maps APIs, Bing Maps API, etc. However, the relevant web products with partially similar purposes use OpenStreetMap API combined with Mapbox API or standalone Google Maps API (see Table 3.3). Therefore, for comparison purposes, these three Map APIs were selected and analyzed.

Map APIs	Web platforms
OpenStreetMap API	Komoot Outdooractive FATMAP Gaia GPS
OpenStreetMap, Mapbox APIs	AllTrails Strava Foursquare Maps.me
Google Maps API	TripAdvisor Airbnb Booking

Table 3.3: Use of Map APIs and libraries by relevant web products.

Comparison of Map APIs

Based on the documentation of APIs and the articles provided by tech blogs^{6,7}, the nine most relevant criteria for the comparison of Map APIs were defined as follows: global coverage, customization options, overlays, map layers, offline maps, the complexity of code, usage limitations, and cost and pricing. The overview of the comparison is presented in Table 3.4.

Criteria	Google Maps API ⁸	OpenStreetMap API ⁹	Mapbox API ¹⁰
Global coverage	Inferior coverage depending on a region, but more accurate than OpenStreetMap and Mapbox APIs	Inferior coverage depending on a region because it relies on collective mapping	Inferior coverage depending on a region because it relies on collective mapping
Customization options	Limited support for creating a unique look and feel of a map	Flexible but using third-party services	More customizable than Google Maps and OpenStreetMap APIs and has unique customization options
Overlays	It supports overlay for images and basic shapes such as polyline, polygon, circle, etc.	Additional use of Overlay API, a programming interface for vectors and pointers on slippy maps	It supports overlay for images and basic shapes such as polyline, polygon, circle, etc.
Map layers	It provides terrain, satellite, traffic, transit, and bicycle layers	Map layers are not part of the project, so additional custom layers can be fetched from Leaflet or Mapbox	Mapbox provides streets, terrain, traffic, satellite, boundaries layers
Offline maps	No offline mode available via API	Map data for the whole globe can be downloaded and used entirely offline	It supports offline functionality
Complexity of code	Less complex code, well-organized examples	It has the longest code, but in combination with Leaflet API, it becomes less complex	More complex in regard to architecture, standardization, and data flow
Usage limitations	No strict limitations	Limitations for heavy usage	No strict limitations
Cost and pricing	Costs per requests	Open-source, free	Costs per usage

Table 3.4: Comparison of Map APIs.

Google Maps API has immense data in Google Maps' database and can outperform OpenStreetMap and Mapbox when users are zooming closely into the map. However, Google Maps API has limited support for creating a unique look and feel when maps are integrated into an application. Mapbox is more customizable than Google Maps and has more unique customization options. It is the best in terms of aggregating and visualizing large amounts of data. However, it is important to consider the difficulty in understanding the data flow on its architecture. OpenStreetMap API is best for basic map integration. However, it requires

⁶ <https://relevant.software/blog/choosing-a-map-amapbox-google-maps-openstreetmap/>

⁷ <https://topdevs.org/blog/choosing-the-best-mapping-services>

⁸ <https://developers.google.com/maps/documentation/javascript/overview>

⁹ <https://wiki.openstreetmap.org/wiki/API>

¹⁰ <https://docs.mapbox.com/#maps>

creating the core infrastructure around its API or working with third-party solutions based on OSM data since it does not have much standalone functionality. While the OpenStreetMap is a free API, Mapbox will have a cost advantage, especially for data-heavy projects compared to Google Maps API. To conclude, Google Maps, OpenStreetMap, and Mapbox APIs have their pros and cons. The selection of API is based on the nature of the application and its need.

Comparison of Map Libraries

To decide what Map API to select, it is essential to analyze corresponding map libraries. Map libraries simplify the development of interactive maps in web browsers and offer simple ways to visualize and stack map layers, including static raster and vector layers with various styling methods. Due to the startup's requirements of developing an application using React libraries based on TypeScript, the map libraries should be compatible with React. To compare the libraries, the six criteria were defined for "*google-map-react*"¹¹, "*react-leaflet*"¹², "*react-geo*"¹³, and "*react-mapbox-gl*"¹⁴ libraries based on their documentation and articles of a tech blog¹⁵. The comparison overview is presented in Table 3.5.

Criteria	Maps JavaScript API (<i>google-map-react</i>)	Leaflet (<i>react-leaflet</i>)	OpenLayers (<i>react-geo</i>)	Mapbox GL (<i>react-mapbox-gl</i>)
The size of the library	12,6 Kbytes	7,1 Kbytes	69,1 Kbytes	15,3 Kbytes
Functionality	A small set of the functionality	Rich functionality by means of plugins	Rich functionality including user interfaces, styling, and interactions	Rich functionality including user interfaces, styling, and interactions
Compatibility	It works only with Google Maps API	It can be used with OpenStreetMap-project and commercial products	It can display map tiles, vector data, and markers loaded from any source	It can be used with OpenStreetMap-project and commercial products
Documentation	Well-structured documentation with various examples	Only very basic examples. There is a need to search the internet to obtain specific information	Well-structured documentation but very large. More code writing is required	Thorough documentation and demos
Vector tiles support	It supports vector tiles	No vector tiles support, but possible by third-party plugins	It supports vector tiles	It supports vector tiles
Costs	Pay per use	Free/Pay per use	Free	Pay per use

Table 3.5: Comparison overview of JavaScript map libraries.

The size of map libraries is an important factor in terms of response time, but most libraries are relatively small, so the response time is fast. While *google-map-react* is best when the

¹¹ <https://www.npmjs.com/package/google-map-react/>

¹² <https://react-leaflet.js.org/>

¹³ <https://terrestris.github.io/react-geo-ws/map-integration/>

¹⁴ <https://docs.mapbox.com/mapbox-gl-js/guides/>

¹⁵ <https://blog.logrocket.com/react-map-library-comparison/>

Google Maps API is used, the *react-leaflet*, *react-geo*, and *react-mapbox-gl* are not bound to any particular mapping service. Open-source solutions like OpenStreetMap, OpenLayers, or a full-featured proprietary solution like Mapbox can be integrated seamlessly. *React-leaflet* and *react-geo* are good options when the open-source, along with some serious functionality, are required. *React-mapbox-gl* library, with its concise documentation, is suitable for a map-heavy application that requires loads of functionality and customizations, but the pay-per-use payment structure has to be considered. Thus, each of the map libraries brings its own set of advantages and disadvantages, which should be taken into account in combination while choosing suitable Map APIs.

3.5.2 Choosing Places API

All Places APIs take a geographic location as input and return nearby places, most often businesses. The place API can be impacted by what type of data is needed for the project, how to filter it, and what to do with the data. The criteria for the comparison of Places APIs were defined based on categories of decision-relevant places information described in Chapter 3.3.2 considering objects' details. The documentation of each Places API was analyzed. The general overview comparison of Places APIs is presented in Table 3.6.

Criteria	Google Places API ¹⁶	OpenStreetMap Overpass API ¹⁷	Foursquare Places API ¹⁸
Accommodation	+	+	+
Food and drink	+	+	+
Local facilities	+	+	+
Health	+	+	+
Transport	+	+	+
Tourism	+	+	+
Photos	+	-	+
Hiking trails	As a point	As segments	As a point
Characteristics of hiking trails	Limited characteristics	Detailed characteristics	Limited characteristics
Limitations	No limitations	<ul style="list-style-type: none"> • 10 000 queries per day • Download less than 5GB data per day 	<ul style="list-style-type: none"> • Free 99 500 Regular Calls + 500 Premium Calls per day • Unlimited API Calls paid version • Need of obtaining an enterprise license
Cost	• 25\$ per 1000 requests	Free	<ul style="list-style-type: none"> • 599\$ monthly subscription • 0,001\$ per Regular Call • 0,06\$ per Premium Call
Compatibility	Google Maps only	Any platform	Any platform

Table 3.6: Overview comparison of Places APIs.

¹⁶ <https://developers.google.com/maps/documentation/places/web-service/overview>

¹⁷ https://wiki.openstreetmap.org/wiki/Overpass_API

¹⁸ <https://developer.foursquare.com/docs/places-api/>

Google Places API has the most complete worldwide set of business listings which can be filtered by name and by type and category. Displaying Places API results are prohibited to use on a map that is not a Google map. Google Places API covers the required decision-relevant information and basic details (name, location, address, photo, URL, type, etc.), contact data fields (phone number, opening hours, website, etc.), and atmosphere data fields (price level, rating, reviews, user total rating). However, the hiking trails are presented as points and have limited characteristics.

Foursquare Places API provides a user-generated database and has an option to sort by popularity or proximity. Foursquare API covers all places information and details such as name, contact, location, category, URL, hours, rating, description, photos, etc. However, it has limited data for hiking trails. Moreover, based on the terms of use, it is only possible to use the API and Foursquare Data if the application is not intended for academic publications. If the application does not meet all of these requirements, it is necessary to obtain an enterprise license.

OpenStreetMap enables access to data using the Overpass API. It acts as a database over the web: a query sent to the API returns the corresponding to this query dataset. It can provide all the needed decision-relevant information besides photos. Moreover, it can provide data on hiking trails in the form of segments not only as points as well as more details on a specific trail. However, there are limitations in downloading big data which should be considered. Overpass API takes longer to generate and download than downloading existing static extracts of the same region. Overpass API is most useful in case the amount of data needed is only a selection of the data available in the region. In case of missing some decision-relevant information, additional Places API can be integrated.

3.5.3 Choosing Weather API

Weather APIs are similar to map APIs in terms of integration and versatility of data sources. Having conducted research, the three weather APIs were selected: OpenWeatherMap API¹⁹, Accuweather Weather API²⁰, and Meteoblue API²¹. Based on weather decision-relevant information, the criteria for the Weather APIs are the possibility of displaying weather widgets, and weather overlays data with corresponding details as well as compatibility, limitations, and cost (see Table 3.7).

Criteria	OpenWeatherMap API	Accuweather API	Meteoblue API
Weather widgets data	+	+	+
Weather overlays data	+	+	+
Compatibility	All platforms	All platforms	All platforms
Limitations	• 60 API calls a minute • 3000 calls a minute	• 50 calls per day	• No trial period or free data

¹⁹ <https://openweathermap.org/api>

²⁰ <https://developer.accuweather.com/>

²¹ <https://content.meteoblue.com/en/access-options/meteoblue-weather-api>

	(with free access to premium data)		
Cost	<ul style="list-style-type: none"> • Free with premium access • 180\$ per month 	<ul style="list-style-type: none"> • Three pricing tiers of \$25 to \$500/month 	<ul style="list-style-type: none"> • Depends on the number of desired data points

Table 3.7: Overview comparison of Weather API.

All three APIs offer weather data for different types of timeline data. They cover the required decision-relevant weather information. OpenWeatherMap API provides historical data, and historical weather overlays only with a premium account. However, there is free access to the premium weather data products for six months. AccuWeather API has limitations with the free trial, and paid plans include current conditions, 24-hour historical, current conditions, forecasts, and indices. Meteoblue API has a special feature in comparison with the above-mentioned APIs which is a sector devoted to the outdoors and sport. It includes assessing travel destinations worldwide with Meteoblue climate diagrams, choosing a suitable travel season for outdoor activities, knowing the risk of cloudy or rainy weather conditions for any destination worldwide, high-resolution weather models for mountains and coastal regions, and finding the right skiing destination with accurate snow prediction. However, there is no trial period or free version. The standard pricing of the Meteoblue weather API depends on the number of desired data points, which can be used to retrieve data, images, datasets, or maps.

3.6 Visualization Concept of Decision-Relevant Map Layers

Based on the general concept of the startup's decision support system, defined user personas, their use cases, and the decision-relevant information, the general concept of decision-relevant map layers of the web application was developed. The overview of the concept is presented in Table 3.8. The visualizations are divided into zoom levels: global, local level, and spot level. The visualizations on global and local levels are the system's recommendations and top 10 hiking within the recommended areas. The visualizations corresponding to spot level are aggregated groups of hiking trails based on the difficulty level (easy, medium, and hard), individual markers of hiking trails, and points of interest such as hotels and restaurants and a hiking path. Besides, the itinerary with all selected items by the user should be visualized by days and be available on all zoom levels. Moreover, the application should include different basemaps to allow the user to switch between them. The weather overlays and widgets for temperature and precipitation data should be integrated.

Category	What should be visualized
Global level	<ul style="list-style-type: none"> • Recommended, less recommended, not recommended countries. • Top 10 hiking trails within the recommended countries.
Local level	<ul style="list-style-type: none"> • Recommended, less recommended, not recommended regions and subregions. • Top 10 hiking trails within the recommended regions and subregions.
Spot level	<ul style="list-style-type: none"> • Aggregated groups of hiking trails based on difficulty level. • Individual markers of hiking trails and points of interest (e.g., hotels, restaurants). • A path of a hiking trail.

Itinerary	Selected and saved individual items (e.g., hiking trails, hotels, and restaurants) should be visualized by days (e.g., Day 1: two easy hiking trails, a restaurant, and a hostel, Day 2: one moderate hiking trail, two restaurants, etc.).
Basemaps	<ul style="list-style-type: none"> • A basemap with a customized style that fits the visualizations mentioned above. • Terrain basemap. • Satellite basemap.
Weather	<ul style="list-style-type: none"> • Weather overlays for temperature and precipitation data (forecast, current, historical weather overlays). • Weather widgets for temperature and precipitation data (forecast, current, historical weather).

Table 3.8: Overview of the general visualization concept of the web application.

3.7 Methods of the User Research

To be able to answer the research questions given in Chapter 1, the most appropriate research methods need to be chosen. This chapter presents methods that can be used to conduct a user study.

3.7.1 Thinking Aloud

Thinking aloud is a research method where participants speak aloud any thoughts they have as they perform the task imagining the role of one of the user personas (Lea & MacLeod, 2018). In this research, thinking aloud can be useful to explain how participants comprehend the proposed visualizations and the logic behind their actions while interacting with the application. Participants should not need any guidance during the test sessions since they should express their thoughts as they are (Lea & MacLeod, 2018). Though it happens for some participants that it can be complicated to report their ideas continuously without demonstrations and practice beforehand. It is important to consider that the thinking aloud method does not provide a deeper thinking process because it can be hard for participants to simplify their thoughts into words. In a qualitative analysis of results, it is crucial to consider non-verbal characteristics as well (e.g., tone of voice) (Charters, 2003).

3.7.2 Questionnaire

Moreover, in case it will not be possible to conduct the thinking aloud method, an online questionnaire can be designed to test participants to find out their characteristics, preferences, and insights into the proposed design and visualization of the web mapping application for the decision support system.

3.7.3 Expert Interview

Expert interviews are a widely used qualitative interview method often aiming at gaining information about or exploring a specific field of action. In case of unclear results of the questionnaire, an expert interview can be conducted to get more details on particular topics.

To conclude, it would be beneficial for the study to combine all the methods in the following order: having developed a prototype, it can be valuable to conduct an online questionnaire and gain insights by analyzing the results. Then, having improved the prototype based on the results of the questionnaire, conduct thinking aloud method and allow users to interact with the application. In addition, it would be useful to invite experts to evaluate the application. However, the expert interview can attract a wider professional audience which may not be desirable for the stealth startup.

4 Visualizing Decision-Relevant Map Layers to Support Travel Planning

To be able to evaluate the concepts introduced in Chapter 3, a prototype of a web-based map application was implemented. This chapter describes the development of the prototype and the design of the user study.

4.1 Prototype Implementation

The prototype of the web-based application consists only of the client-side user interface. It is supposed to have a server-side that provides needed data. Instead, local data or already developed and easy-to-use APIs were used to simplify the development process.

4.1.1 Datasets and APIs

In order to visualize the system's recommendations, the following datasets were necessary: countries boundaries, country subdivision, hiking trails, and places (hotels and restaurants). Based on the evaluation of APIs, first, it was decided to use the combination of OpenStreetMap API and Overpass API since Leaflet library seemed more flexible, free as places API, and provides more details for hiking trails, hotels, and restaurants. However, many technical problems and errors occurred while obtaining data from these APIs. To obtain one hiking trail, it was necessary to make at least three requests. Thus, the server was often either too slow to respond or responded with an error "too many requests". The same happened while displaying accommodation and restaurants data from Overpass API. To resolve this problem, it could be possible to create an own server to store the data and create access to these data via own API. Besides, while clustering obtained data using Leaflet cluster React library, there were many TypeScript import errors which were known bugs that creators of the library did not fix. Due to the time constraints and the fact that it was not the focus of the thesis, it was decided to switch to Google Maps API due to better documentation and libraries. However, the main issue with Google Maps API is that the Places API is not flexible. For example, it cannot return all the data within the bounding box. It returns around 20 results. Thus, it was decided to show decision-relevant places information (restaurants and hotels) from Overpass API using Python and the JSON file stored locally in the React app. To obtain hiking trails and relevant information, the Outdooractive API was used. The issue with Outdooractive API is poor coverage, a lot of missing data for different countries but enough for the thesis purposes.

Countries Boundaries

Since the Google Maps JavaScript API was chosen to implement the prototype, the clickable countries compatible with it had to be obtained. The dataset in GeoJSON format consisting

of the geometry of countries with additional properties and the sample code²² were used to visualize the system's recommendations on the global level.

Germany's Boundaries

Germany was chosen for illustrating the system's recommendation on the local level. Therefore, Germany's administrative areas in the format of WGS84 GeoJSON were imported²³. The module contained separate lists of GeoJSON objects for the following layers that were used: "laender" - states (e.g., Saxony, Bavaria, etc.) and "regierungsbezirke" - administrative districts (e.g., Regierungsbezirk Münster).

Basemaps

The Google Maps JavaScript API was used to customize a map with its own content. The Google Maps JavaScript API features basic map types such as satellite and terrain which were added to the prototype.

Hiking trails

The two methods of Outdooractive API were used to obtain hiking trails data: the "NearBy" API method²⁴ provides all hikes in a specific area, and the "OOI" API method²⁵ sends detailed information about several hikes. Thus, the following hiking trails data available from Outdooractive were collected within European boundaries: title, difficulty, length, elevation, and geometry.

Places

For the prototype purposes, it was decided to download only the datasets of restaurants and hotels to visualize decision-relevant information in the form of point objects. These datasets were pre-uploaded in the JSON format using the Public Overpass API instances²⁶ since the Public Overpass API has low performance. The following data were obtained within European boundaries: coordinates, name, address, and a website link.

4.1.2 Client-Side User Interface

TypeScript libraries

Most of the UI elements of the prototype were based on the "Material UI"²⁷ library (e.g., the search bar, the filter menu, the layer menu, icons, etc.). The "Google-map-react" library was used to display the map and markers on the map. All Google Maps APIs worked along with the "google-map-react" library and were actively used (e.g., removing native UI elements of Google maps, adding own UI elements, etc.). Furthermore, the fast JavaScript library "Supercluster"²⁸ was used for geospatial point clustering of hiking trails.

²² <https://github.com/arturssmirnovs/Clickable-countries-using-Google-Maps-API>

²³ <https://github.com/juliuste/german-administrative-areas>

²⁴ <https://developers.outdooractive.com/API-Reference/Data-API.html#nearby>

²⁵ <https://developers.outdooractive.com/API-Reference/Data-API.html#ooi>

²⁶ https://wiki.openstreetmap.org/wiki/Overpass_API

²⁷ <https://mui.com/guides/typescript/>

²⁸ <https://www.npmjs.com/package/use-supercluster>

UI Elements

It is important to note that the prototype's user interface was not the focus of the thesis. It was developed to help users to understand the proposed design and visualizations of the system's recommendations. The general structure of the prototype includes the following interactive UI elements: search bar (1), filter menu (2), buttons "Top Picks", "Hotels", "Restaurants", "Hotels" (3), layer menu (4) shown in Figure 4.1.

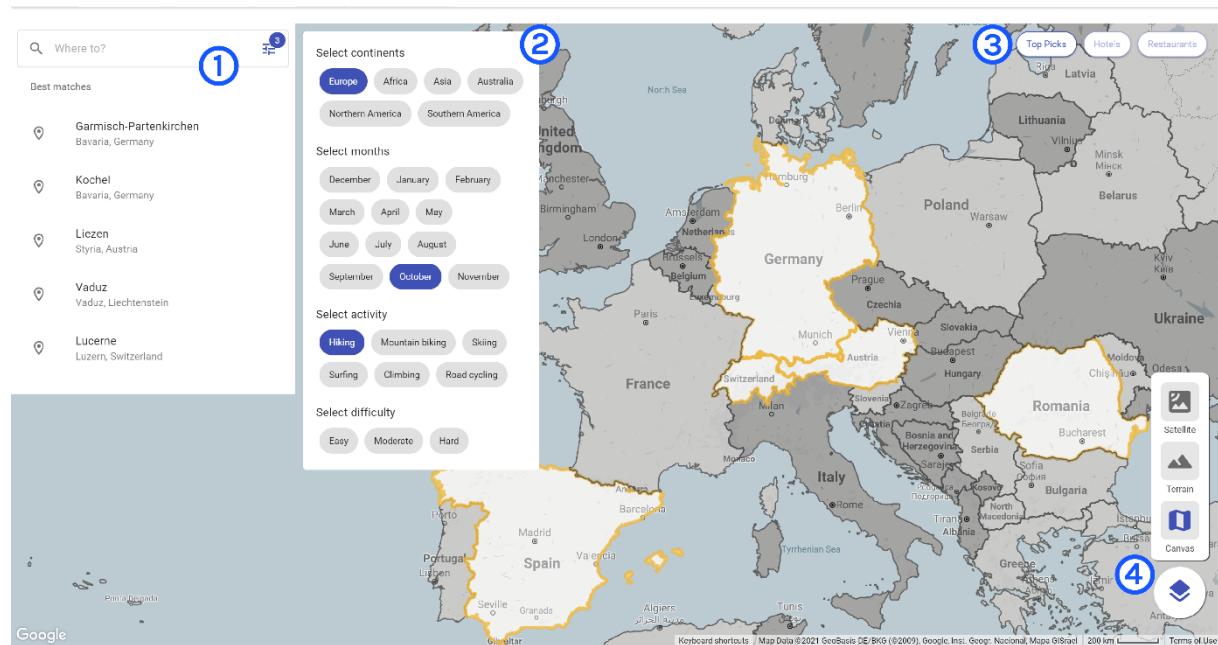


Figure 4.1: UI elements of the prototype.

The search bar (1) is supposed to search for places (cities, states, countries) by location. The filter menu (2) includes such filter categories as "Select continents", "Select months", "Select activity", and "Select difficulty". It allows users to set parameters for the trip they would like to find. However, the filtering functionality does not work since an additional application logic had to be developed, which was not the goal of the thesis. Therefore, it only helps the user to understand which filtering options exist. Thus, based on the selected filters, the search bar (1) is supposed to show the best matches.

The button "Top Picks" in the top left corner (3) shows/hides markers of the top 10 recommended hiking trails on the map. The buttons "Hotels" and "Restaurants" (3) show/hide markers of hotels and restaurants. The layer menu (4) is open by tapping on the button in the lower right corner. It allows the user to select a preferred basemap layer from the list ("Canvas", "Terrain", or "Satellite").

Furthermore, the core UI elements of the prototype are the left-sidebar (1) and the right-sidebar (2) presented in Figure 4.2. The left-sidebar (1) has two tabs "TRAILS" and "ITINERARY". The tab "Trails" shows the list of markers displayed on the map, including additional properties of items. The tab "Itinerary" includes saved items by the user by clicking the "Add" button, which appears in the left-sidebar and the right-sidebar. The right-side bar (2) shows profiles, the details of items after an item was clicked. However, the UI and the functionality of the sidebars

are simplified for the prototype. Further elements that can be found on the map are scale and attribution information (both bottom right corner).

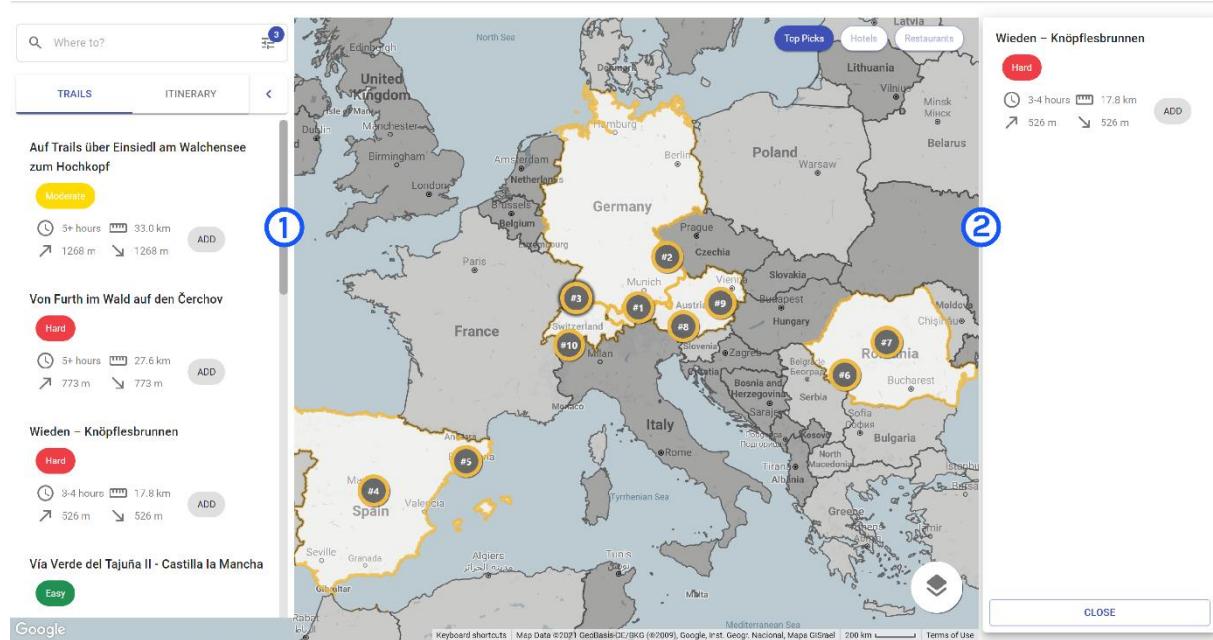


Figure 4.2: UI elements of the prototype: right sidebar (1) and left sidebar (2).

The following core UI element is the map which is the basis for the overlaying content. As mentioned, there are three basemap layers ("Canvas", "Terrain", and "Satellite"). The "Canvas" basemap was designed with Google Maps Platform by customizing the default map of Google Maps (see Figure 4.3).

The resulting style has the characteristics that it is unobtrusive, uses light and achromatic colour hues to present cartographic features without overwhelming overlaid content. It focuses on global political and administrative boundaries, roads, water bodies, and relief. However, there was no possibility to represent the volume of the terrain while creating own map style. This is why additional standard Google Maps' layers such as "Terrain" and "Satellite" were added (see Figure 4.4 and Figure 4.5, respectively).

The UI elements of the prototype vary depending on the zoom level. The three different groups of zoom levels are:

- Global maps showing continents, countries with corresponding zoom levels 1-6.
- Local maps presenting items within regions with corresponding zoom levels 7-9.
- Spot map displaying details on a selected item with corresponding zoom levels 10+.

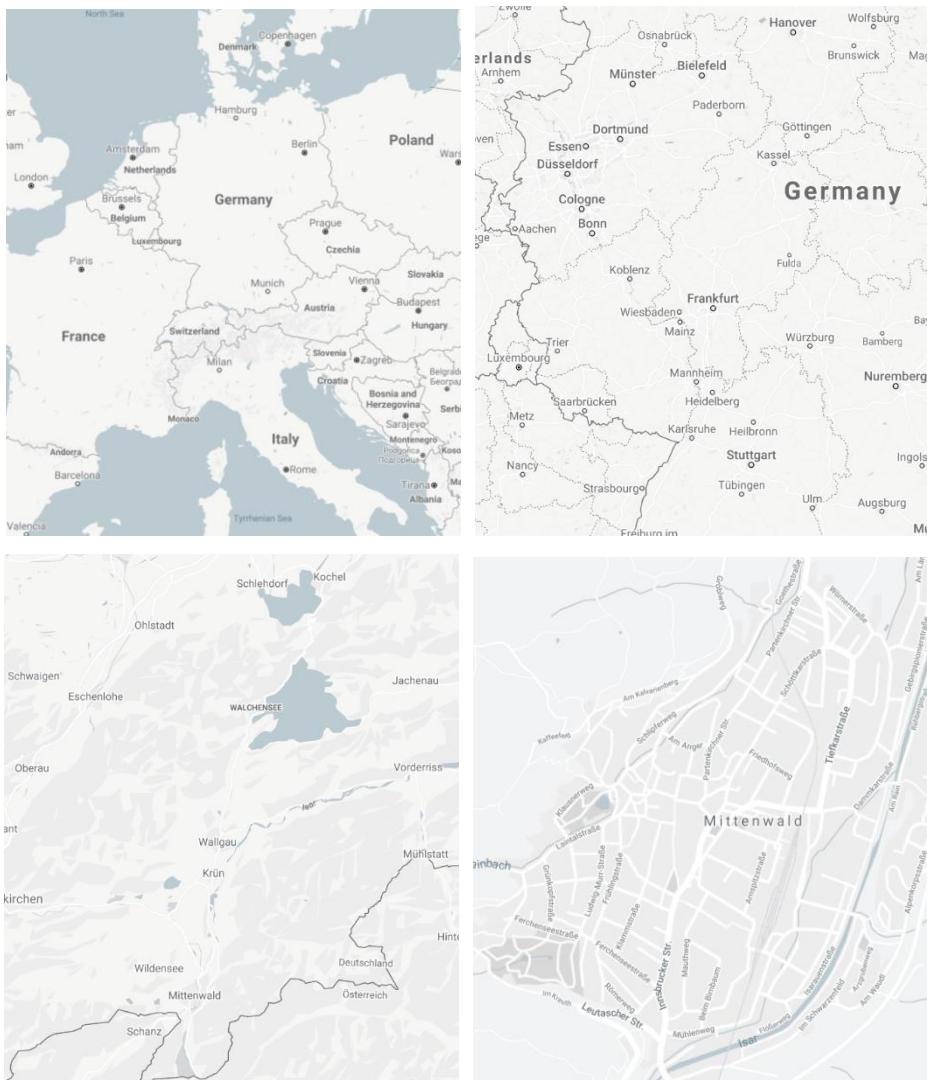


Figure 4.3: Screenshots of the customized “Canvas” basemap.

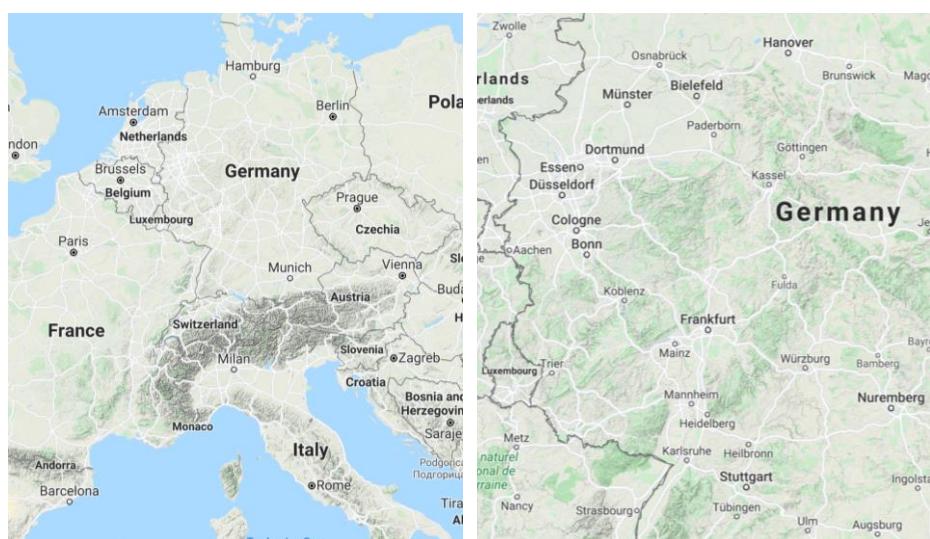


Figure 4.4: Screenshots of the standard “Terrain” basemap.



Figure 4.5: Screenshots of the standard “Satellite” basemap.

The following will demonstrate the specific UI elements of the global, local, and spot maps. When the user selects continent *Europe*, the month *October* and the activity *Hiking*, the map appears on the screen with countries colored in white and different shades of grey (see Figure 4.6). The white color and the different shades of grey of the countries correspond to recommendations of the system based on selected filters. The white color and the golden outline mean the recommended countries for hiking in October in Europe. The grey color means that a country is less recommended. The dark grey color means that a country is not recommended.

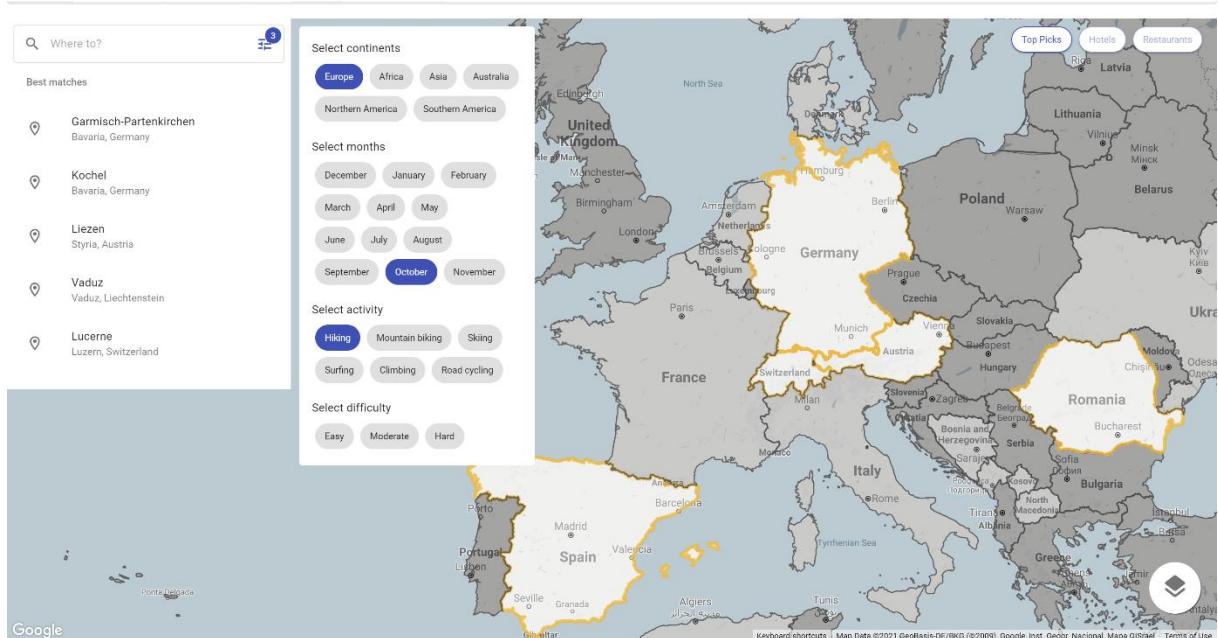


Figure 4.6: The system’s recommendations on the global level.

Then when the user clicks on the button “*Top Picks*”, ten markers with numbers appear on the screen (see Figure 4.7). The markers with numbers correspond to the top 10 hiking trails recommended by the system.

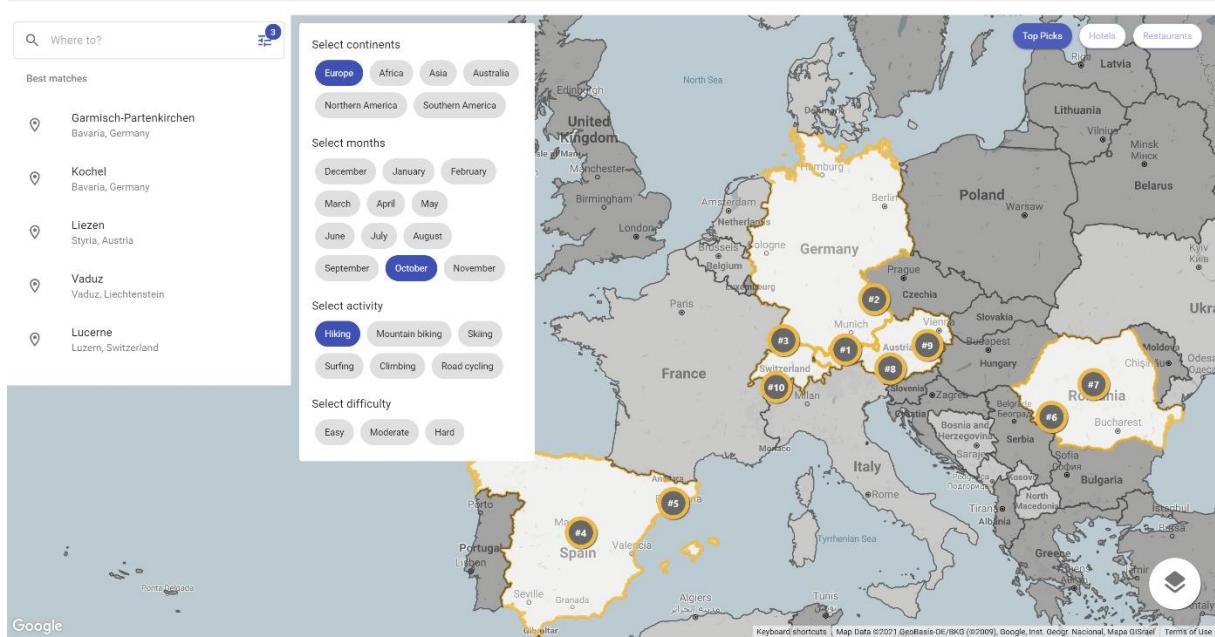


Figure 4.7: The top 10 recommended hiking trails on the global level.

Then when the user chooses and clicks on Germany, one of the recommended countries by the system, the map zooms in to Germany divided into smaller regions (see Figure 4.8).

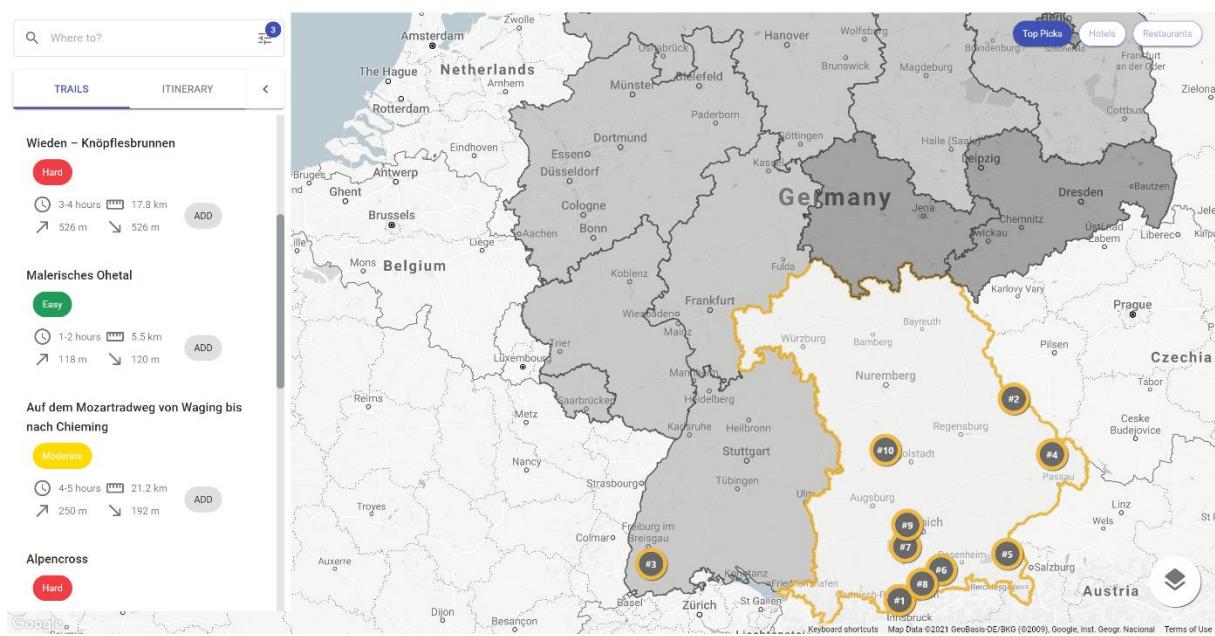


Figure 4.8: The system's recommendations by regions on the local level.

Afterward, when clicking on the recommended region, the map zooms in, and the regions are divided into subregions (see Figure 4.9).

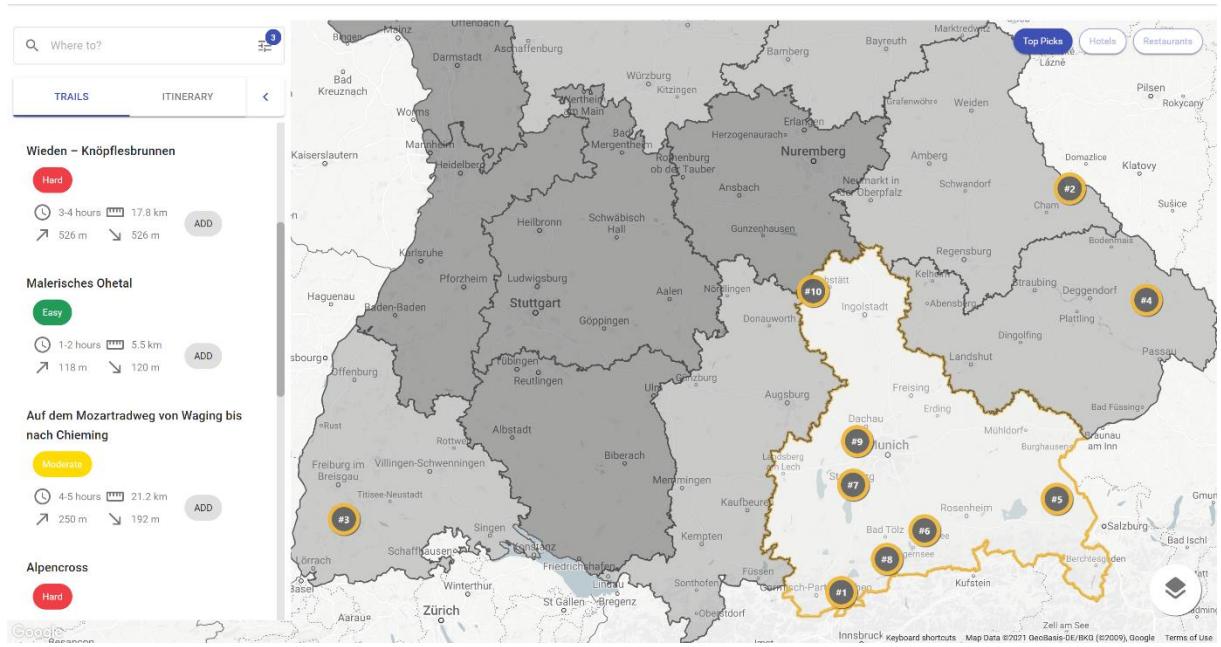


Figure 4.9: The system's recommendations by subregions on the local level.

Then the user chooses and clicks on the recommended subregion. The map zooms in and the previous division of sub-regions disappears (see Figure 4.10). The markers with numbers correspond to the cluster of hiking trails indicating the number of hikes. The markers' outline corresponds to difficulty levels of hiking trails. The outline of clusters represents the combination of difficulty levels within a specific cluster. The outline of individual hiking trails represents the difficulty level of a specific hiking trail. The buttons "Hotels" and "Restaurants" become active on this zoom level.

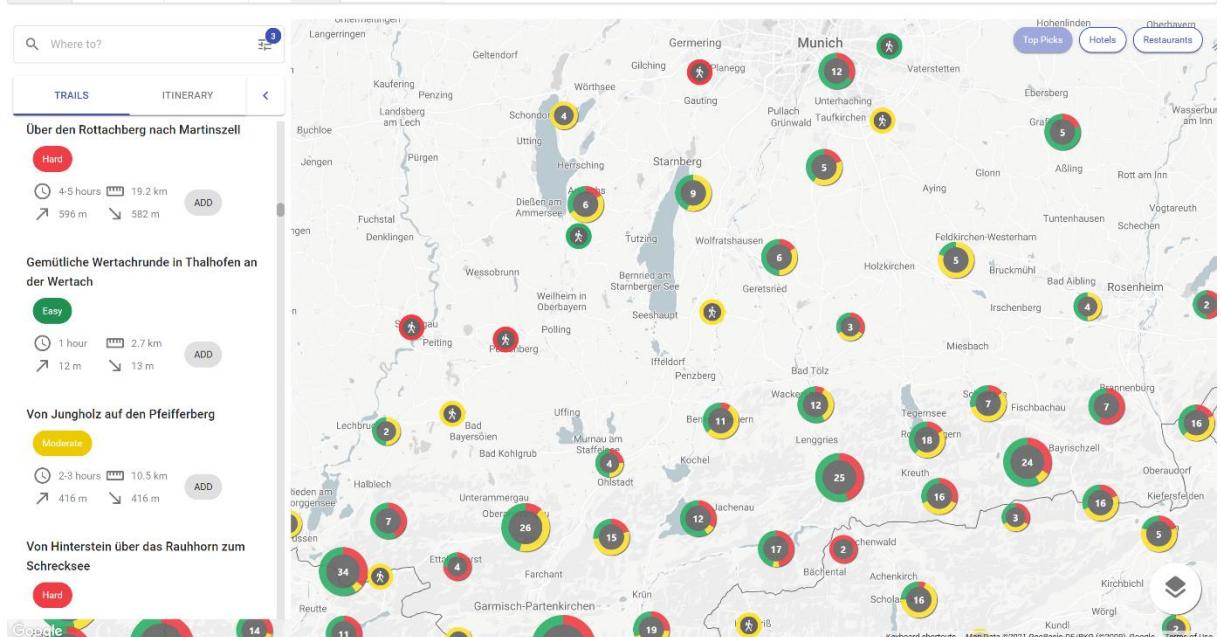


Figure 4.10: The system's recommendations on the spot level.

Then the user clicks on one of the clusters of hiking trails (see Figure 4.11). The map zooms in and the cluster is divided into individual markers of hiking trails. The user clicks on one of the markers and on the buttons “Hotels” and “Restaurants”. The brown polyline corresponds to the path of the selected hiking trail.

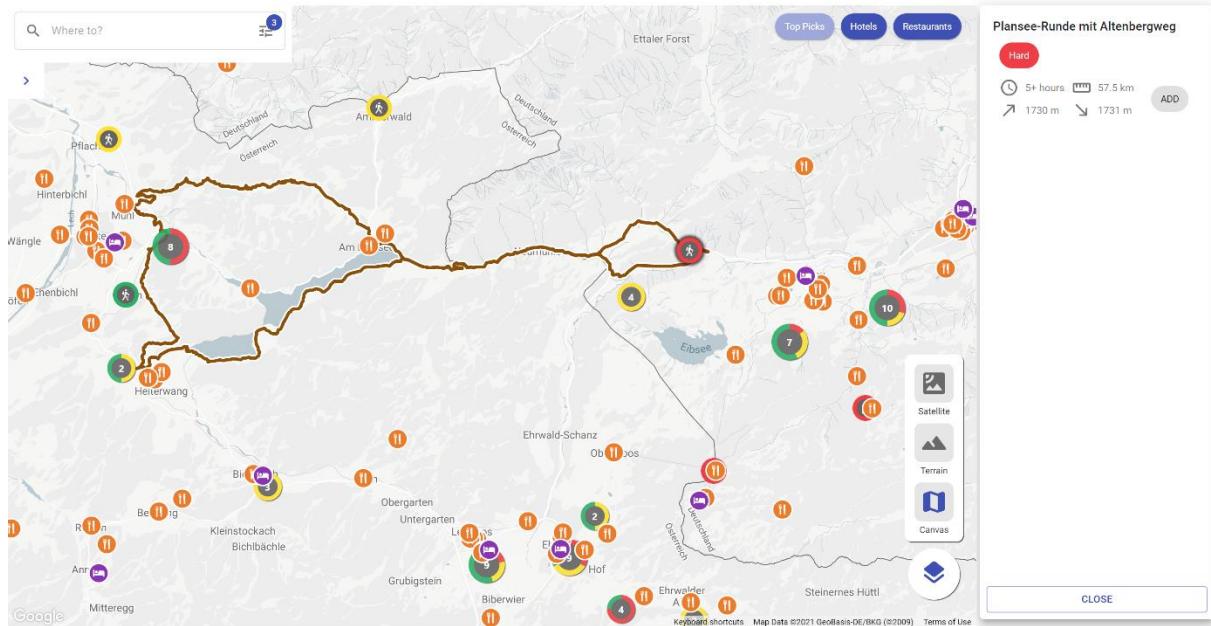


Figure 4.11: The user’s selection of a hiking trail on a spot level.

Then the user explores the map and selects three hiking trails, three restaurants, and three hotels for the trip (one day - one hiking trail, one restaurant, and one hotel). They added these items to the itinerary. Consequently, the items appear in the “ITINERARY” tab. The user shows all itinerary items on the map by clicking the “Show itinerary” button at the bottom of the itinerary tab (see Figure 4.12). The legend in the top left corner explains the meaning of the colors highlighting different days.

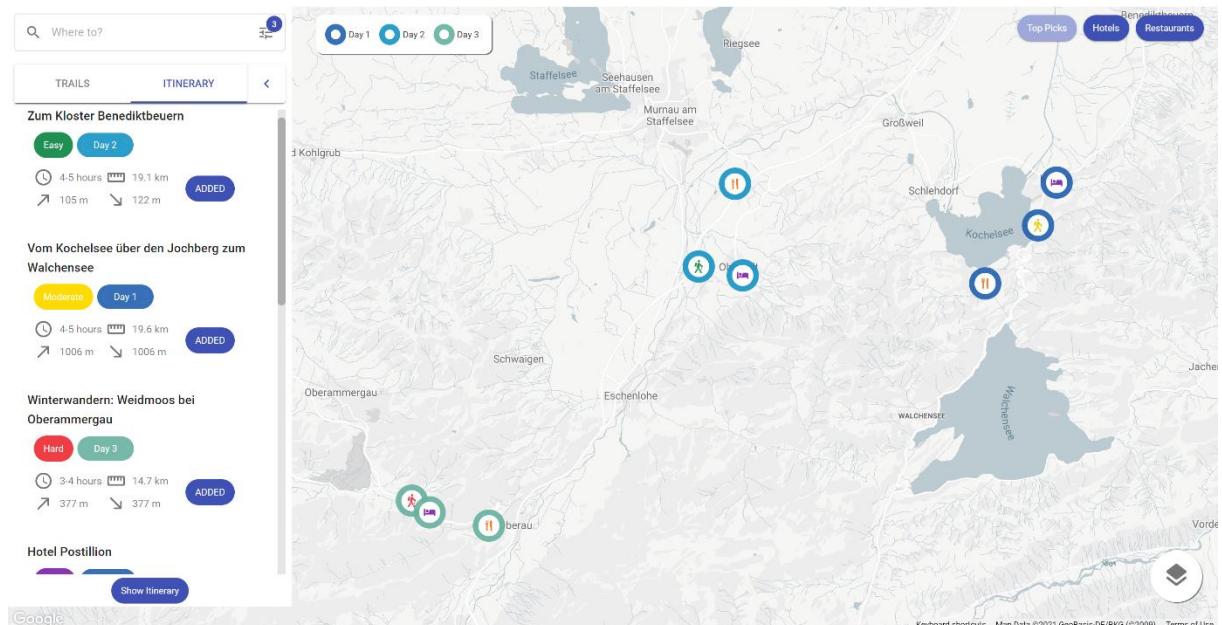


Figure 4.12: Visualization of the itinerary.

Thus, the summary of the proposed visualization of decision-relevant information is presented in Table 4.1.

Category	What was visualized and how
Global level (1-6 zoom levels)	<ul style="list-style-type: none"> • Recommended countries colored in white (with golden outline). • Less and not recommended countries colored in different shades of grey. • The top 10 hiking trails are markers with numbers in the shape of circles. • Choice of canvas, terrain, or satellite basemaps.
Local level (7-9 zoom levels)	<ul style="list-style-type: none"> • Recommended regions and subregions colored in white (with a golden outline). • Less and not recommended regions and subregions colored in different shades of grey. • Division on regions and subregions. • The top 10 hiking trails are markers with numbers in the shape of circles. • Choice of canvas, terrain, or satellite basemaps.
Spot level (10+ zoom levels)	<ul style="list-style-type: none"> • Clusters of hiking trails with the outline colored in red, green, and yellow. • Individual markers of hiking trails with the outline colored in red, green, and yellow depending on the difficulty level. • Markers of hotels and restaurants. • Path of a hiking trail as a brown polyline. • Choice of canvas, terrain, or satellite basemaps.
Itinerary	<ul style="list-style-type: none"> • Markers of items with the outline colored according to a selected day. • A legend explaining the meaning of the colors highlighting different days.

Table 4.1: Summary of the visualized decision-relevant information of the prototype

4.2 Prototype Evaluation

The user study sought to gain insights into the proposed design and visualization of the web mapping application for the decision support system. The initial intention was to conduct expert qualitative interviews either remotely over the internet due to the ongoing COVID-19 pandemic or in-person in case of lifted restrictions. However, due to the not optimal performance of the developed prototype, the format was changed to an online questionnaire based on static screenshots of the prototype.

The study was designed with the online survey platform *QuestionPro*²⁹ that offers a wide range of tools for the creation, distribution, and analysis of online surveys, polls, and forms. The questionnaire contained a combination of qualitative and quantitative questions. Qualitative questions were mainly asked in the form of comment box open-ended questions: "Please briefly explain your associations". It was used to collect open text answers of respondents to elaborate or expand on their closed answers. Most quantitative questions that required an

²⁹ <https://www.questionpro.com/>

estimation from respondents were asked in the form of multiple-choice questions, single select matrix questions, rank order questions, and Likert scale questions. The complete questionnaire was structured in five sections (see Chapter 4.2.2). The whole questionnaire can be found in Appendix.

Multiple-choice questions allowed one to select one or many responses from a given list of options ("What kind of trips have you conducted?"). Single select matrix questions asked respondents to select only one option for each row using the same set of column answer choices ("What applications do you generally use for planning your above-mentioned trips and how often?"). Rank order scaling questions were used to rank a set of options against each other in the order of choice ("Please rank the basemaps based on the look and feel, with 1 being the best"). 5-point Likert scale questions related to an agreement ("Please rate the following statement: I think I understand what the markers with numbers mean"), intuitiveness ("The brown polyline corresponds to the path of the selected hiking trail. How intuitive do you think this is?") and expectation ("Have you expected that the clusters are clickable?"). Participants were able to choose from five response anchors for questions related to the level of agreement (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree), intuitiveness (not at all intuitive, somewhat unintuitive, neutral, somewhat intuitive, very intuitive) and expectation (not at all expected, somewhat unexpected, neutral, somewhat expected, expected).

The application is considered to be helpful for users of different age groups with different experiences in hiking and using web mapping applications. Therefore, its target group is expected to be beginners and professional hikers of all ages, confident and least confident users of web mapping applications. For the evaluation, the participants were asked to imagine themselves in the role of one of the two user personas described in Chapter 3.

4.2.1 Structure of the Study

Users participating in the study were offered to fill an online questionnaire consisting of introduction, consent, and five main sections: (1). Participants Overview; (2). System's Recommendations; (3). Responses to Itinerary; (4). Responses to Basemaps; and (5). Summary. Table 4.2 outlines the different survey sections and their purpose. A full outline of the survey structure and sequence of questions can be found in Appendix.

Introduction and Consent
Explaining the purpose of the survey and providing information related to data protection and consent.
1. Participants Overview
Knowing the gender of participants, the age of participants, the experience of trips related to outdoor activities, and the experience of web mapping applications.
2. System's Recommendations

Gaining an understanding of the proposed design of the system's recommendations on the global, local, and spot levels.
3. Responses to Itinerary
Gaining an understanding of the proposed design of the trip itinerary.
4. Responses to Basemaps
Participants were asked to rank the proposed basemaps against each other.
5. Summary
Gaining an understanding of the overall impression of the web app prototype.

Table 4.2: Survey sections and their purpose.

Introduction and Consent

The first page of the questionnaire was set up to give participants an idea of the topic of the study, to assure the user that their participation is entirely voluntary, anonymous, and secure, and to receive their consent to start the questionnaire. Only by clicking "Yes, I agree" users were able to move on to the first section with general questions.

1. General questions

In the first section, participants were asked questions related to their gender (Q1.1), age (Q1.2), the experience of trips related to outdoor activities (Q1.3), applications they use for planning the trips as well as the frequency of use (Q1.4, Q1.5), and how confident they are with web mapping applications (Q1.6). If participants have no trip experience related to outdoor activities (Q1.3), they were assigned another set of questions with the same structure but different applications listed (Q1.4.1, Q1.5.1, Q1.6.1). An overview of the questions is presented in Table 4.3.

1. General questions

Q1.1: *What is your gender?*

Q1.2: *How old are you?*

Q1.3: *What kind of trips have you conducted?*

Q1.4: *What applications do you generally use for planning your above-mentioned trips and how often?*

Q1.5: *In case you use any other applications, please name them here.*

Q1.6: *I think I am a confident user of web mapping applications (e.g., Google Maps, AllTrails, Komoot, etc.).* or *Q1.6: I think I am a confident user of web mapping applications (e.g., Google Maps, Maps.me, etc.).*

Table 4.3: Questions of section 1.

2. System's recommendations

The second section was divided into six subsections (2.1 - 2.6). The first subsection (2.1) and second subsection (2.2) questioned participants for their understanding of the proposed design of the system's recommendations on the global level. An overview of questions is presented in Table 4.4 and Table 4.5, respectively.

Subsection 2.1

Q2.1: Please rate the following statement: I think I understand what the white color and the different shades of grey color for some countries mean. I also understand what the golden outline of some countries means.

Q2.1.2: Please briefly explain your associations.

Q2.1.3: The white color and the different shades of grey of the countries correspond to recommendations of the system based on selected filters. The white color and the golden outline mean the recommended countries for hiking in October in Europe. The grey color means that a country is less recommended. The dark grey color means that a country is not recommended. How intuitive do you think this is?

Q2.1.4: Please rate the following statement: The chosen color for the outline of recommended countries looks good to me.

Q2.1.5: Please rate the following statement: I think a legend explaining the meaning of the white color and the different shades of grey of the countries would be useful for this case.

Table 4.4: Questions of subsection 2.1.

Participants were asked to rate how they understood the meaning of the white color and the different shades of grey color for the countries (Q2.1.1) as well as what the markers with numbers mean (Q2.2.1). Then, participants were questioned to briefly explain their associations in the comment box (Q2.1.2, Q2.2.2). Afterward, participants were given the correct explanation and asked to rate how intuitive the proposed visualization is (Q2.1.3, Q2.2.3). In the first subsection, participants were asked to rate the look of the chosen color for the outline of recommended countries (Q2.1.4). And the last question in both subsections was to rate if a legend would be useful for these cases (Q2.1.5, Q2.2.4).

Subsection 2.2

Q2.2.1: Please rate the following statement: I think I understand what the markers with numbers mean.

Q2.2.2: Please briefly explain your associations.

Q2.2.3: The markers with numbers correspond to the top 10 hiking trails recommended by the system. How intuitive do you think this is?

Q2.2.4: Please rate the following statement: I think a legend explaining the meaning of the markers with numbers would be useful for this case.

Table 4.5: Questions of subsection 2.2.

The third subsection (2.3) and fourth subsection (2.4) questioned participants for their understanding of the proposed design of the system's recommendations on the local level. An overview of questions is presented in Table 4.7 and Table 4.8, respectively. Participants were asked to rate the division of the regions (Q2.3.1), subregions (Q2.4.1, Q2.4.2), and the zoom level (Q2.3.2). Also, participants were offered to provide additional comments (Q2.3.3, Q2.4.3).

Subsection 2.3

Q2.3.1: Please rate the following statement: I think I understand why Germany is divided into smaller regions.

Q2.3.2: Please rate the following statement: I think the zoom level of the map meets my expectations.

Q2.3.3: Please provide any additional comments if you like.

Table 4.6: Questions of subsection 2.3.

Subsection 2.4

Q2.4.1: Have you expected that the regions will be divided into subregions?

Q2.4.2: Please, rate the following statement: I would like to have a further division of subregions for the planning of the trip.

Q2.4.3: Please provide any additional comments if you like.

Table 4.7: Questions of subsection 2.4.

The fifth subsection (2.5) and the sixth subsection (2.6) consisted of questions asking participants for their understanding of the proposed design of the system's recommendations on the spot level. An overview of questions is presented in Table 4.8 and Table 4.9, respectively. The questions had a similar structure to the first subsection. First, participants were asked to rate how they understood what the markers with numbers and the markers' outline mean (Q2.5.1). The next question was to explain their associations (Q2.5.2). Then, the correct explanation was given, and participants were asked to rate how intuitive the visualizations were (Q2.5.3, Q2.5.4). Afterward, the questions were to rate if a legend would be useful for these cases (Q2.5.5, Q2.5.6) and the look of colors for the difficulty levels (Q2.5.7). The last question was to provide additional comments (Q2.5.8).

Subsection 2.5

Q2.5.1: Please, rate the following statement: I think I understand what the markers with numbers and the markers' outline (red, green, yellow) mean.

Q2.5.2: Please briefly explain your associations.

Q2.5.3: The markers with numbers correspond to the cluster of hiking trails indicating the number of hikes. How intuitive do you think this is?

Q2.5.4: The markers' outline corresponds to difficulty levels of hiking trails. The outline of clusters represents the combination of difficulty levels within a specific cluster. The outline of individual hiking trails represents the difficulty level of a specific hiking trail. How intuitive do you think this is?

Q2.5.5: Please rate the following statement: I think a legend explaining the meaning of the markers with numbers would be useful for this case.

Q2.5.6: Please rate the following statement: I think a legend explaining the meaning of the colors would be useful for this case.

Q2.5.7: Please rate the following statement: The chosen colors for the difficulty levels look good to me.

Q2.5.8: Please provide any additional comments if you like.

Table 4.8: Questions of subsection 2.5.

In the sixth subsection, participants were questioned whether they expected the clusters (Q2.6.1) and the single markers of hiking trails to be clickable (Q2.6.2). Then, the question was to rate how they understood the meaning of the brown polyline (Q2.6.3) and explain their associations (Q2.6.4). Then, the correct explanation was provided, and participants were asked to rate the intuitiveness of the visualization (Q2.6.5), the look of chosen color for the hiking trail (Q2.6.6), and the look of the icons of hotels and restaurants (Q2.6.7). The last question was to provide additional comments (Q2.6.8).

Subsection 2.6

Q2.6.1: Have you expected that the clusters are clickable?

Q2.6.2: Have you expected that single markers of hiking trails are clickable?

Q2.6.3: Please rate the following statement: I think I understand what the brown polyline means.

Q2.6.4: Please briefly explain your associations.

Q2.6.5: The brown polyline corresponds to the path of the selected hiking trail. How intuitive do you think this is?

Q2.6.6: Please rate the following statement: The chosen color for the path of a hiking trail looks good to me.

Q2.6.7: Please rate the following statement: The icons of hotels and restaurants look good to me.

Q2.6.8: Please provide any additional comments if you like.

Table 4.9: Questions of subsection 2.6.

3. Responses to Itinerary

The third section included five questions and questioned participants for their understanding of the proposed design of the itinerary. An overview of the questions is presented in Table 4.10. Participants were asked to rate the intuitiveness (Q3.1) and usefulness (Q3.2) of the itinerary's legend, the visualization of the itinerary (Q3.3), and if they can clearly distinguish which objects belong to which days (Q3.4). The last question was to provide additional comments (Q3.5).

3. Responses to Itinerary

Q3.1: The legend in the top left corner explains the meaning of the colors highlighting different days. How intuitive do you think this is?

Q3.2: Please rate the following statement: I think the legend explaining the meaning of the colors highlighting different days is useful in this case.

Q3.3: Please rate the following statement: The visualization of the itinerary on the map looks good to me.

Q3.4: Please rate the following statement: I can clearly distinguish which objects belong to which days.

Table 4.10: Questions of section 3.

4. Responses to Basemaps

This section included three subsections corresponding to global, local, and spot levels. An overview of the questions is presented in Table 4.11. On the global level, participants were asked to rank the three proposed basemaps against each other based on the general look and feel (Q4.1.1), how the markers look on top of the basemaps (Q4.1.2), how the countries look on the basemaps (Q4.1.3). On the local level, participants were asked to rate the basemaps based on the look and feel (Q4.2.1), how the markers (Q4.2.2), and the regions look (Q4.2.3). On the spot level, participants were asked to rate the basemaps based on the look and feel (Q4.3.1), how the markers and clusters (Q4.3.2), and the hiking trail look (Q4.3.3).

4. Responses to Basemaps

Global level

Q4.1.1: Please rank the basemaps based on the look and feel, with 1 being the best.

Q4.1.2: Please rank the basemaps based on how the markers look on top of the basemaps, with 1 being the best.

Q4.1.3: Please rank the basemaps based on how the countries look on the basemaps, with 1 being the best.

Local level

Q4.2.1: Please rank the basemaps based on the look and feel, with 1 being the best.

Q4.2.2: Please rank the basemaps based on how the markers look on top of the basemaps, with 1 being the best.

Q4.2.3: Please rank the basemaps based on how the regions look on the basemaps, with 1 being the best.

Spot level

Q4.3.1: Please rank the basemaps based on the look and feel, with 1 being the best.

Q4.3.2: Please rank the basemaps based on how the markers and the clusters look on top of the basemaps, with 1 being the best.

Q4.3.3: Please, rank the basemaps based on how the hiking trail looks on the basemaps, with 1 being the best.

Table 4.11: Questions of section 4.

5. Summary

The final section questioned participants to rate whether the proposed visualizations of the web app prototype may be helpful to make decisions when planning a hiking trip (Q5.1), and whether the web application could be useful for planning a trip for other outdoor activities (Q5.2). Lastly, participants were asked to provide final comments (Q5.3). An overview of the questions is presented in Table 4.12.

5. Summary

Q5.1: Please, rate the following statement: I think the previously shown visualizations of the web app prototype could help me to make decisions when planning a hiking trip.

Q5.2: Please, rate the following statement: I think such a web application could be useful for planning a trip for other outdoor activities (skiing, climbing, surfing, etc.).

Q5.3: Please provide final comments if you like.

Table 4.12: Questions of section 5.

4.2.2 Pretest

A pre-test of the questionnaire was conducted ahead of the publication of the survey with three participants. One participant was an experienced hiker and cartographer; the other two were beginner hikers with a background in economics and land use planning. They were well-fit defined user personas.

Having conducted the pretest, several changes in the prototype and the questionnaire were made. The introduction of the questionnaire was shortened. The button "Top Picks" was added to the interface to make it possible to show and hide the ten recommended hiking trails from the map. The visualization of the itinerary was adjusted: the partially transparent halos of the icons were changed to a solid outline, and the color scheme of the days was changed to a sequential color scheme.

4.3 Conclusion

This chapter detailed how the case study was conducted. First, the implementation of a prototype using the methodology presented in Chapter 3 was outlined. The second part of the chapter is devoted to the subsequent user test. The five sections of the questionnaire were listed and explained. The results will be discussed in more detail in the next chapter.

5 Results and Discussion

The user study detailed in section 4.2 ran for one week in September 2021. During this period, 60 volunteers participated in the user study, of whom 53 completed the entire questionnaire. There is no specific reason why the seven participants terminated the questionnaire at some moment. They finished either by the end of the second or the third section. However, these seven participants provided valuable feedback in several parts of the survey, which was considered in the analysis. In the following, the results will be explained and discussed based on the five sections of the questionnaire.

5.1 Overview of Participants

Of the 60 responses, 32 identified as female, 28 as male. The gender distribution was rather even. The participants contributed nearly proportionately to the study. This is beneficial since the participants had to imagine the role of the defined user persona, which can be both female and male. Figure 5.1 illustrates the number of female and male participants.

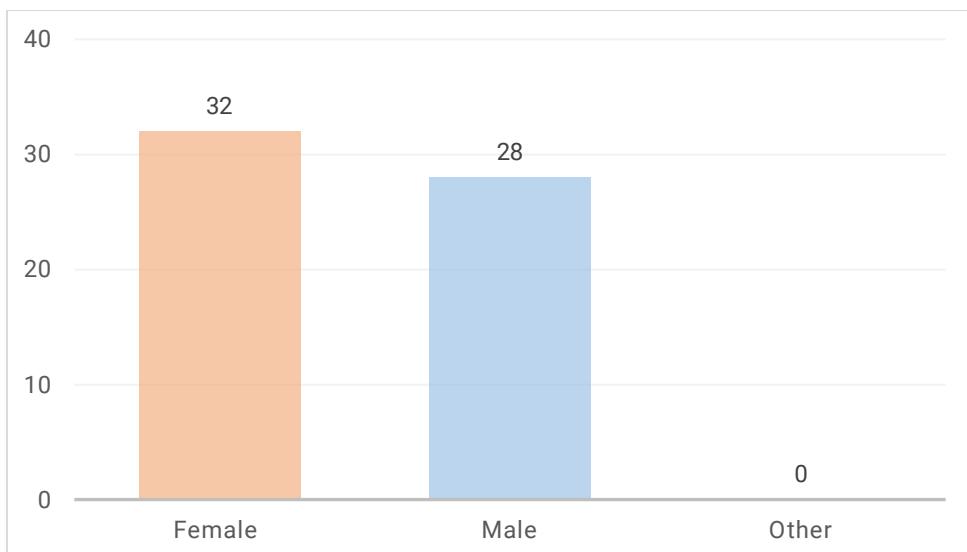


Figure 5.1: Gender of participants.

The dominant age group of participants was 18-29. Fewer users were in the age group of 30-39. However, having more even age groups including more participants older than 29 would have been more representative. Figure 5.2 provides insights into the distribution age among the participating users.

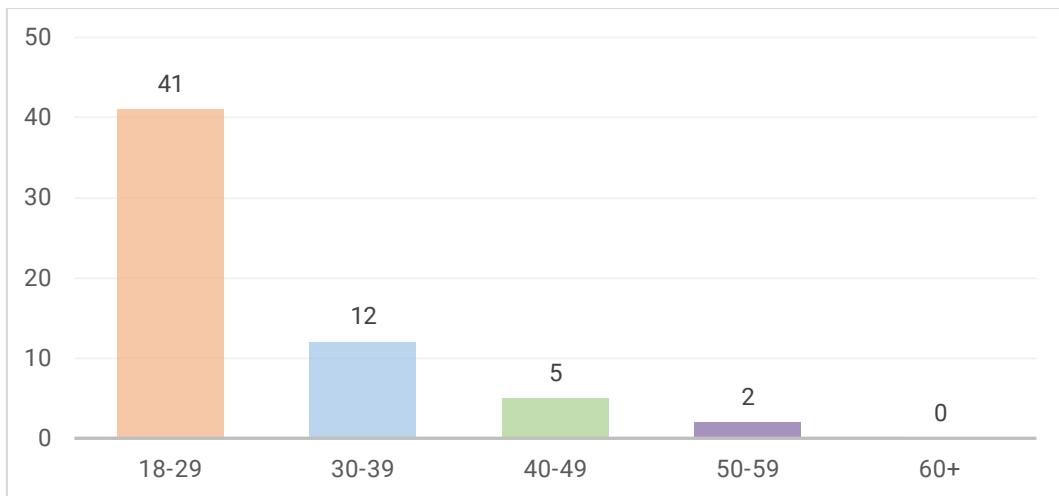


Figure 5.2: Age of participants.

Almost all the participants had ever conducted hiking trips. Nearly half of them had experience in other trips related to outdoor activities. Only one participant had no experience (Figure 5.3). It is beneficial for the study that the majority had experience in hiking trips. Therefore, participants can well imagine the role of the user persona and give more representative feedback.

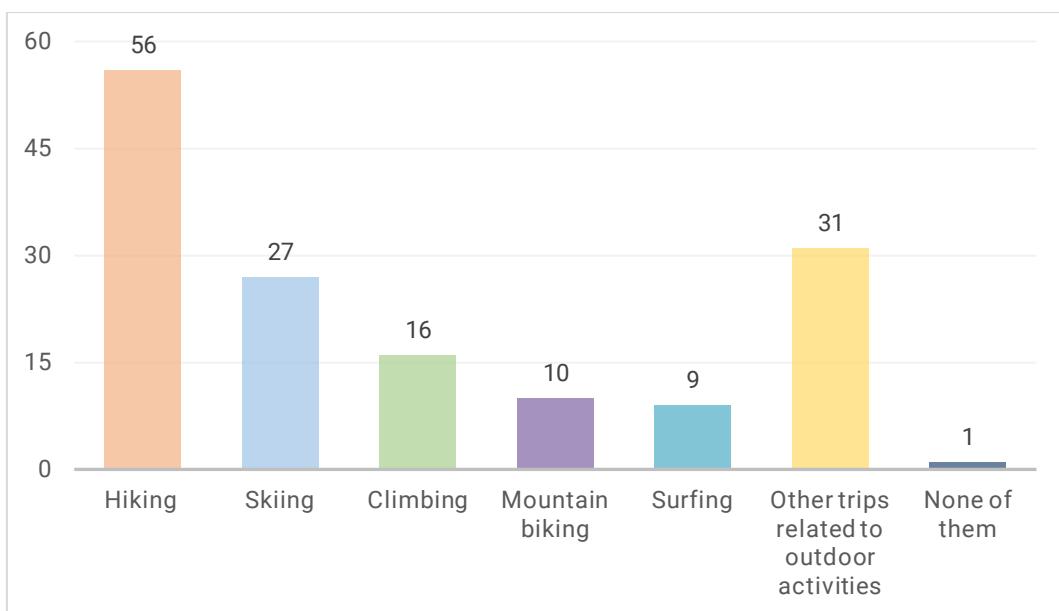


Figure 5.3: Experience of trips related to outdoor activities.

Figure 5.4 illustrates what kind of applications participants use to plan the trips and the frequency of their use, with 4 being very often and 0 – not at all. From the answers, it is visible that most of the participants often used Google Maps for planning their trips among the other applications. For the participant who had no experience in trips related to outdoor activities, the applications listed in the question were Google Maps, TripAdvisor, Booking, Foursquare, Yelp, and Maps.me. However, the participant chose only Google Maps among the listed applications. Thus, most of the participants used to the interface and functionality of Google

Maps, which does not focus on outdoor activities, so the proposed design and visualizations might be unfamiliar to some participants.

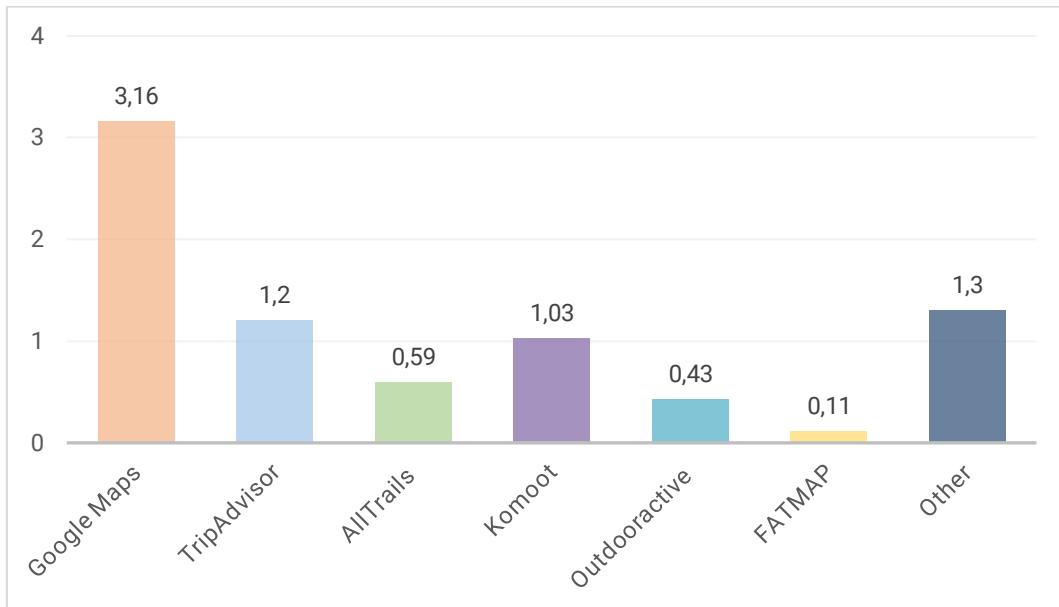


Figure 5.4: Frequency of use of applications for planning the trips.

In addition, participants were asked to specify if they use other products to plan the trips. Maps.me and YandexMaps were mentioned most (Figure 5.5). Maps.me provides offline maps based on OpenStreetMap data and is used to search for points of interest, tourist guides, hiking trails, and places missing from other maps. Whereas the Russian web mapping service YandexMaps does not focus specifically on outdoor activities. Its functionality is similar to Google Maps. It is mostly used among Russian users to search for places, transport, and routes.

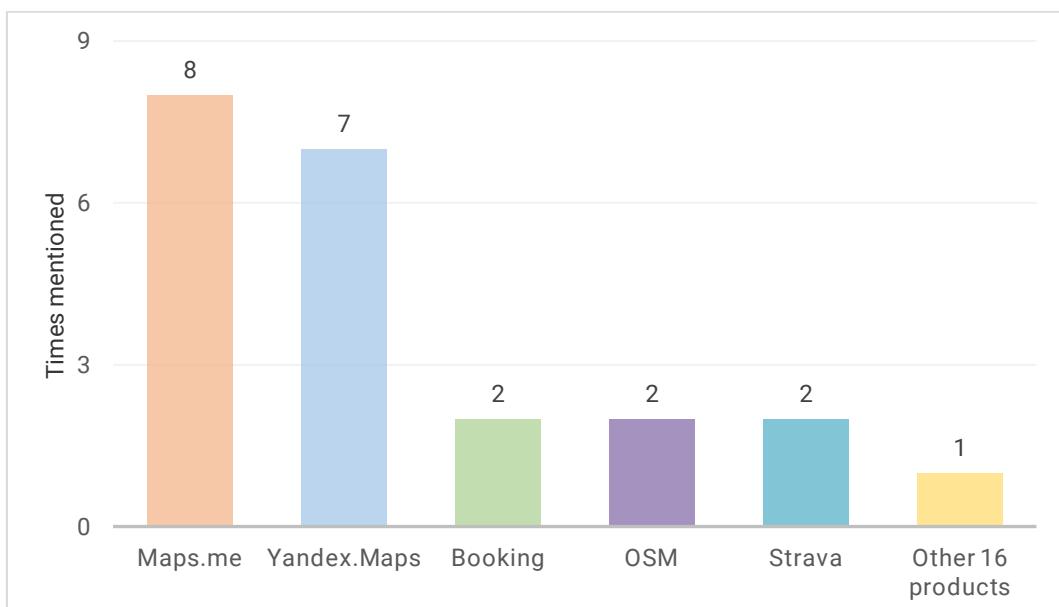


Figure 5.5: Other applications mentioned by participants.

To obtain information about the users' prior experience with web mapping applications they were questioned whether they think they are confident users of web mapping applications (e.g., Google Maps, AllTrails, Komoot, etc.). For the participant who has no experience in trips related to outdoor activities, the question was formulated as follows: "*Please rate the following statement: I think I am a confident user of web mapping applications (e.g., Google Maps, MAPS.ME, etc.)*". As can be seen in Figure 5.6, the majority of the participants considered themselves as confident or very confident users, so they are familiar with the basic actions carried out using web mapping applications. However, having more non or less confident users would have given more diverse insights on the proposed design and visualizations.

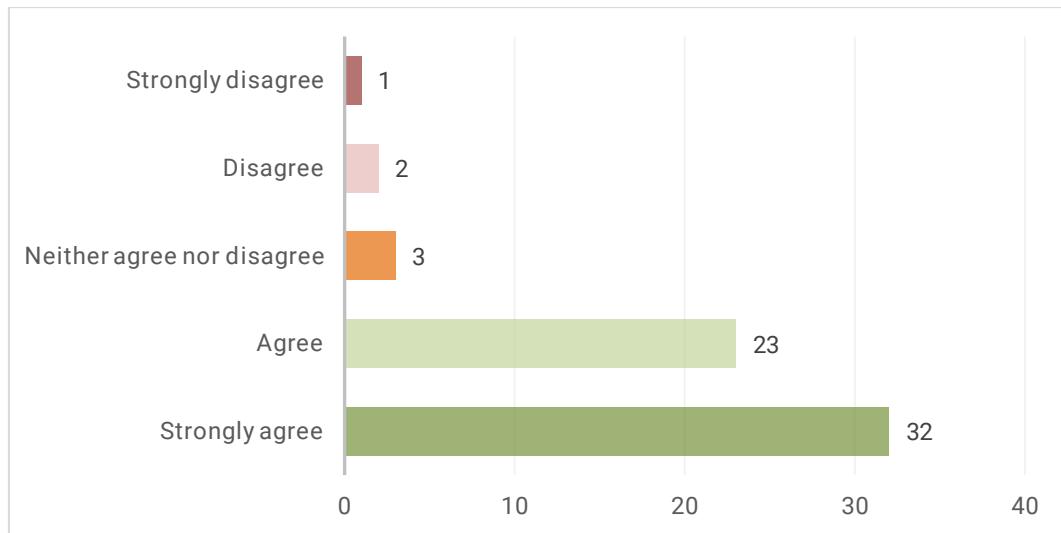


Figure 5.6: Distribution of answers for Q1.6.

5.2 System's Recommendations

As described in chapter 4.2.2, the second section of the online questionnaire was divided into six subsections (2.1 - 2.6). Participants were asked about their opinion regarding their understanding of the proposed design of the system's recommendations. As mentioned in 4.2.1, the questionnaire includes 5-point Likert scale questions related to the agreement (*strongly disagree, disagree, neither agree nor disagree, agree, strongly agree*), intuitiveness (*not at all intuitive, somewhat unintuitive, neutral, somewhat intuitive, very intuitive*), and expectation (*not at all expected, somewhat unexpected, neutral, somewhat expected, expected*). In order to group the results for the analysis, the mentioned scales are substituted to the broad scale (*very, somewhat, neutral, not very, not at all*) since they indicate the same degree of opinion (*from positive to negative*).

To better analyze the survey's results, the mean value μ and the standard deviation σ were calculated. The following approach was used for the Likert scale questions. Each participant's answer was considered a ceiling value, the discrete uniform distribution from 0 to 4, with 0 being "*not at all*" and 4 being "*very*". In general, the standard deviation does not indicate either "*right or wrong*" nor "*better or worse*", and a lower standard deviation σ is not necessarily more desirable. However, it cannot be ignored that quite a different set of responses can have

similar mean values μ but quite different standard deviation σ . For example, the mean value would be “neutral” in both cases: if all participants respond “neutral” to some questions, and if half of the responses are “strongly agree” and half are “strongly disagree”. In one situation, it is possible to conclude that, in general, participants tend to respond “neutral” in another it is not (Clason, D., & Dormody, T. (1994)). It was decided to assess mean μ , whether it has any meaningful explanation or not, based on the standard deviation σ . The low standard deviation σ indicates that most of the responses are around the calculated mean μ representing the participant's consensus (either positive, neutral, or negative). The high standard deviation σ denotes the mean ranking is a number that does not give any meaningful information. Based on the calculated standard deviation σ for all questions, it was decided that if the value is less than 1.2, the standard deviation σ is considered low. If the value is more than 1.2, the standard deviation σ is considered as high. If there are borderline values, the additional review of responses' distribution should be done.

The first (2.1) and the second (2.2) subsections included questions related to the proposed design of the system's recommendations on the global level. An overview of the distribution of all answers to the four questions of the first subsection can be found in Figure 5.7.

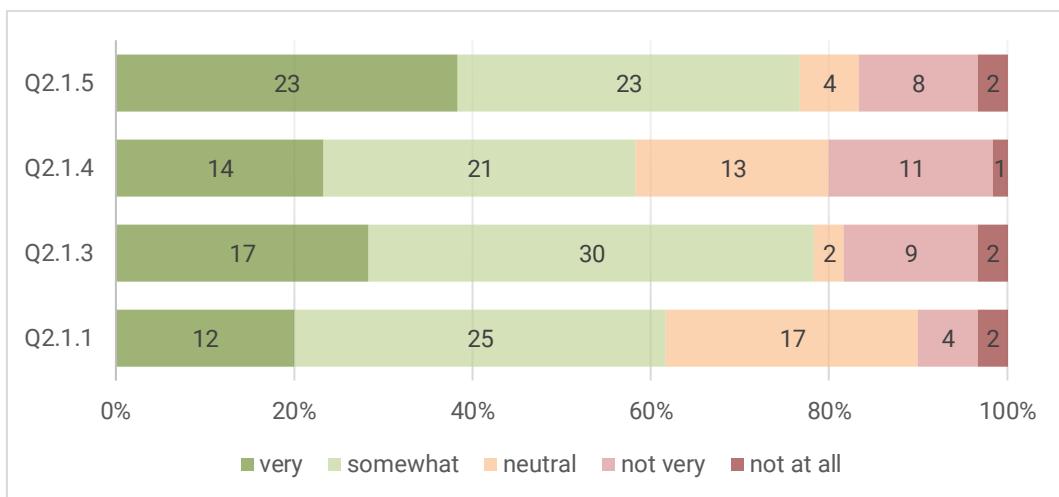


Figure 5.7: Distribution of answers for Q2.1.1, Q2.1.3 – Q2.1.5.

The first question to examine was “Q2.1.1: Please rate the following statement: I think I understand what the white color and the different shades of grey color for some countries mean. I also understand what the golden outline of some countries means.” Most participants tended to agree with this statement ($\mu = 2.68$, $\sigma = 0.983$).

The next question was “Q2.1.2: Please briefly explain your associations”. As seen in Figure 5.8, the majority of the answers were considered correct (70%). One example of a correct participants' answer was “It's obvious the white and outlined are the main suggestions that meet all the criteria. Not entirely sure what the grey means, perhaps light grey is ideal for some of the criteria but not all or not the best, and dark grey is not recommended at all for such a trip”. However, some of the participants (22%) partially understood the visualization, e.g., “White areas show the countries that match the filter. Golden outline limit of those countries. Don't know what the grey shades are for”. Besides, four answers (7%) were incorrect, e.g., “The white

color representation for the country may be is associated with how safe and unsafe the countries are for hiking during that season. I do not understand the usage of golden outline."

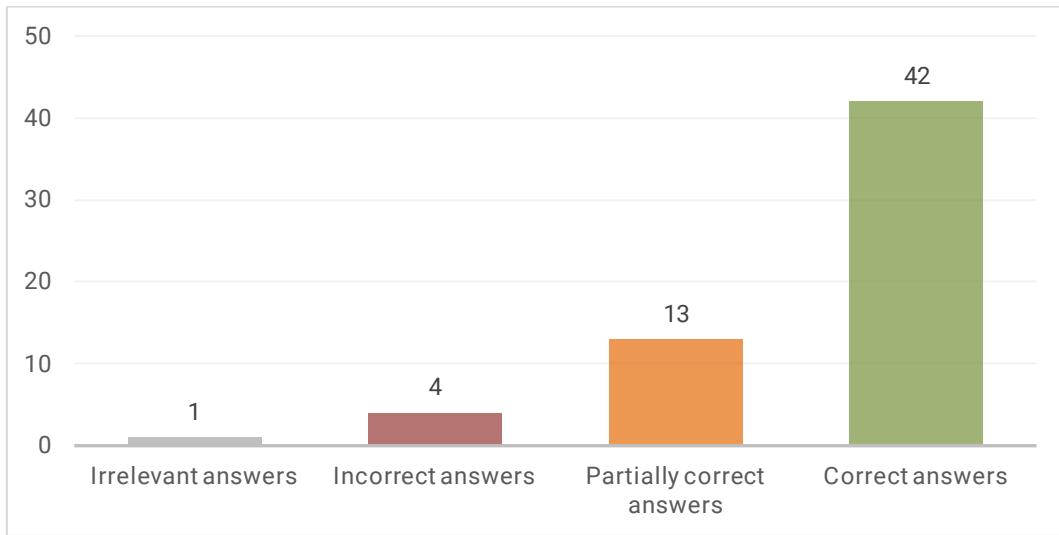


Figure 5.8: Distribution of answers for Q2.1.2.

The next question presented the correct explanation for the colours and outline to the participants and asked them to rate how intuitive the proposed visualization was "Q2.1.3: *The white color and the different shades of grey of the countries correspond to recommendations of the system based on selected filters. The white color and the golden outline mean the recommended countries for hiking in October in Europe. The grey color means that a country is less recommended. The dark grey color means that a country is not recommended. How intuitive do you think this is?*". Most participants tended to consider this visualization intuitive ($\mu = 2.85, \sigma = 1.102$). For the question "Q2.1.4: *Please rate the following statement: The chosen color for the outline of recommended countries looks good to me.*", most participants tended to agree with this statement ($\mu = 2.6, \sigma = 1.092$). The last question in the first subsection was "Q2.1.5: *Please rate the following statement: I think a legend explaining the meaning of the white color and the different shades of grey of the countries would be useful for this case.*". Most participants tended to agree with this statement ($\mu = 2.95, \sigma = 1.141$).

Even though most participants understood the proposed visualization and considered it intuitive, they preferred having a legend explaining the system's recommendations. Most participants easily could recognize the recommended countries, but it was not completely clear what the different shades of grey meant. The two possible directions to improve the proposed visualization are either to add a legend to the interface or to choose another more intuitive color scheme to visualize less recommended and not recommended countries.

An overview of the distribution of all answers to the three questions of the second subsection can be found in Figure 5.9. The first question of the subsection was "Q2.2.1: *Please rate the following statement: I think I understand what the markers with numbers mean*". Most participants tended to agree with this statement ($\mu = 3.47, \sigma = 0.676$).

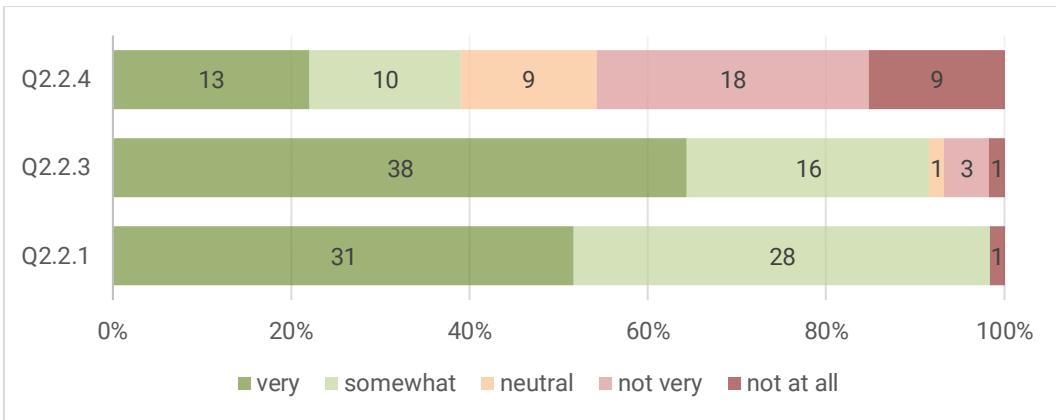


Figure 5.9: Distribution of answers for Q2.2.1, Q2.2.3, and Q2.2.4.

For the question “Q2.2.2: Please briefly explain your associations”, the majority of the answers (67%) were considered correct (Figure 5.10). An example of a correct description is “*The numbers represent the locations of the recommended hiking trails. #1 would be the most recommended trail, whereas #10 means the less recommended trail. However, #10 is also a top pick*”. Though some participants (15%) partially understood the visualization and gave answers like “*Could mean individual hikes but this is not clear*”. Besides, nine answers (15%) were incorrect, e.g., “*The number of trails near that point*”.

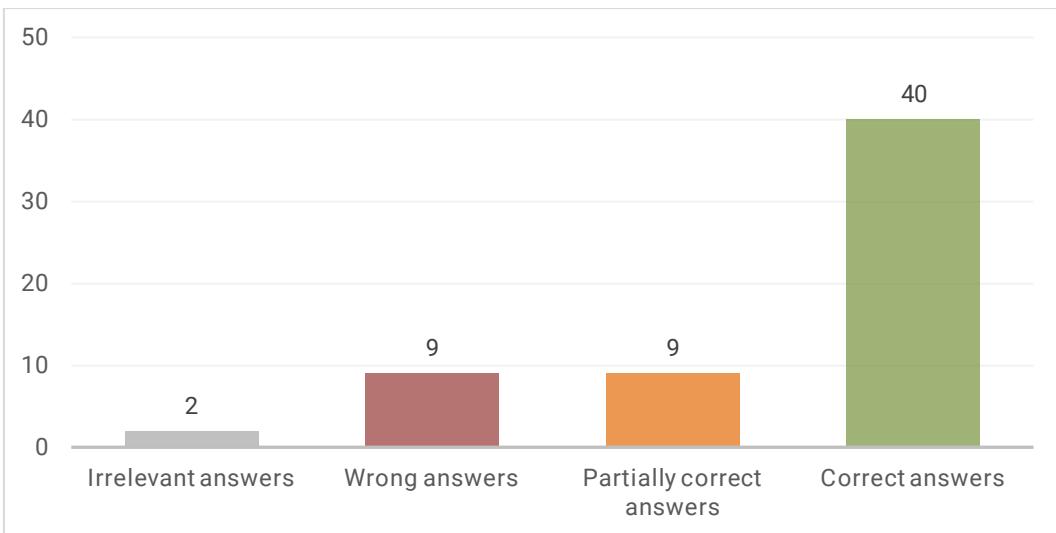


Figure 5.10: Distribution of answers for Q2.2.2.

The next question was “Q2.2.3: The markers with numbers correspond to the top 10 hiking trails recommended by the system. How intuitive do you think this is?”. Most participants tended to consider this visualization intuitive ($\mu = 3.47$, $\sigma = 0.897$). The final question of the subsection was “Q2.2.4: Please rate the following statement: I think a legend explaining the meaning of the markers with numbers would be useful for this case”. Even though the mean value indicates neutrality ($\mu = 2.0$), but the standard deviation is high ($\sigma = 1.414$), so it cannot be concluded that participants tended to respond neutrally. Thus, there was no clear preference among the participants. Despite most participants understood the meaning of markers representing the top 10 hiking trails and considered it intuitive, there was no consensus opinion if a legend was needed. The interface already had a button explaining the meaning of the markers. The

possible directions to improve the proposed visualization are either to redesign the button and/or the icons of markers or to add the legend to the interface.

The third subsection (2.3) and fourth subsection (2.4) included questions related to the proposed design of the system's recommendations on the local level. An overview of the distribution of all answers to the third subsection can be found in Figure 5.11.

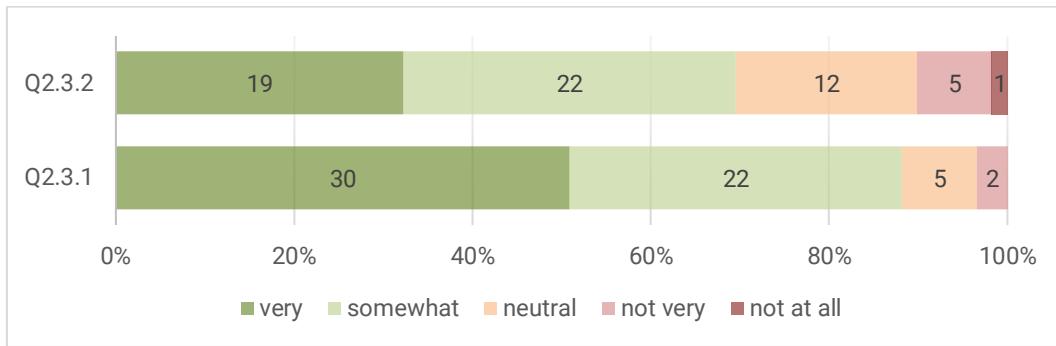


Figure 5.11: Distribution of answers for Q2.3.1 and Q2.3.2.

For the questions of the third subsection “Q2.3.1: Please rate the following statement: I think I understand why Germany is divided into smaller regions” and “Q2.3.2: Please rate the following statement: I think the zoom level of the map meets my expectations”, most participants tended to agree with these statements ($\mu = 3.36$, $\sigma = 0.783$ and $\mu = 2.9$, $\sigma = 1.012$, respectively).

In the comment filed of the question Q2.3.3, participants addressed the issue regarding the division of the regions:

- “I understand what the regional divisions in Germany mean, but I don't think it would be valuable information for a foreign tourist. Also the zoom level is good for figuring out general location of hiking trails in the country, I guess not for investigating a particular trail”.
- “Again the lines resemble political borders (Ländergrenzen) within Germany. I am not sure if that is needed or helpful, because Germany's subdivision in Bundesländer (Provinz/State) is not important for hiking. It could be more helpful to use geographical regions like the Alps, low mountain areas, waterways, wooded areas, urban areas and so on that are more important for my hiking trip”.

Some participants noted that they would prefer the zoom level allowing the whole country to be fit on the screen:

- “I would expect to see the whole of Germany when I have selected it, even if the Northern part isn't recommended for hiking in the app”.
- “It's unfortunate that zoom level does not allow for the entirety of Germany to be visible. I think the zoom level should fit the extent of the suggested hikes”.

An overview of the distribution of the answers to the fourth subsection can be seen in Figure 5.12. The questions of the fourth subsection were “Q2.4.1: Have you expected that the regions will be divided into subregions?” and “Q2.4.2: Please, rate the following statement: I would like to have a further division of subregions for the planning of the trip”. Even though the mean value indicates neutrality ($\mu = 2.14$ and $\mu = 1.85$, respectively) but the standard deviation is high ($\sigma =$

1.414 and $\sigma = 1.284$, respectively), so it cannot be concluded that participants tended to respond neutrally. There were no clear preferences among the participants.

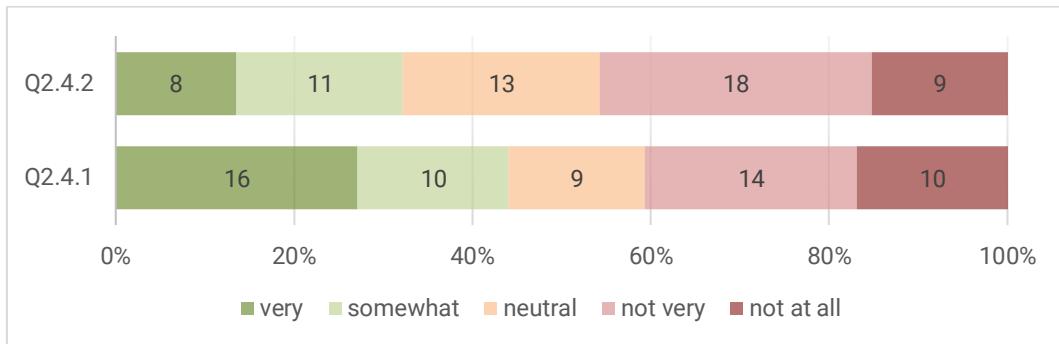


Figure 5.12: Distribution of answers for Q2.4.1 and Q2.4.2.

In the comment field of question Q2.4.3, more participants addressed the issue regarding the division of the sub-regions:

- *"The further divisions are usually only administrative units, they often don't represent cultural or even historical borders. While it makes sense to show the borders or countries: one might wanna go to Spain rather than to Switzerland, due to language, culture, weather or expected costs of the trip, it does not make much sense to me to divide countries furtherly".*
- *"As stated before, I would prefer a more precise subdivision into geographical areas with going along with different hiking conditions and requirements".*

Since the participants provided many comments regarding the division of regions and subregions, another division related more to geographical areas (not to administrative units) can be considered. Additionally, participants noted that they prefer seeing entire Germany on the screen, so the zoom level should cover the full extent of the recommended country on the local level. Though this issue is more related to the size of the users' screen. The zoom level was chosen thoroughly to make a good compromise in terms of readability.

The fifth subsection (2.5) and the sixth subsection (2.6) consisted of questions related to the proposed design of the system's recommendations on the spot level. An overview of the distribution of all answers to the fifth subsection can be found in Figure 5.13.

The first question of the subsection was "*Q2.5.1: Please, rate the following statement: I think I understand what the markers with numbers and the markers' outline (red, green, yellow) mean*". Most participants tended to agree with this statement ($\mu = 2.9$, $\sigma = 1.029$).

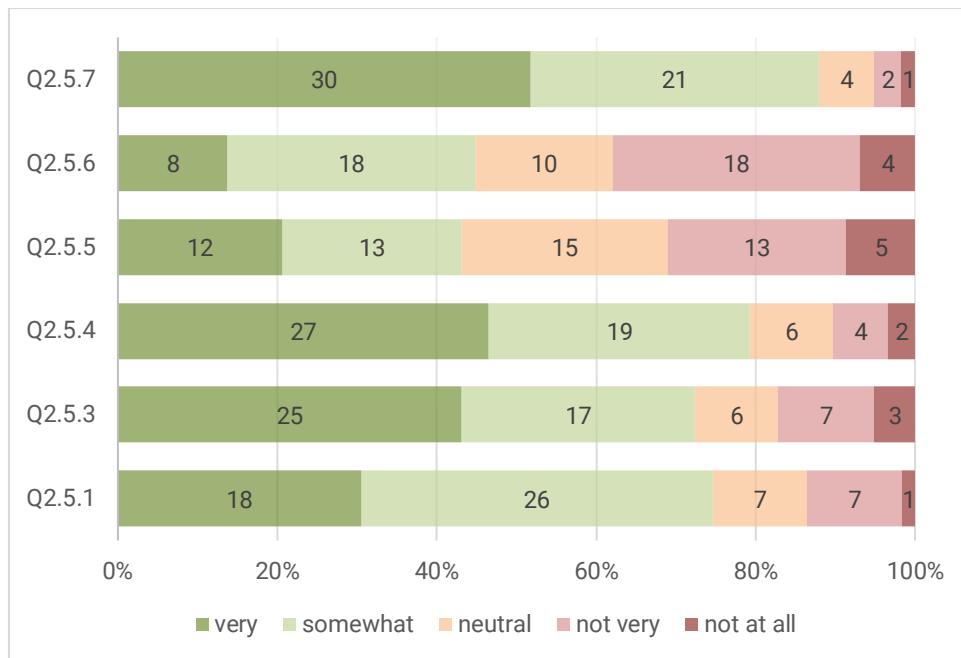


Figure 5.13: Distribution of answers for Q2.5.1, Q2.5.3 – Q2.5.7.

For the question “Q2.5.2: Please briefly explain your associations”, most of the answers were (47%) considered correct (Figure 5.14). A correct description given was like “*The three colours represent the difficulty of the hikes. The number within the pie charts represents the number of possible hikes in the region and the color represents the percentage of hikes within a certain difficulty*”. However, some of the participants (32%) partially understood the visualization. A participant described that “*I understand that the colors means the level of difficulty, however I do not know what the numbers are representing*”. Seven answers (12%) were incorrect and explanations like “*I think numbers might be kilometers and colors representing the difficulty of different stages of trails*” were given.

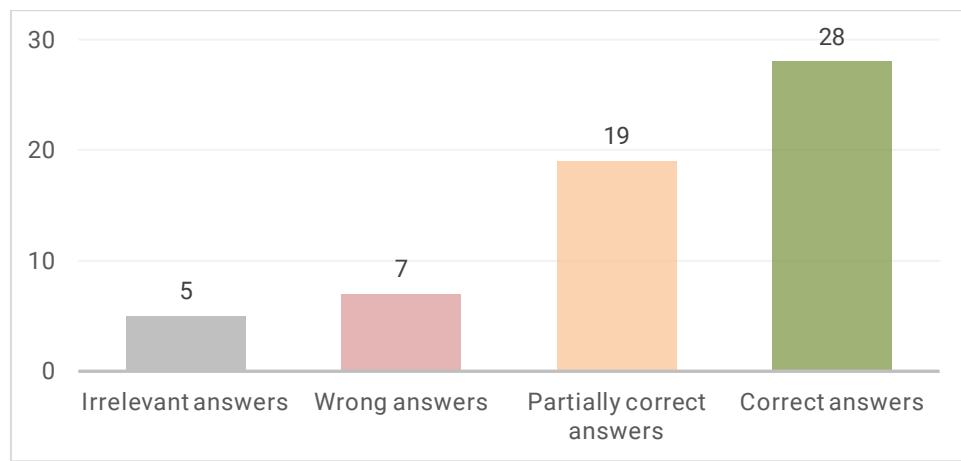


Figure 5.14: Distribution of answers for Q2.5.2.

The next question of the subsection was “Q2.5.3: The markers with numbers correspond to the cluster of hiking trails indicating the number of hikes. How intuitive do you think this is?”. The standard deviation has a borderline value ($\sigma = 1.226$), but the mean value ($\mu = 2.93$) indicates that most participants tended to consider this visualization intuitive. For the question “Q2.5.4:

The markers' outline corresponds to difficulty levels of hiking trails. The outline of clusters represents the combination of difficulty levels within a specific cluster. The outline of individual hiking trails represents the difficulty level of a specific hiking trail. How intuitive do you think this is?", the majority tended to consider this visualization intuitive ($\mu = 3.12$, $\sigma = 1.077$). The following questions were "Q2.5.5: Please rate the following statement: I think a legend explaining the meaning of the markers with numbers would be useful for this case" and "Q2.5.6: Please rate the following statement: I think a legend explaining the meaning of the colors would be useful for this case". Even though the mean value indicates neutrality ($\mu = 2.24$ and $\mu = 2.14$, respectively) but the standard deviation is high ($\sigma = 1.261$ and $\sigma = 1.226$, respectively), so it cannot be concluded that participants tended to respond neutrally. There are no clear preferences among the participants. For the question "Q2.5.7: Please rate the following statement: The chosen colors for the difficulty levels look good to me", most participants tended to agree with this statement ($\mu = 3.33$, $\sigma = 0.886$).

Some participants suggested using another color scheme to represent the difficulty levels:

- "I would suggest another colouring system: blue, red, black".
- "Maybe I would suggest blue instead of yellow".

Moreover, participants indicated the accessibility needs and color blindness:

- "Colours should be checked for accessibility needs and with WCAG for contras".
- "Should consider people with colour blindness, it may not be suitable for them (red/green)".

Even though most participants understood the meaning of the clusters of hiking trails and considered it intuitive, some had difficulties comprehending the meaning of the number inside the cluster indicating the number of hikes. Furthermore, there was not a consensus opinion regarding the need for a legend explaining the meaning. Some participants noted that they understood the colors of difficulty levels since the left-sidebar had the listed hikes and it served like a legend for them but without this, the colors are still intuitive: "*If the sidebar with the hikes is open by default, then a legend with the difficulty colours is not necessary. If not open by default then a legend could be nice, although the colours are already quite intuitive*". Already in the pre-test, two participants stated that they would have better understood the meaning of the clusters if they could interact with the prototype for some time. Moreover, clustering visualization is commonly used, and usually, web mapping applications do not offer a particular legend explaining the meaning of numbers inside clusters. However, the possible solution to improve the proposed visualization could be to add a possibility when a user hovers over a cluster, the icons of hiking trails appear on the screen. Thus, it might be clear that there are several individual hikes.

Furthermore, although most participants agreed with the colors chosen to represent the difficulty levels, some suggested using another color scheme: red, blue, green or red, blue, black. However, the color scheme (red, yellow, green) was chosen since the application aims to consider different properties for different outdoor activities, so the universal color palette was proposed. Moreover, it will be essential to consider users with color blindness and propose an additional color scheme.

An overview of the distribution of all answers to the sixth subsection can be found in Figure 5.15. As it can be seen in Table 5.1, most participants tended to agree with the statements of the questions Q2.6.1, Q2.6.2, Q2.6.3, Q2.6.6, and Q2.6.7. For question Q2.6.5, the majority tended to consider the visualization very intuitive.

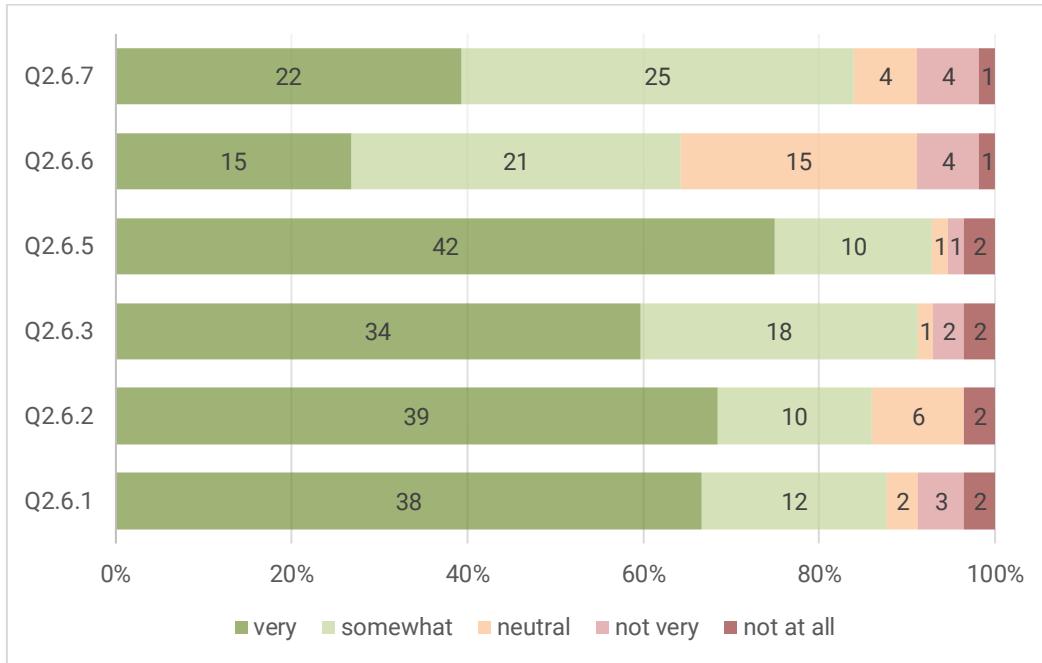


Figure 5.15: Distribution of answers for Q2.6.1 – Q2.6.3 and Q2.6.5 – Q2.6.7.

Question	Mean value, μ	Standard deviation, σ
Q2.6.1 <i>Have you expected that the clusters are clickable?</i>	3.42	1.034
Q2.6.2 <i>Have you expected that single markers of hiking trails are clickable?</i>	3.47	0.947
Q2.6.3 <i>Please rate the following statement: I think I understand what the brown polyline means.</i>	3.4	0.961
Q2.6.5 <i>The brown polyline corresponds to the path of the selected hiking trail. How intuitive do you think this is?</i>	3.6	0.91
Q2.6.6 <i>Please rate the following statement: The chosen color for the path of a hiking trail looks good to me.</i>	2.8	0.98
Q2.6.7 <i>Please rate the following statement: The icons of hotels and restaurants look good to me.</i>	3.12	0.955

Table 5.1: Calculated mean value and standard deviation for Q2.6.1 – Q2.6.7.

For the question “Q2.6.4: Please briefly explain your associations”, most of the answers (82%) were considered correct (Figure 5.16). An example of the correct description given was “Brown polyline is the path of the chosen trail”. Eight answers (15%) were incorrect, e.g., “The

brown polyline means the region to be visited". Perhaps, these participants did not completely understand the general concept of the application.

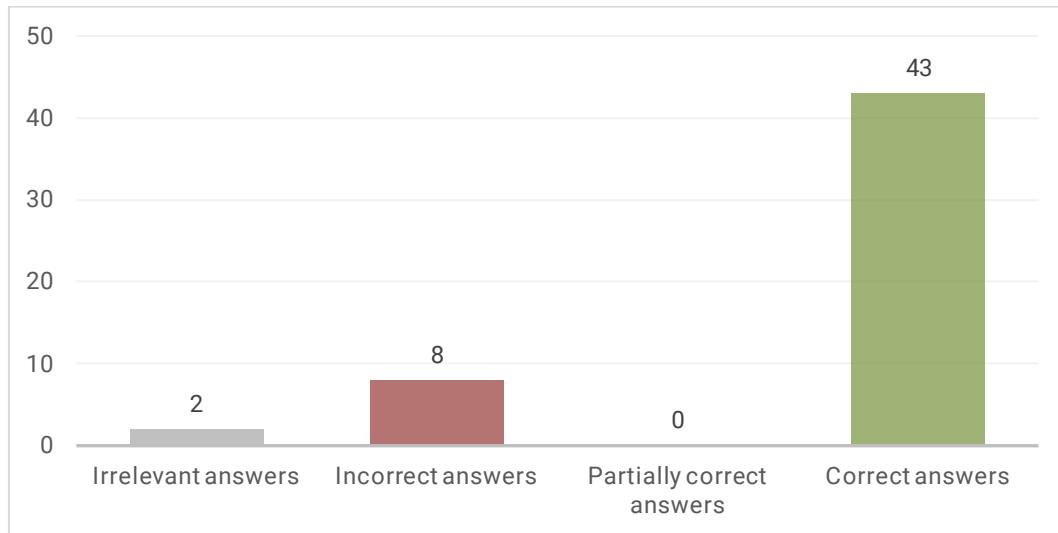


Figure 5.16: Distribution of answers for Q2.6.4.

Participants provided the following issues in the comment filed of question Q2.6.8:

- *"I would add the information about the relief and also the roads, now this trail looks irrelevant to the map content".*
- *"The hike markers are now behind the restaurant/hotel markers. Is there a reason for this? Otherwise I might find it more logical to keep the hike markers in the foreground, since that's the main event".*

Besides, some participants suggested:

- *"I'm thinking the trail paths could also be the same color as the difficulty level. There's no problem with this route, but when several routes are located in the same area, colors could help to distinguish which one belongs which route with what difficulty level".*
- *"To make it more intuitive I guess it would be better to have the line feature the same as the hiking icon hotels and restaurant icons are too simple, the colours do not make any sense to me".*

Based on the analysis of the results of this subsection, it would be more logical to show the markers of individual hikes in the foreground relatively the icons of hotels and restaurants when they overlap each other. The option to color the path of a hiking trail according to its difficulty level can be considered.

5.3 Responses to Itinerary

The third section questioned participants for their understanding of the proposed design of the itinerary. An overview of the distribution of all answers can be found in Figure 5.17.

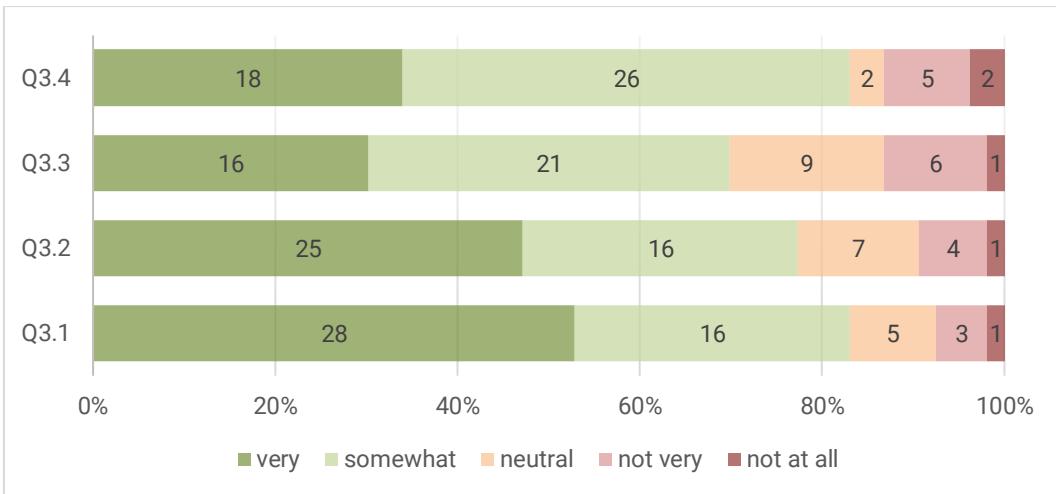


Figure 5.17: Distribution of answers for Q3.1 – Q3.4.

As it can be seen in Table 5.2, most participants tended to agree with the statements of the questions Q3.2 – Q3.4. For question Q3.1, the majority tended to consider the legend intuitive.

Question	Mean value, μ	Standard deviation, σ
<i>Q3.1 The legend in the top left corner explains the meaning of the colors highlighting different days. How intuitive do you think this is?</i>	3.26	0.984
<i>Q3.2 Please rate the following statement: I think the legend explaining the meaning of the colors highlighting different days is useful in this case.</i>	3.13	1.038
<i>Q3.3 Please rate the following statement: The visualization of the itinerary on the map looks good to me.</i>	2.84	1.045
<i>Q3.4. Please rate the following statement: I can clearly distinguish which objects belong to which days.</i>	3.0	1.056

Table 5.2: Calculated mean value and standard deviation for Q3.1 – Q3.4.

At the end of the section, participants were asked to provide additional comments (Q3.5). Some participants noted that they would like to see the paths of the selected hiking trails in the itinerary on the map in combination with point items.

A participant described:

- “I think the itinerary map is missing the visualization of the hiking trail itself” and “I would like to see the hiking trail or selected hiking trail as well”.

Another issue that participants mentioned was that the chosen color scheme for the legend is not easily distinguishable, especially for people with colorblindness:

- “I can distinguish the colours, but this might not be the case for people with impaired colour reception! Overall the colours are too close to each other”.

One participant expressed:

- *"The hue is not differentiated enough, day 2 and 3 are not easily differentiated on the map. Also I wonder how this hue would work with more than 5 days".*

Another participant suggested:

- *"Maybe it could be an option to let people select their own colour per day".*

Another participant observed:

- *"I was not expecting to see a legend and did not see one until the question pointed it out. Relied on the table of contents because the information is there. It took longer to orient myself to the different colors and what they meant".*

Thus, one of the options to improve the design of systems' recommendations on the spot level can be to propose a qualitative color scheme to visualize different days of the itinerary. Moreover, a feature allowing users to select a particular color for a specific day can be considered. In addition, a path of a hiking trail along with other point items in the itinerary can be visualized.

5.4 Responses to Basemaps

This section included three subsections corresponding to global, local, and spot levels. Participants had to rank three basemaps (Canvas, Terrain, Satellite) for the levels. An overview of the distribution of the answers to questions related to the global, local, and spot levels can be found in Figures 5.18 – 5.20, respectively.

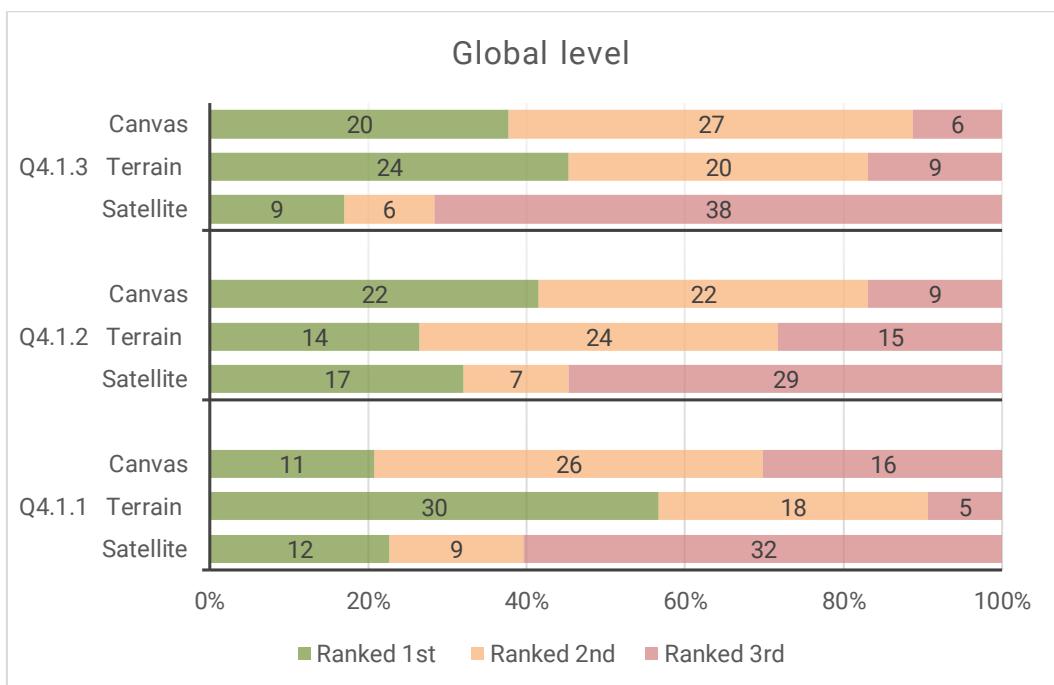


Figure 5.18: Distribution of answers for Q4.2.1 – Q4.2.3.

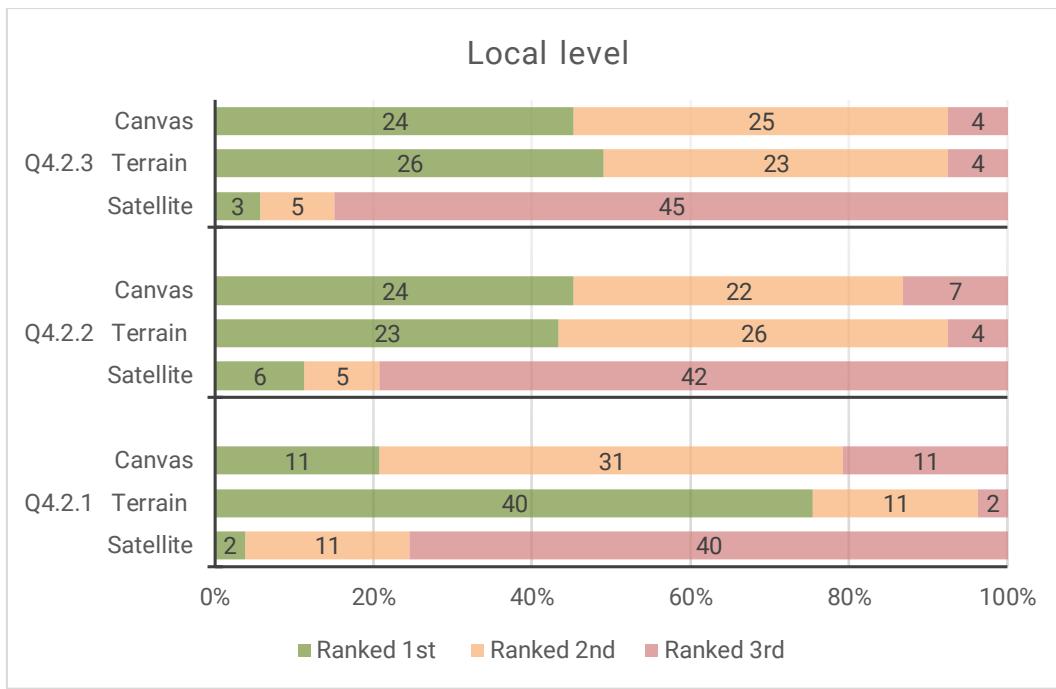


Figure 5.19: Distribution of answers for Q4.2.1 – Q4.2.3.

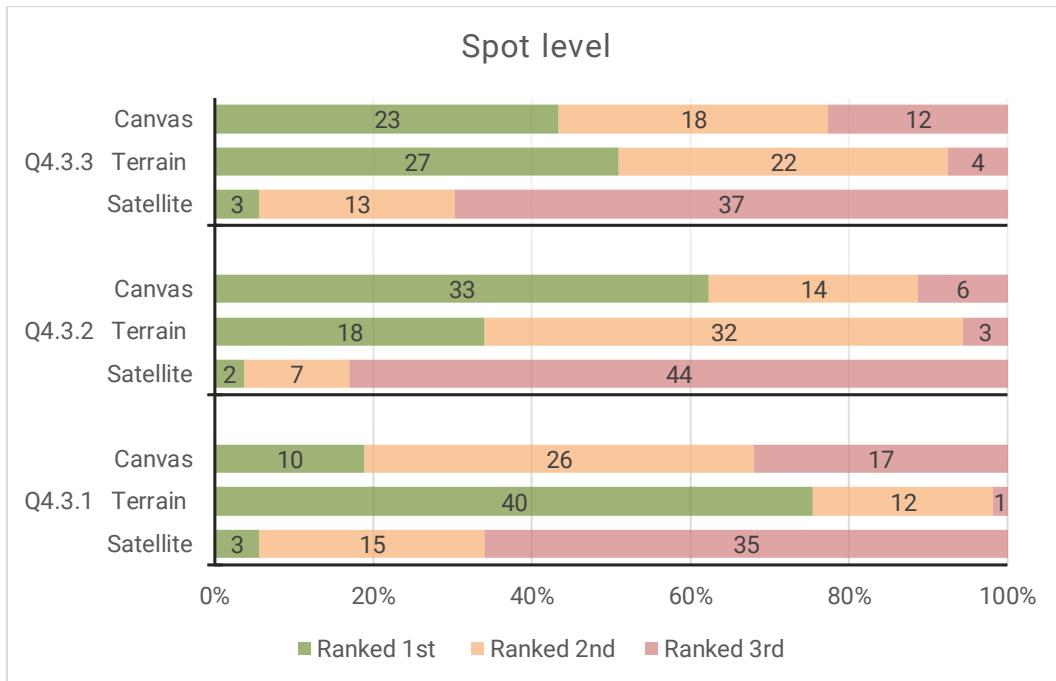


Figure 5.20: Distribution of answers for Q4.3.1 – Q4.3.3.

For the questions related to the look and feel of the basemaps Q4.1.1, Q4.2.1 and Q4.3.1, most participants ranked the terrain basemap first (57%, 76%, and 75%, respectively), the canvas basemap second (50%, 59%, and 49%, respectively) and the satellite third (60%, 76%, and 66%, respectively) on all three levels. For the questions related to the look of markers (and clusters on the spot level) on the top of the basemaps Q4.1.2, Q4.2.2, and Q4.3.2, the majority ranked the canvas basemap first (42%, 45%, and 62%, respectively), the terrain basemap second (45%, 49%, and 60%, respectively) and the satellite basemap third (72%, 79%, and 83%, respectively) on all levels. For the questions related to the look of regions, countries, and the hiking trail on

the corresponding levels Q4.1.3, Q4.2.3, and Q4.3.3, the majority ranked the terrain layer first (45%, 49%, and 50%, respectively), the canvas basemap second (51%, 47%, and 34%, respectively) and satellite basemap third (72%, 85%, and 70%, respectively).

Besides, participants were asked to provide additional comments after each subsection (Q4.1.4, Q4.2.4, Q4.3.4). They elaborated more on the reasons for their choices. One participant expressed:

- *"I think the terrain map is by far the best of the three options. It shows a combination of physical and political geographical features, which is important for planning a hiking trip".*

Another participant noted:

- *"Canvas looks cleanest and the highest contrast with the hiking path, so it is clear to see it. But more useful information comes from terrain and satellite, which provide overview of elevation and imagery, which are important at this zoom level as well".*

Moreover, it was mentioned that the option to choose a type of the basemaps is useful "*Being able to change a base map from time to time, related to your interest, is very useful*" and "*...It would be nice to choose between basemaps, so that one can focus on different aspects on demand ...*".

It can be concluded that participants preferred the terrain basemap as the default basemap. However, participants remarked the markers and clusters look more legible on the top of the canvas basemap. This is why it was ranked first on all the levels when asked about the look of markers. Moreover, participants noted having the possibility to choose between different types of basemaps as an essential option.

To conclude, it is necessary to consider adding the relief to the canvas basemap since most participants preferred to see the terrain basemap on all zoom levels. The color scheme of the terrain basemap should be changed to make markers and clusters more legible on all zoom levels.

5.5 Summary

An overview of the distribution of final answers in the last section can be found in Figure 5.21. For the questions "*Q5.1: Please, rate the following statement: I think the previously shown visualizations of the web app prototype could help me to make decisions when planning a hiking trip*" and "*Q5.2: Please, rate the following statement: I think such a web application could be useful for planning a trip for other outdoor activities (skiing, climbing, surfing, etc.)*", most participants tend to agree with the statements of the questions ($\mu = 3.32$, $\sigma = 0.673$ and $\mu = 3.34$, $\sigma = 0.618$, respectively).

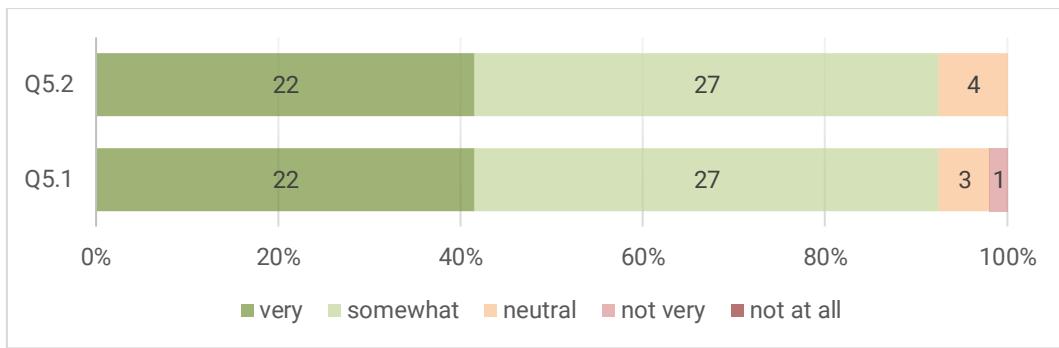


Figure 5.21: Distribution of answers for Q5.1 and Q5.2.

The last question of the survey was to provide final comments (Q5.3). In general, participants gave positive feedback but noted that they would like to interact live with the application. One participant expressed: *"I would really like to use it"*. Another participant said: *"It is difficult to evaluate. It would be nice to try out the application "live". Looking forward to it"*.

Thus, the proposed visualizations of the developed prototype can be helpful and support the decisions while planning a hiking trip. However, the prototype needs to be improved based on participants' feedback and in terms of performance. Afterward, it would be beneficial to conduct the user study again but allow the users to interact with it live.

6 Conclusion and Outlook

This thesis aimed at defining, visualizing, and evaluating decision-relevant map layers of a web-based application for the decision support system focusing on hiking. This chapter reports on the main findings in doing so and gives an outlook towards future research that needs to be conducted in this field of work.

6.1 Answers to the Research Questions

To achieve the research objectives, all research questions were investigated and elaborated upon. Based on the current state of the art, a methodology was developed and applied to a prototype, which in turn was evaluated in a user study.

To answer the research question "*I-a) What is the decision-relevant information for a decision support system for travellers focusing on hiking activity?*", based on the defined general concept and two primary user personas of the web application, the decision-relevant information can be divided into three main groups: decision-relevant map layers, decision-relevant places information, and decision-relevant weather information. Decision-relevant map layers include two categories such as basemaps (terrain, satellite, and customized basemaps) and map overlays (countries' boundaries and country subdivision overlay, and weather overlays) with corresponding details. Based on the needs of the defined user personas, decision-relevant places information can be divided into seven categories: accommodation, food and drink, local facilities, health, transport, tourism, and hiking,. Decision-relevant weather information should include current weather, daily forecast, and historical temperature and precipitation data displayed in the form of weather widgets.

Most of the defined decision-relevant information can be applied to other outdoor activities that the startup aims to integrate. For example, for surfing, the places information may be relevant besides the information related to hiking activity itself. However, additional data about weather information should be considered specifically based on surfers' needs.

To answer the research question "*I-b) What APIs are available and relevant for a decision support system focusing on hiking activity, and what criteria do the APIs have to fulfill?*", the relevant APIs were defined based on the programming stack required by the startup and the decision-relevant information. The available Map APIs are Google Maps API, OpenStreetMap API, and Mapbox API. The corresponding to the Map APIs map libraries were also defined: google-map-react, react-leaflet, react-geo, and react-mapbox-gl. The relevant Places APIs are Google Places API, Overpass API, and Foursquare Places API. The relevant weather APIs are OpenWeatherMap API, Accuweather API, and Meteoblue API.

These APIs and map libraries were evaluated and compared with each other based on the defined criteria for each type of APIs. Thus, for Map APIs, the defined criteria are the global coverage, customization options, overlays, map layers, offline maps, the complexity of code, usage limitations, and cost and pricing. The defined criteria for the map libraries are the size

of the library, functionality, compatibility, documentation, and vector tiles support. The criteria for the comparison of Places APIs were defined based on categories of decision-relevant places information: accommodation, food and drink, local facilities, health, transport, tourism, photos, hiking trails, characteristics of hiking trails as well as limitations, cost, and compatibility. The criteria for the Weather APIs are the possibility of displaying weather widgets and weather overlays data with corresponding details as well as compatibility, limitations, and cost. Thus, the relevant APIs chosen for the prototype's implementation were Google Maps API, Overpass API with the corresponding map library, and Overpass API. Due to time constraints and the complexity of the task, the chosen OpenWeather API was not integrated. Moreover, during the prototype implementation, an additional Outdooractive API was chosen to obtain hiking information. Thus, it can be concluded that the choice of APIs heavily depends on the decision-relevant information, and for other outdoor activities, additional APIs have to be considered.

To answer the research question "*II-a) What web mapping applications exist, and how do they support travellers' decisions?*", five web mapping applications supporting travellers and outdoor enthusiasts in their travel-related decisions were analyzed: (1) AllTrails, (2) Komoot, (3) FATMAP, (4) Google Maps, and (5) TripAdvisor. All these applications support users' decisions individually, e.g., AllTrails allows users to access a database of trail maps. Komoot provides sport-specific routing, route planning, and navigation. FATMAP supports planning a sport-related trip with high-resolution 3D topographic maps. Google Maps support users with real-time navigation and offers satellite imagery, aerial photography, street maps, 360° interactive panoramic views of streets, route planning for traveling by foot and cars. TripAdvisor supports users' decisions while booking a hotel, transportation, restaurants, etc.

To answer the research question "*II-b) How are the decision-relevant map layers visualized in the existing web mapping applications?*", five different web mapping products supporting travellers and outdoor enthusiasts in their travel-related decisions were analyzed. Based on the results of the user research conducted by the startup, it was decided to choose the applications most often mentioned by participants: AllTrails, Komoot, FATMAP, Google Maps, and TripAdvisor. The web mapping products visualize decision-relevant information differently. Though the applications focused on outdoor activities present more details about hiking trails on the map. Komoot and AllTrails aggregate hiking trails into clusters in different zoom levels. Komoot, AllTrails, and FATMAP visualize a hiking path on terrain or satellite basemap. AllTrails and FATMAP offer a wide range of basemaps and overlays relevant to outdoor activities. Google Maps also provides terrain and satellite layers but displays hiking trails as points of interest like TripAdvisor. However, the mentioned applications do not have the functionality of highlighting groups of areas which is relevant to this study.

To answer the research question "*II-c) What decision-relevant information should be visualized in different zoom levels?*", the prototype was implemented and evaluated within a user study. Table 6.1 summarizes all the information that was visualized in different zoom levels and how the information was visualized (column 1). Column 2 presents what the participants of the user study preferred to be visualized and what they suggested to change.

	What was visualized and how	What participants preferred to be visualized
Global level	<ul style="list-style-type: none"> Recommended countries colored in white (with golden outline). Less and not recommended countries colored in different shades of grey. The top 10 hiking trails are markers with numbers in the shape of circles. Choice of canvas, terrain, or satellite basemaps. 	A legend explaining the system's recommendations would be useful. No consensus opinion if a legend was needed. Terrain basemap is the best choice in terms of overall feel and look. Canvas is best in terms of how markers and clusters look (more legible).
Local level	<ul style="list-style-type: none"> Recommended regions and subregions colored in white (with a golden outline). Less and not recommended regions and subregions colored in different shades of grey. Division on regions and subregions. <ul style="list-style-type: none"> The top 10 hiking trails are markers with numbers in the shape of circles. Choice of canvas, terrain, or satellite basemaps. 	A legend explaining the system's recommendations would be useful. Some participants preferred geographical areas instead of administrative units. No consensus opinion if a legend was needed. Terrain basemap is the best choice in terms of overall feel and look. Canvas is best in terms of how markers and clusters look (more legible).
Spot level	<ul style="list-style-type: none"> Clusters of hiking trails with the outline colored in red, green, and yellow. Individual markers of hiking trails with the outline colored in red, green, and yellow depending on the difficulty level. Markers of hotels and restaurants. Path of a hiking trail as a brown polyline. <ul style="list-style-type: none"> Choice of canvas, terrain, or satellite basemaps. 	Suggestions of using another color scheme: red, blue, green or red, blue, black. Showing the markers of individual hikes in the foreground relatively the icons of hotels and restaurants when they overlay each other. Suggestions of coloring the path of a hiking trail according to its difficulty level. Terrain basemap is the best choice in terms of overall feel and look. Canvas is best in terms of how markers and clusters look (more legible).
Itinerary	<ul style="list-style-type: none"> Markers of items with the outline colored according to a selected day. <ul style="list-style-type: none"> A legend explaining the meaning of the colors highlighting different days. 	Suggestions to apply another color scheme with more distinguishable colors. In addition, visualization of a hiking trail's path along with other point items in the itinerary. A legend was considered useful.

Table 6.1: Visualized decision-relevant information and participants' preferences.

The outcome of the research question "*II-d) How should the map elements be designed to support the traveller best?*" is described further.

On the global and local level, map elements should be designed as follows:

- Recommended areas can be colored in white with the golden outline.
- Less and not recommended areas can be colored in different shades of grey but a legend has to be added. Another option is to choose a more intuitive color scheme.
- The top 10 hiking trails are markers with numbers in the shape of circles and with the golden outline.
- However, the division of the local level on regions and subregions, can be substituted by the division on geographical areas visualized in the same way.

On the spot level, map elements should be designed as follows:

- Clusters of hiking trails can be depicted as proportional symbols with the outline colored in red, green, and yellow.
- Individual markers of hiking trails can be visualized with the outline colored in red, green, and yellow depending on the difficulty level. They should be shown foreground relatively markers of hotels and restaurants.
- Markers of hotels and restaurants can be differently colored.
- Path of a hiking trail as a brown polyline.

Elements of the itinerary may look as follows:

- Markers of items with the outline colored according to a selected day. The qualitative color scheme can be used to visualize different days of the itinerary.
- A legend explaining the meaning of the colors highlighting different days should be visualized.

As for the basemaps, there should be the choice of canvas, terrain, and satellite basemaps. The canvas should have hill-shaded relief. The color scheme of the terrain map should be adjusted to fit the markers on the map.

6.2 Limitations and Future Work

While the user test produced predominantly positive results, the conducted user test gave ideas on how to improve the proposed visualization of decision-relevant map layers further.

The most needed refinement to improve the proposed visualization is probably to add a legend to the interface or to choose another more intuitive color scheme to visualize less recommended and not recommended countries or regions on global and local levels.

Although the majority understood the meaning of the markers of the top 10 options, it may be possible to consider redesigning the button "Top Picks" and/or the icons of markers, or to add the legend to the interface explaining the top 10 options recommended by the system.

Further research might go into the necessity of showing the systems' recommendations on the local level based on geographical areas instead of administrative units to make it more hiking relevant. However, the same idea of visualizing the system's recommendations might be applied.

It might be interesting to improve the proposed visualization of clusters by adding a possibility when a user hovers over a cluster, the icons of hiking trails appear on the screen to make it clear that there are several individual hikes. Moreover, it will be essential to consider users with color blindness and propose an additional color scheme. It would be more logical to show the markers of individual hikes in the foreground relatively the icons of hotels and restaurants when they overlay each other. The option to color the path of a hiking trail according to its difficulty level can be considered.

The important refinement can be the use of a qualitative color scheme to visualize different days of the itinerary. Also, it might be interesting to add a feature allowing users to select a particular color for a specific day. In addition, a path of a hiking trail along with other point items (like restaurants) in the itinerary can be visualized.

It is necessary to consider adding the relief to the canvas basemap since most participants preferred to see the terrain basemap on all zoom levels, however, at the same time, they would like to have an option to switch between basemaps. The color scheme of the terrain basemap should be changed to make markers and clusters more legible on all zoom levels.

Since the user-centered design is an iterative design process, this research needs to be refined and continued in a future study. Thus, it might be useful to improve the design based on the described recommendations, improve the performance of the prototype, and conduct a follow-up user study based on the thinking aloud method and allow users to interact with the prototype.

Since the startup aims to develop a mobile application for the decision support system, it can be said that the proposed visualizations can be used in the mobile version but have to be adapted to the smaller screen size. However, mostly the UI elements should be adopted, e.g., a current location button can be added, right and left sidebars have to be replaced, etc.

To conclude, the proposed visualizations of the developed prototype have potential since participants stated that it can be helpful and support the decisions while planning a hiking trip.

Appendix A: Questionnaire

Designing a web-based application for planning hiking trips.

Hello!

Welcome to this questionnaire about designing a web-based application for planning hiking trips. This study is being conducted as part of my M.Sc. Cartography thesis at the Technical University of Munich, Germany. The survey will ask you about your thoughts and perception of the proposed design and visualization and how you understand them. It will take you approximately 20-25 minutes to complete. It is best if you do it on the PC screen. Your participation in this study is completely voluntary and you can withdraw at any time. All information you submit is anonymous. The collected information will only be used for the master thesis outlined above. Raw data will not be passed onto third parties.

If you have any questions, please do not hesitate to contact me at naioseliani@gmail.com.

Thank you very much for your time and contribution!

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Cartography M.Sc. student
Technical University of Munich, Germany

By clicking "Yes, I agree" below you are indicating that you are at least 18 years old, have read and understood this consent and agreed to participate in this research study.

1. Yes, I agree
2. No, I do not agree

Section 1. General questions

1.1 What is your gender?

1. Female
2. Male
3. Other

1.2 How old are you?

1. 18-29
2. 30-39
3. 40-49
4. 50-59
5. 60+

1.3 What kind of trips have you conducted?

1. Hiking
2. Skiing
3. Climbing
4. Mountain biking
5. Surfing
6. Other trips related to outdoor activities
7. None of them

1.4 What applications do you generally use for planning your above-mentioned trips and how often?

	Not at all	Seldom	Sometimes	Often	Very often
Google Maps	<input type="checkbox"/>				
TripAdvisor	<input type="checkbox"/>				
AllTrails	<input type="checkbox"/>				
Komoot	<input type="checkbox"/>				
Outdooractive	<input type="checkbox"/>				
FATMAP	<input type="checkbox"/>				
Other	<input type="checkbox"/>				

1.5 In case you use any other applications, please name them here.

1. 6 Please rate the following statement:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I think I am a confident user of web mapping applications (e.g. Google Maps, AllTrails, Komoot, etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1.4 What applications do you generally use for planning your trips and how often?³⁰

	Not at all	Seldom	Sometimes	Often	Very often
Google Maps	<input type="checkbox"/>				
TripAdvisor	<input type="checkbox"/>				
Booking	<input type="checkbox"/>				
Foursquare	<input type="checkbox"/>				
Yelp	<input type="checkbox"/>				

³⁰ For respondents without travel experience (When answering "None of them" in Q1.3)

MAPS.ME	<input type="checkbox"/>				
Other	<input type="checkbox"/>				

1.5 In case you use any other applications, please name them here.

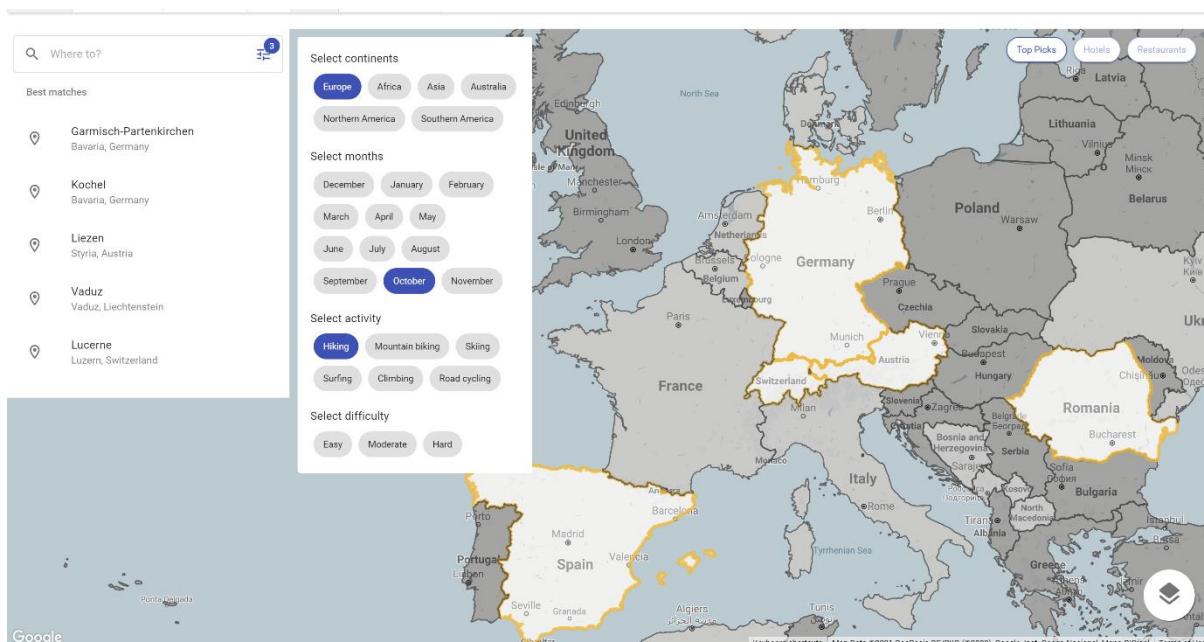
1.6 Please rate the following statement:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	N/A
I think I am a confident user of web mapping applications (e.g. Google Maps, MAPS.ME, etc.).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Section 2.

Important note: The interface and data used in the prototype are not final and for testing purposes only. Please pay attention to the design and visualizations related to the map.

2.1 Imagine the following scenario. You work and live in Moscow. You are quite an experienced hiker. You are planning a hiking trip which is fixed to 5 days at the end of October. You want to spend your vacation not too far from home, somewhere in Europe. You devote 3 days to 3 separate hiking trails, one trail per day. Therefore, you need new overnight stays and places to eat every day. So you decide to use the app which can help you to plan the trip and give you recommendations where to go, eat and sleep in Europe. On the screenshot below you can see an interface of the web app prototype. You select the continent **Europe**, the month **October** and the activity **Hiking**. Based on the selected filters, the map appears on the screen with countries colored in white and different shades of grey.



2.1.1 Please rate the following statement: I think I understand what the white color and the different shades of grey color for some countries mean. I also understand what the golden outline of some countries means.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.1.2 Please briefly explain your associations.

2.1.3 The white color and the different shades of grey of the countries correspond to recommendations of the system based on selected filters. The white color and the golden outline mean the recommended countries for hiking in October in Europe. The grey color means that a country is less recommended. The dark grey color means that a country is not recommended. How intuitive do you think this is?

1. Very intuitive
2. Somewhat intuitive
3. Neutral
4. Somewhat unintuitive
5. Not at all intuitive

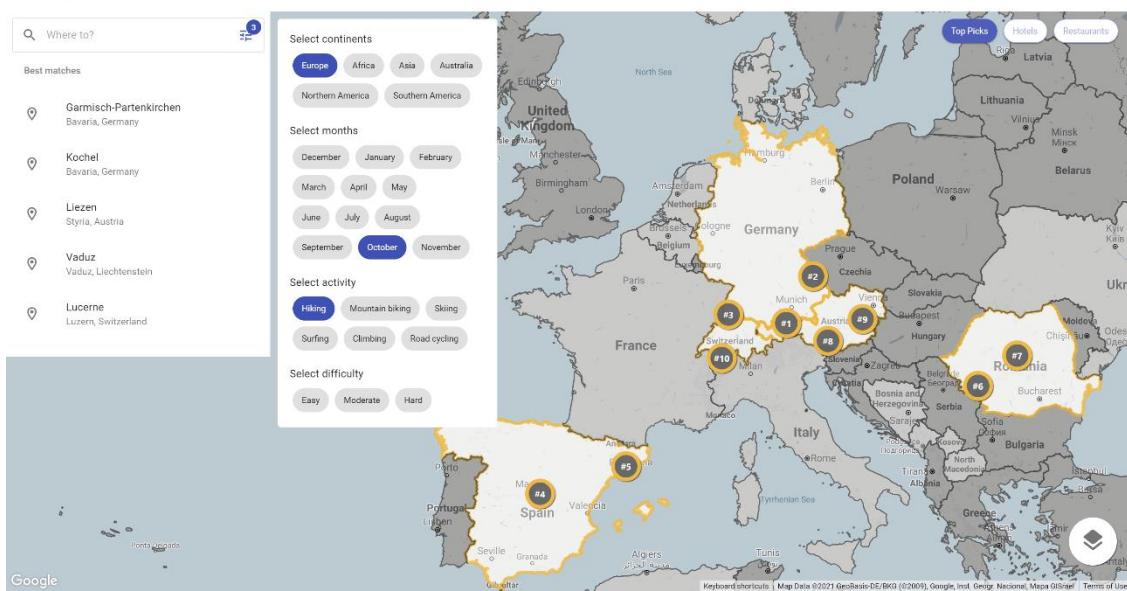
2.1.4 Please rate the following statement: The chosen color for the outline of recommended countries looks good to me.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.1.5 Please rate the following statement: I think a legend explaining the meaning of the white color and the different shades of grey of the countries would be useful for this case.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.2 Then you click on the button 'Top Picks' in the top right corner. 10 markers with numbers appear on the screen.



2.2.1 Please rate the following statement: I think I understand what the markers with numbers mean.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.2.2 Please briefly explain your associations.

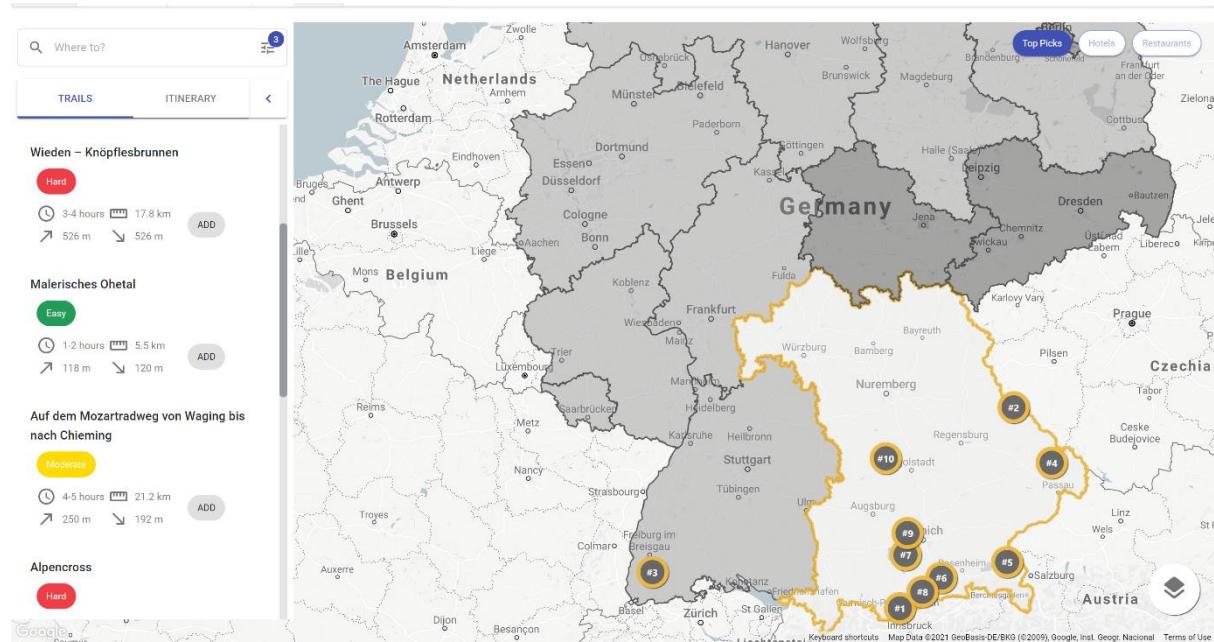
2.2.3 The markers with numbers correspond to the top 10 hiking trails recommended by the system. How intuitive do you think this is?

1. Very intuitive
2. Somewhat intuitive
3. Neutral
4. Somewhat unintuitive
5. Not at all intuitive

2.2.4 Please rate the following statement: I think a legend explaining the meaning of the markers with numbers would be useful for this case.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.3 Then you choose and click on Germany, one of the recommended countries by the system. The map zooms in to Germany. The screen looks like the screenshot below.



2.3.1 Please rate the following statement:I think I understand why Germany is divided into smaller regions.

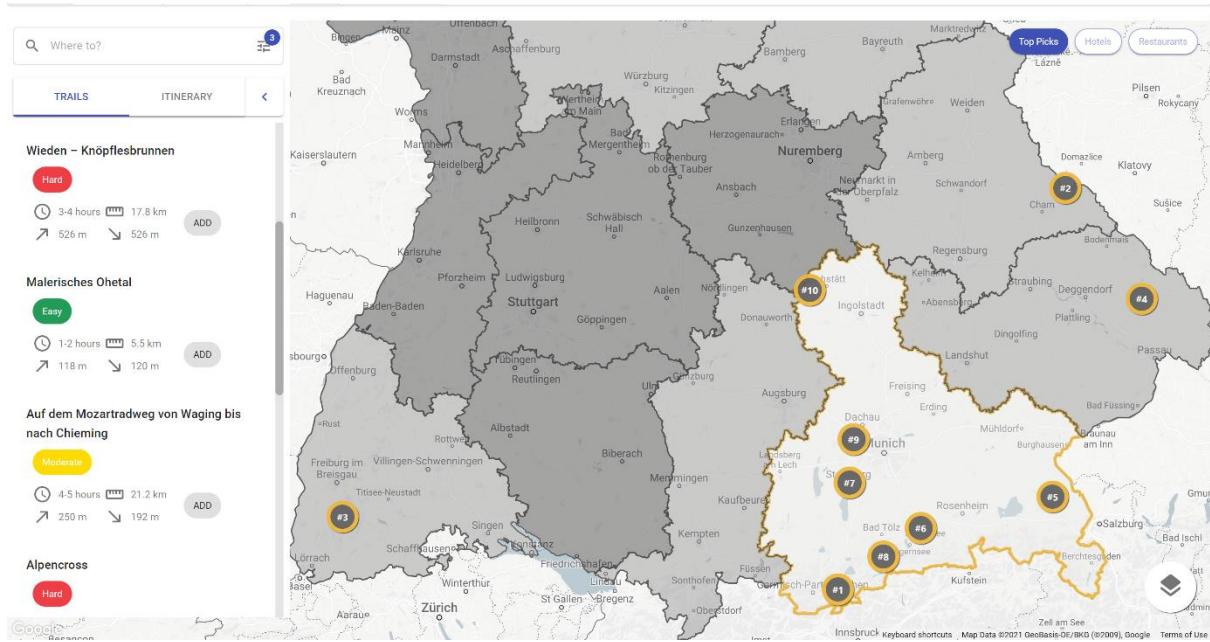
1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.3.2 Please rate the following statement: I think the zoom level of the map meets my expectations.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.3.3 Please provide any additional comments if you like.

2.4 Then you choose and click on the recommended region. The map zooms in and the regions are divided into subregions. The screen looks like the screenshot below.



2.4.1 Have you expected that the regions will be divided into subregions?

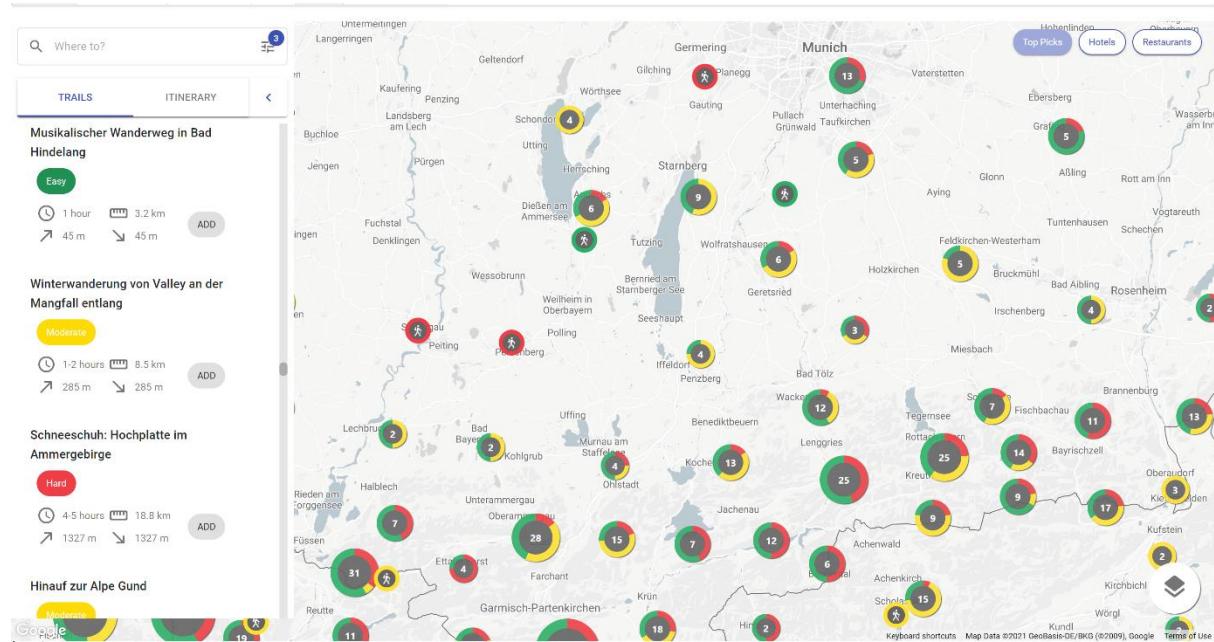
1. Expected
2. Somewhat expected
3. Neutral
4. Somewhat unexpected
5. Not at all expected

2.4.2 Please, rate the following statement:I would like to have a further division of subregions for the planning of the trip.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.4.3 Please provide any additional comments if you like.

2.5 Then you choose and click on the recommended sub-region. The map zooms in and the previous division of sub-regions disappears. The screen looks like the screenshot below.



2.5.1 Please, rate the following statement: I think I understand what the markers with numbers and the markers' outline (red, green, yellow) mean.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.5.2 Please briefly explain your associations.

2.5.3 The markers with numbers correspond to the cluster of hiking trails indicating the number of hikes. How intuitive do you think this is?

1. Very intuitive
2. Somewhat intuitive
3. Neutral
4. Somewhat unintuitive
5. Not at all intuitive

2.5.4 The markers' outline corresponds to difficulty levels of hiking trails. The outline of clusters represents the combination of difficulty levels within a specific cluster. The outline of individual hiking trails represents the difficulty level of a specific hiking trail. How intuitive do you think this is?

1. Very intuitive
2. Somewhat intuitive
3. Neutral
4. Somewhat unintuitive
5. Not at all intuitive

2.5.5 Please rate the following statement: I think a legend explaining the meaning of the markers with numbers would be useful for this case.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.5.6 Please rate the following statement: I think a legend explaining the meaning of the colors would be useful for this case.

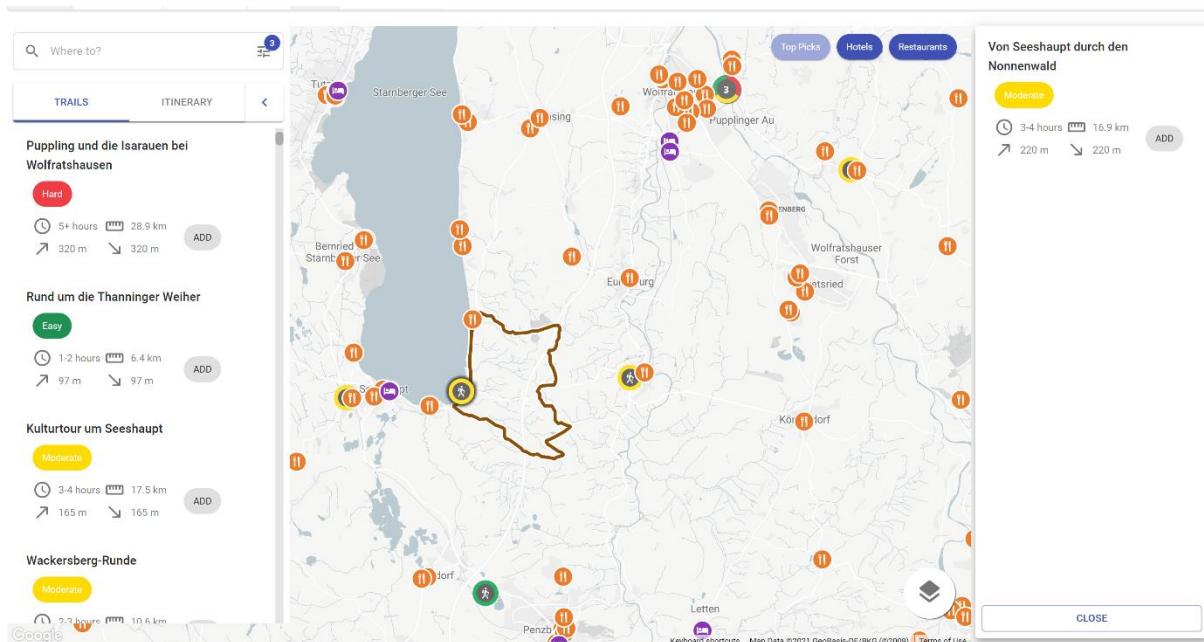
1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.5.7 Please rate the following statement: The chosen colors for the difficulty levels look good to me.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.5.8 Please provide any additional comments if you like.

2.6 Then you click on one of the clusters of hiking trails. The map zooms in and the cluster is divided into individual markers of hiking trails. You click on one of the markers. Then you click on the buttons 'Hotels' and 'Restaurants' in the top right corner. The screen looks like the screenshot below.



2.6.1 Have you expected that the clusters are clickable?

1. Expected
2. Somewhat expected
3. Neutral
4. Somewhat unexpected
5. Not at all expected

2.6.2 Have you expected that single markers of hiking trails are clickable?

1. Expected
2. Somewhat expected
3. Neutral
4. Somewhat unexpected
5. Not at all expected

2.6.3 Please rate the following statement: I think I understand what the brown polyline means.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.6.4 Please briefly explain your associations.

2.6.5 The brown polyline corresponds to the path of the selected hiking trail. How intuitive do you think this is?

1. Very intuitive
2. Somewhat intuitive
3. Neutral
4. Somewhat unintuitive
5. Not at all intuitive

2.6.6 Please rate the following statement: The chosen color for the path of a hiking trail looks good to me.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

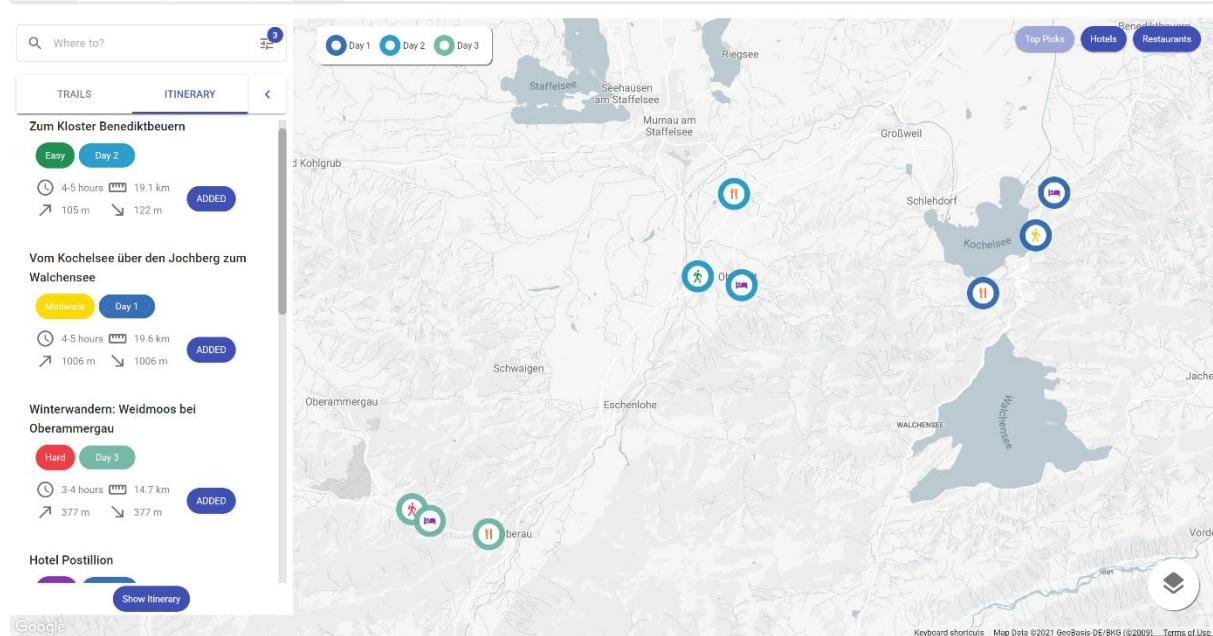
2.6.7 Please rate the following statement: The icons of hotels and restaurants look good to me.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

2.6.8 Please provide any additional comments if you like.

Section 3. Itinerary

You explore the map and select three hiking trails, three restaurants and three hotels for your trip (one day - one hiking trail, one restaurant and one hotel). You added these items to the itinerary. Consequently, the items appear in the 'ITINERARY' tab in the left sidebar. You show all items of the itinerary on the map by clicking the 'Show itinerary' button at the bottom of the itinerary tab. The screen looks like the screenshot below.



3.1 The legend in the top left corner explains the meaning of the colors highlighting different days. How intuitive do you think this is?

1. Very intuitive
2. Somewhat intuitive
3. Neutral
4. Somewhat unintuitive
5. Not at all intuitive

3.2 Please rate the following statement:I think the legend explaining the meaning of the colors highlighting different days is useful in this case.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

3.3 Please rate the following statement:The visualisation of the itinerary on the map looks good to me.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

3.4 Please rate the following statement:I can clearly distinguish which objects belong to which days.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

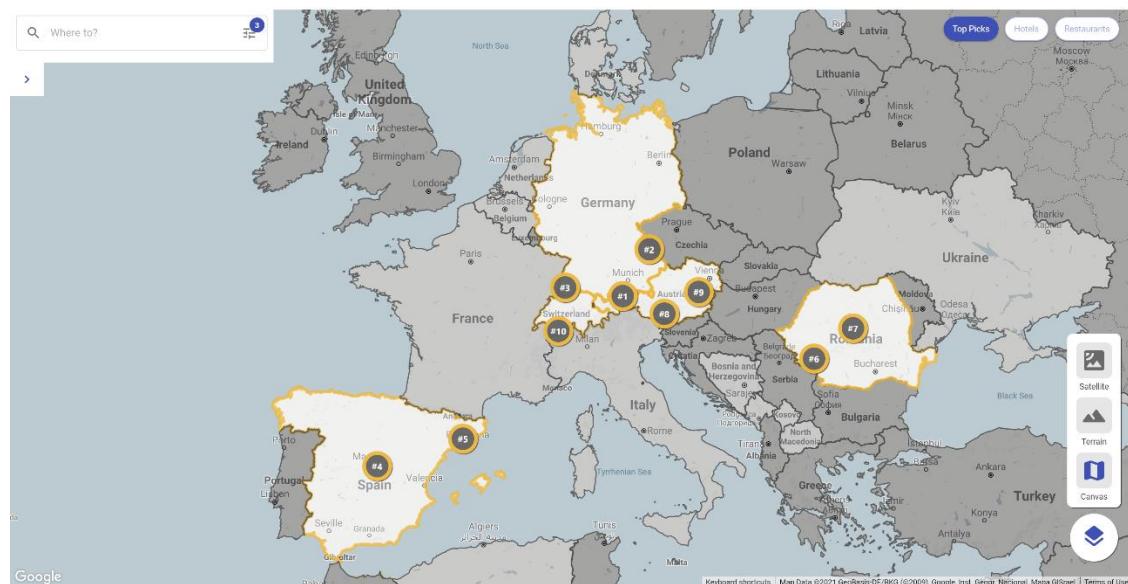
3.5 Please provide any additional comments if you like.

Section 4. Basemaps

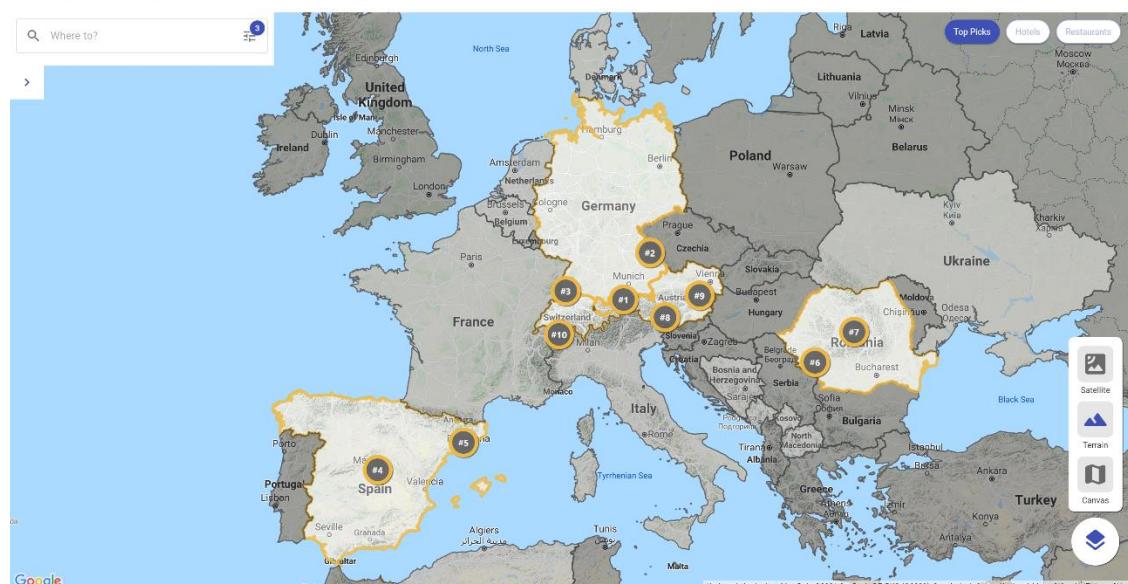
In this section, you are asked to rank the look of three different basemaps (Canvas, Terrain and Satellite) based on three different zoom levels ("global", "local" and "spot"). The system allows changing the basemap according to your personal preferences.

4.1 Global zoom level

Canvas



Terrain



Satellite



4.1.1 Please rank the basemaps based on the look and feel, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

4.1.2 Please rank the basemaps based on how the markers look on top of the basemaps, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

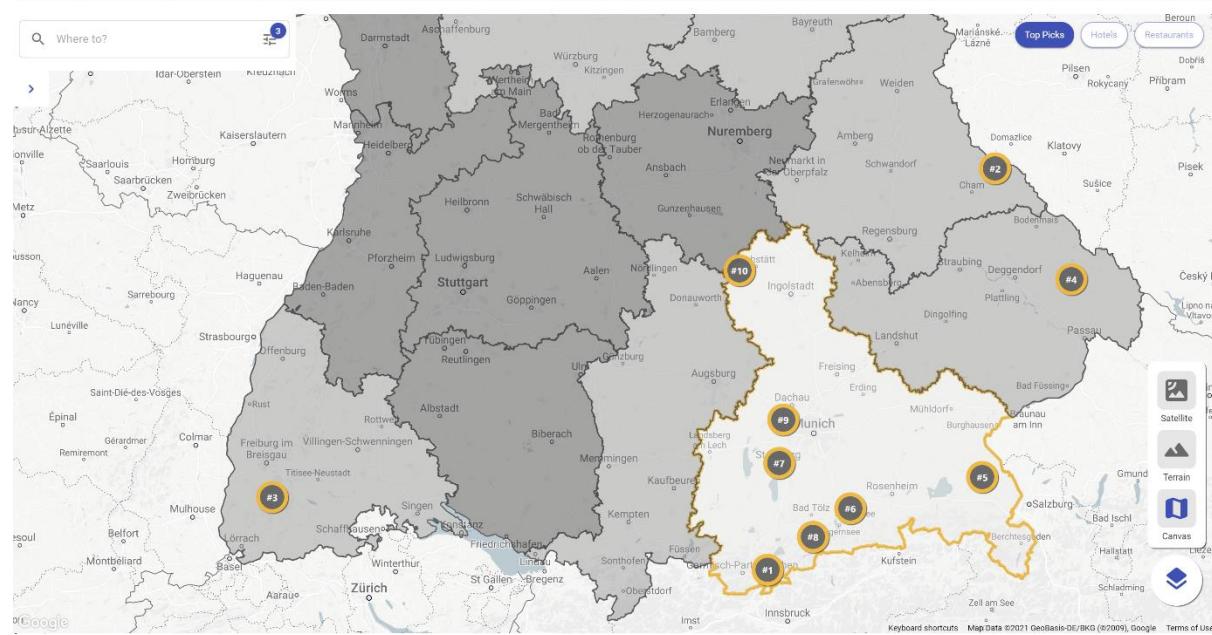
4.1.3 Please rank the basemaps based on how the countries look on the basemaps, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

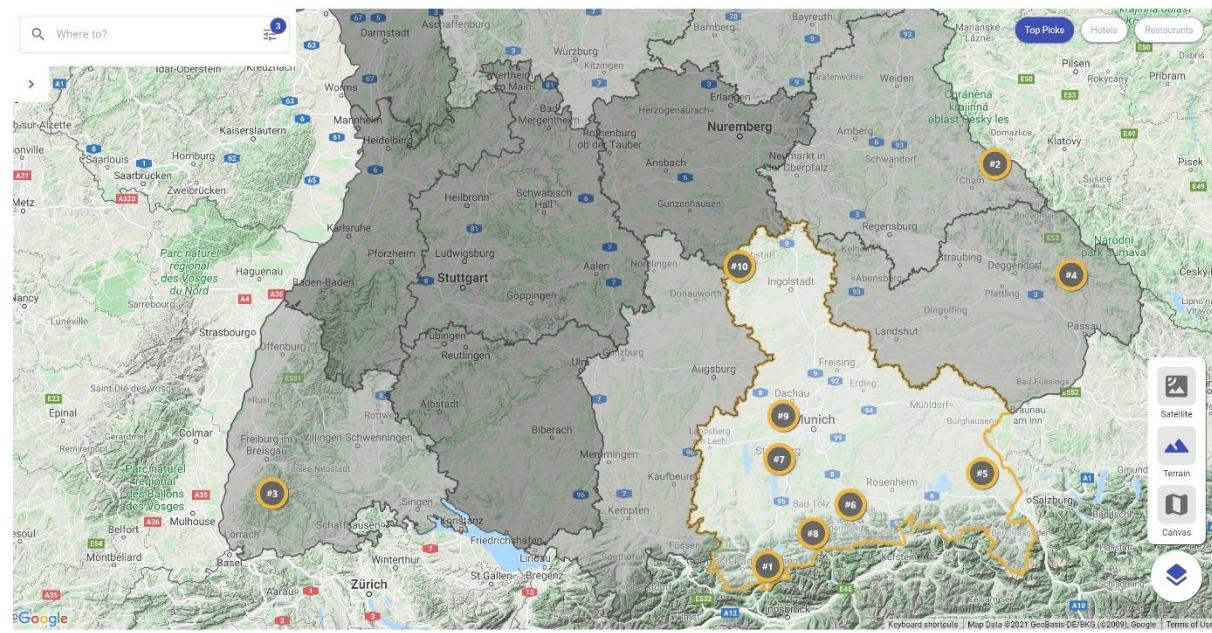
4.1.4 Please provide any additional comments if you like.

4.2 Local zoom level

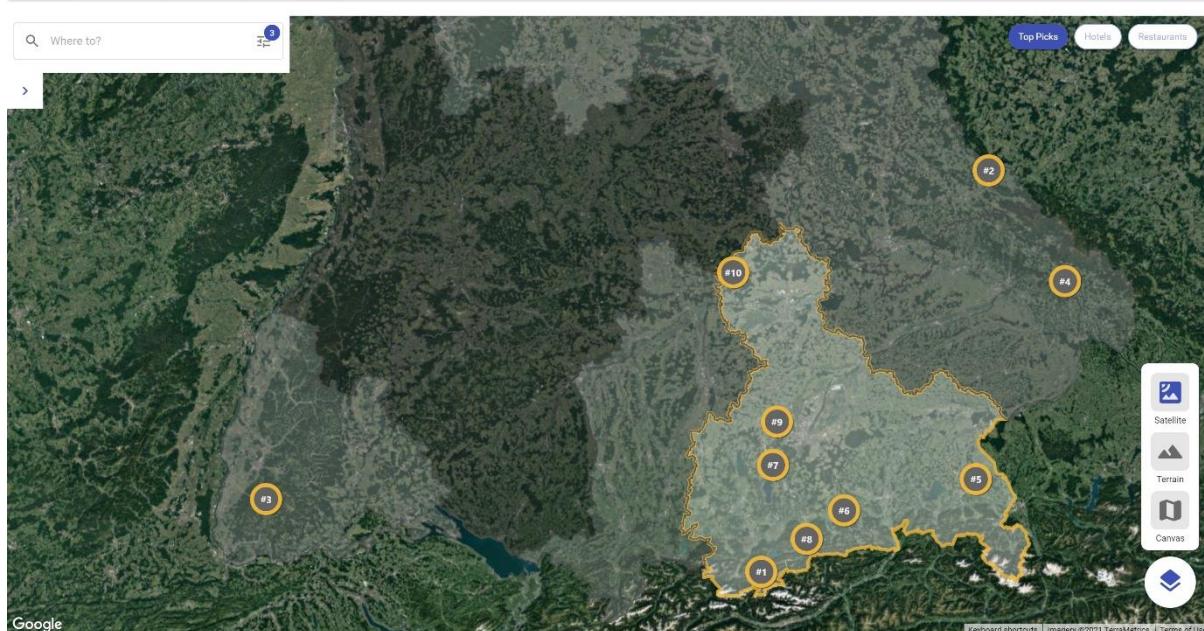
Canvas



Terrain



Satellite



4.2.1 Please rank the basemaps based on the look and feel, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

4.2.2 Please rank the basemaps based on how the markers look on top of the basemaps, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

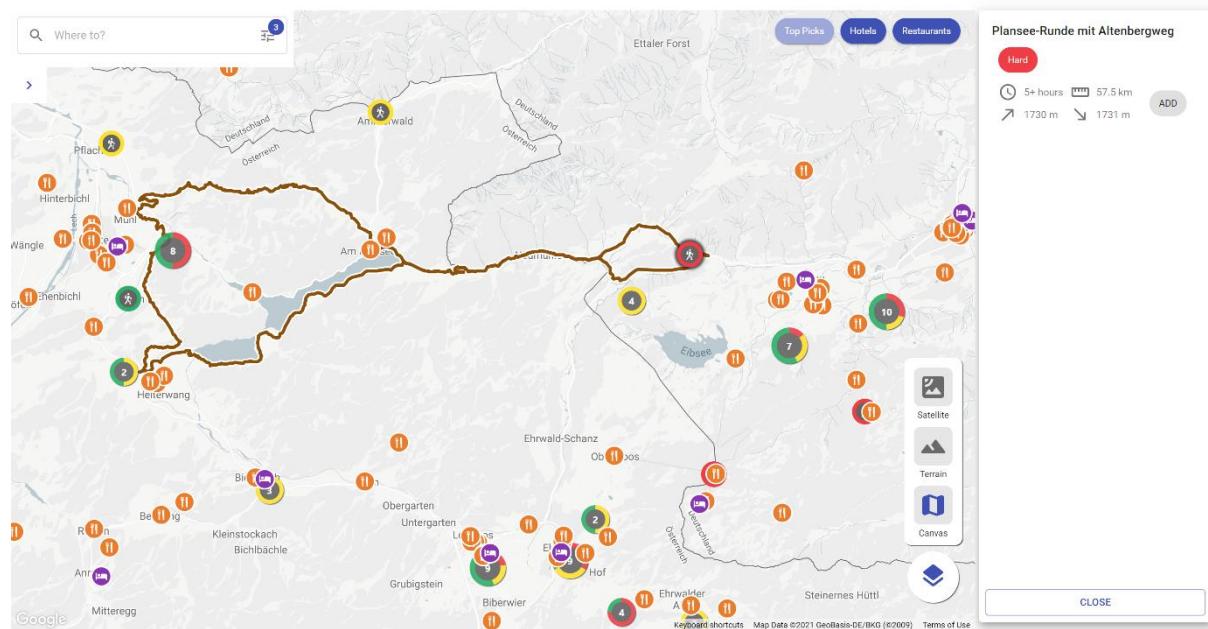
4.2.3 Please rank the basemaps based on how the regions look on the basemaps, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

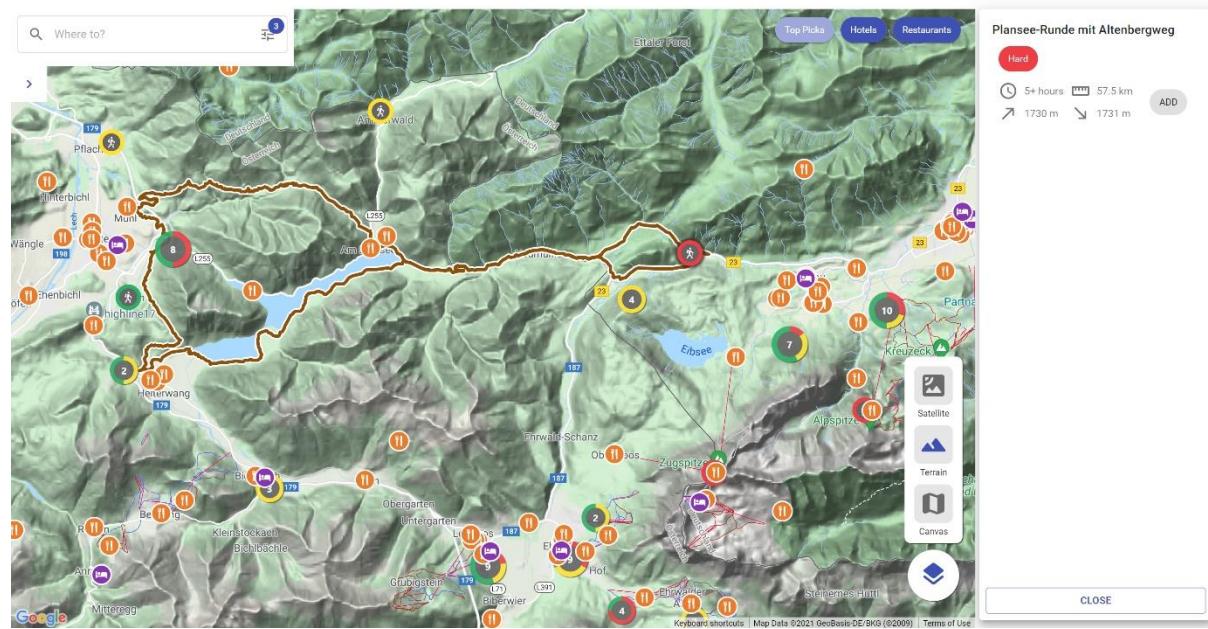
4.2.4 Please provide any additional comments if you like.

4.3 Spot zoom level

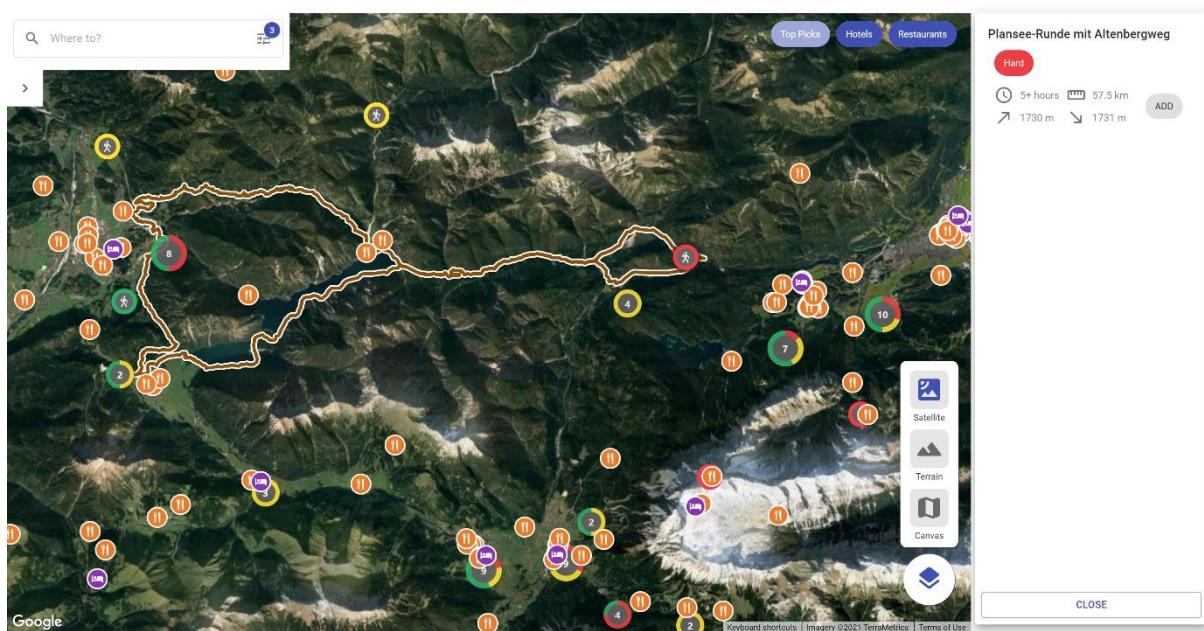
Canvas



Terrain



Satellite



4.3.1 Please rank the basemaps based on the look and feel, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

4.3.2 Please rank the basemaps based on how the markers and the clusters look on top of the basemaps, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

4.3.3 Please, rank the basemaps based on how the hiking trail looks on the basemaps, with 1 being the best.

- Canvas _____
- Terrain _____
- Satellite _____

4.3.4 Please provide any additional comments if you like.

Section 5. Summary

5.1 Please, rate the following statement: I think the previously shown visualizations of the web app prototype could help me to make decisions when planning a hiking trip.

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

5.2 Please, rate the following statement: I think such a web application could be useful for planning a trip for other outdoor activities (skiing, climbing, surfing, etc.).

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

5.3 Please provide final comments if you like.

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