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Introducing a Mobile Application with Suitable Hiking Routes Created Using Geographic Information System to Promote Hiking Tourism: The Case of Horton Plains National Park, Sri Lanka

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Abstract:- This study presents a robust methodology for discovering and classifying novel hiking trails within mountainous terrains, which are subsequently ranked based on their suitability for hiking and their difficulty level. The identified routes are then introduced to the broader hiking community through the innovative use of a mobile application. The ultimate objective of this research is to bolster hiking tourism. To validate the methodology, a real-world experiment was conducted in Horton Plains National Park (HPNP) located in Sri Lanka. An impressive number of 60 distinct trails were successfully identified within HPNP's terrain, with each trail's suitability and difficulty meticulously calculated. The study revealed that among the 60 trails uncovered, 12 pose moderate challenges to hikers, while the remaining 48 are characterized by low difficulty. We refined the selection by choosing five trails from each difficulty level based on the highest suitability scores. In collaboration with domain experts, we developed a user-friendly mobile application to showcase the selected trails. These trails were stored in the Google My Maps platform, which was integrated with our mobile application, facilitating seamless access of trail data. Additionally, this integration enables the usage of the Google Maps application for offline navigation along the trails, utilizing GPS technology for accurate positioning. This research has accomplished its intended goal, evidenced by the successful identification of new hiking routes within Horton Plains National Park using Geographical Information System (GIS) technology, and the creation of a mobile application featuring the most suitable hiking trails.

Keywords:- *Hiking Trails; Hiking Tourism; GIS; Trail Recommendation System.*

I. INTRODUCTION

Nature-based tourism has become the most popular and commercially significant type worldwide. Tourists participate in nature-based activities, particularly in protected areas and other natural sites where nature draws significant tourism Sri Lanka is a popular hiking destination due to its abundant biodiversity and spectacular views of mountain ranges such as the Knuckles Range, Horton Plains, Ella Rock, and the famous Little Adams's Peak (Daminda Sumanapala, 2020).

Finding a secure and comfortable way to a camping site or a mountain peak in Sri Lanka has been challenging. Due to the low signal strength in hilly areas, an offline mapping application is required to locate the desired path. The Global Positioning System (GPS)technology can track a user's location. A mobile app with these characteristics could inspire hikers from all over the world to visit Sri Lanka.

A geographic Information System (GIS) is a database navigation and analysis system for sophisticated and dynamic terrain-based databases (D.Koller, 1995). When it comes to constructing hiking routes, GIS technology is a significant concern. It would assist the forest authority in identifying and recommending new paths across protected areas and ensuring the site's protection. This strategy relieves overcrowding in existing hiking locations while promoting new trekking destinations (Vias, 2014).

This study aims to find feasible and safe hiking paths in Sri Lanka's Horton Plains National Park. Kirigalpoththa and Agrabopath Kanda are two popular hiking spots in Horton Plains, but only one trail exists. Authorities will be encouraged to promote hiking tourism in Sri Lanka with a mobile application that includes new routes and destinations. As a side effect, communities around hiking spots will benefit economically due to the influx of tourists.

II. LITERATURE REVIEW

Hiking, particularly thru-hiking, is growing in popularity, evidenced by the increased footfall on trails like the Appalachian and Pacific Crest. Although boosting local economies and fostering personal growth, this increase also leads to trail degradation, disrupting wildlife and affecting the hiker experience. Managing trail use, addressing hiker safety, and enhancing trail maintenance while sustaining the positive effects of this recreational activity, presents a significant challenge for trail authorities and local communities. Thru-hiking is growing in popularity yet remains relatively unstudied, especially regarding the challenges and social aspects of the experience. Researchers examine the thru-hiker expertise on the Pacific Northwest National Scenic Trail using semi-structured interviews, assessing how pre-hike expectations and prior experiences impact the hike and subsequent return to everyday life. The findings can guide trail management strategies, balancing resource preservation with hiker experience (Cole, 2018).

The other study explores the physical and mental benefits of hiking as a tourist activity, using a survey conducted at different hiking sites in southern Norway. The results indicate that physical benefits are highly valued, though the mental benefits are perceived as most important. However, these mental benefits were rated lower in experience, suggesting the need for further research and practice to enhance hiking tourism's psychological rewards (Prebensen, 2015).

Leisure time is increasingly valued in society, with physical activity being a popular choice for its entertainment and positive impact on our well-being. Hiking, mainly walking, is a widely accessible form of physical activity that promotes spiritual, physical, and mental health. It is a popular tourism product worldwide, exploring natural beauty and landmarks. The researcher examines mountain hikers' motivations and decision-making processes, including terrain, difficulty level, and environmental attractiveness. The findings contribute to developing sustainable and appealing tourism products for the territory (Mario Molokac, 2022).

Adventure activities, particularly hiking, are crucial in global tourism destinations. Research focuses on exploring the motivations and experiences of mountain hikers in the context of soft adventure. A mixed-method approach combining surveys and interviews identified six factors (relaxation, socializing, discovery, recognition, etc.) influencing hiking satisfaction. Moreover, it highlights the recreational meaning of mountain hiking and offers valuable insights for developing customized tourism products (Peters, 2021).

Using the Analytic Hierarchy Process, a study assessed the suitability of forest roads as hiking routes in Hatila Valley National Park, Turkey. Parameters; slope, altitude, and landscape quality were evaluated, with the slope being the most critical. Forest roads were deemed suitable for hiking without harming nature. Future research could explore conservation-use balance, and parameter weighting, refine the Hiking Suitability Index, conduct comparative studies, and assess environmental impacts. The study contributes to planning recreational areas and provides insights into using forest roads for hiking in protected areas (Hilal Turgut, 2020).

The research focuses on the role of tourists' perceived value in hiking tourism and its impact on their quality of life. It examines the connection between tourists' engagement, connections with nature, and their perceived value in the context of hiking tourism. The study was conducted in the Astraka Refuge in Greece, collecting data from hikers. The results show that tourists' perceived value influences their engagement in hiking tourism and connections with nature, improving their quality of life. The research contributes to understanding the quality of life in hiking tourism and provides suggestions for destination marketers to promote hiking tourism (Seonjeong Ally Lee, 2018).

Terrain Complexity Assessment (TCA) is crucial for identifying geological features, extracting hydrological information, and utilizing land resources. Existing TCA models have limitations, such as inadequate consideration of terrain factors and difficulty quantifying terrain complexity. A TCA model based on Principal Component Analysis (PCA) and Geographic Information System (GIS) is proposed to overcome these issues. The model is applied to Jiangxi province in China, extracting ten terrain factors using a digital elevation model (DEM) and conducting a comprehensive evaluation to obtain terrain complexity indexes and a terrain complexity map. The results demonstrate that the PCA method provides a more comprehensive and accurate representation of terrain complexity than other methods (Faming Huang, 2020).

The research presents a recommendation system for hiking routes in a protected area. The system suggests routes based on hikers' preferences and the needs of protected area managers, aiming to manage congestion and promote environmental education. The system utilizes network analysis, multi-criteria decision analysis, and geographic information systems. Tested in Sierra de las Nieves Nature Reserve, 34% of the 182 recommended routes were considered viable, with a great difficulty level matching the mountainous nature of the area (Jesus Vias, 2018).

The research introduces a semantic model for representing the difficulty of hiking trails using Semantic Web ontologies. The model considers factors such as effort, technique, and risk to assess trial difficulties comprehensively. By linking these aspects with the geometry information of a hiking trail, the model enables the development of location-based services for personalized trail recommendations. The paper discusses the principles of the model and its potential use in creating knowledge graphs for trail recommendations.

The proposed model addresses the need for accurate trail characterization and personalized recommendations for hikers of varying capabilities and preferences (Jean-Paul Calbimonte, 2020).

The researchers interviewed Appalachian Trail (AT) hikers to examine the outcomes and values associated with hiking. They found that values such as self-fulfillment, self-reliance, fun and enjoyment of life, and warm relationships with others emerged from the interviews. Strong links were found between hiking, exercise, health, and fun and enjoyment of life. The study suggests that these findings can be used by professionals working with AT or other hiking trails to promote the appropriate use of natural resources. The research highlights the potential benefits of hiking, including physical activity and a connection with nature (Eddie Hill, 2009).

The Horton Plain National Park in Sri Lanka is a significant area for geo-tourism due to its diverse geological and geomorphological features. With high scientific value (57.36%) and moderate additional value (39.62%), it offers attractions like peaks, escarpments, and waterfalls. The park is rich in endemic plant and animal species, making it ecologically important. Interpretive centers, trails, and web-based maps are recommended to promote sustainable geo-tourism. Overall, Horton Plain National Park is ideal for appreciating its unique geodiversity (Edirisooriya K. V. D, 2018).

A strategic plan is needed to transform Sri Lanka's tourism industry, improve competitiveness, and achieve sustainable development goals. The current tourism sector lacks diversity and value-added opportunities, limiting its potential. By expanding markets, improving the visitor experience, and adding value to products and services, Sri Lanka can disperse visitors across the island and enhance the overall tourism experience. Involving communities, ensuring a skilled workforce, and coordinating government efforts are crucial for success. The plan will position Sri Lanka as a world-class and diverse tourism destination by 2025 (Tourism, 2021).

Recommender systems (RS) have been widely used in reducing information overload and providing travel recommendations to tourists. Mobile RSs for tourism offer personalized and context-aware services, enriching tourist experiences with multimedia content, peer reviews, and location-based recommendations. This article reviews the state-of-the-art mobile tourism RSs, classifies them based on architecture and user involvement, and discusses the challenges and future research directions. Popular web-based e-tourism RSs like TripAdvisor and DieToRecs are examined. Mobile RSs offer attractions and tourist services recommendations, considering user preferences, location, time, and social context (Damianos Gavalas, 2014).

With the "Semantic Data Models for Hiking Trail Difficulty Assessment" research study, Calbimonte et al. (2020) proposed a hiking trail characterization approach based on the trail's difficulty. One reason for the complication is that the degree of sound judgment required by the challenge is linked to the hiker's comparative opinion. Everyone believes in work based on their previous adventures, experience, health, and age. A rough mountain trail, for example, may be demanding for a young climber but extremely difficult for an older climber. Various symmetrical views can also be used to identify issues. A flyover, for example, may not be linked to physical hardship. However, if the bridge is built across a deep gorge, it may trigger dizziness or other mental effects in some explorers. Similarly, a difficult path may necessitate an unusual procedure level, even if it is not particularly difficult.

The Swiss climbing method is represented in data available near tourism industry offices and public organizations, which includes some data comparable to trail toil. On the other hand, this data contains critical information such as the growth in apparent difficulty, distance, and overall assessed time.

In the journal article "Regional Terrain Complexity Assessment Based on Principal Component Analysis and Geographic Information System: A Case of Jiangxi Province, China," Huang et al. (2020) suggested a regional terrain complexity assessment (TCA) method. It is necessary for identifying geological features and can also be used to recommend hiking trails. The foundations of this model are geographic information system (GIS) and principal component analysis (PCA). The researchers used the Chinese province of Jiangxi as a case study. They then used geographic information system software's digital elevation model (DEM) approach to derive eleven terrain characteristics. They identify superfluous terrain component information and compress the data using principal component analysis (PCA). The compressed terrain components can be thoroughly assessed to produce a terrain complexity map (TCM) and quantitative terrain complexity indices.

Vías et al. (2018) proposed the most effective method for determining hiking routes. They mostly used multi-criteria decision analysis, network analysis, and geographic information systems (GIS) to find optimal hiking routes. The technique of the recommendation system is summarized in Figure 2. This research records the relevant data for each trail segment using a geographic information system. A multi-criteria assessment selects the best trial segment for the proposed path. Numerous elements are examined for the assessment, including physical obstacles, terrain suitability, and management. The network analysis utilizing the A* algorithm finds the starting point and endpoint linking route.

III. METHODOLOGY

A. *Identifying Hiking Trails*

There is no specific approach for identifying hiking routes documented in the literature. Existing hiking trails in the online databases are discoveries of people by experience. In this study, AllTrails.com referred to 50 current trails from India, Nepal, New Zealand, and Sweden to reveal new hiking trails.

During the analysis of existing trails, two fundamental characteristics were discovered. The routes were examined considering the contour lines on the map. The following two features could be seen on most of the trails.

- On hilly terrain, the trails follow either a ridgeline or a valley line
- On flat terrain or slope, the trails follow contour lines

B. *System Criteria for Recommending Routes*

According to Vías et al. (2018), the routes suggested by a recommendation system must meet several criteria and be economically viable. A two-stage approach ensures this:

- Assess the route's suitability by linking trail sections that enhance environmental qualities using a variety of factors
- Assess the route's viability in terms of the time it will take to complete it, as well as its difficulty

➢ *Evaluating The Routes' Suitability*

The following factors were used to assess route suitability. Criteria A is critical for users to choose the preferred trail. Criteria B and C are based on user preferences since they use natural features most appealing to a tourist hiker. Criteria D is critical for the park's administration because they employ these tracks to avoid crowding.

- Criteria A: Selection of the route's start and finish points
- Criteria B: Suitability of the route
- Criteria C: The route's circularity
- Criteria D: Whether the trail section is included in the public use program

The possible starting points must provide quick and easy access to the hiking trail for criterion A. Greater weight was given to points close to an urban area, a public use program facility, a restaurant, or a car parking area. Endpoints represent natural area landmarks (such as a peak, a monument, a unique tree, a waterfall, etc.). However, greater weight was given to those that show undiscovered areas with significant environmental values.

Regarding criterion B, this study assessed the suitability of trail sections using the methodology proposed by Vías and Ocana (2014). This method considers the suitability of every route section of the system based on the following aspects.

- The section's "hikability" determines whether the trails are naturally suitable for hiking. This factor considers the following parameters:

✓ trail type (this refers to the type of trail that hikers prefer)
✓ slope (the average slope of the trail sections)
✓ slope obstacle (the volume of hiking distance that a person must cover in each section with a consistent steep slope)

- To examine the territory's scenery or ecological value, or attractiveness. Biological or ecological variables, as well as environmental, cultural, or historical landmarks, contributed to this component
- The land management in this area, which included public space design based on the level of protection granted to various portions of the selected location

Criterion C considers how much of the route distance must be repeated and whether the trail is essentially circular or straight. The second situation (where the same path must be travelled to return to the initial point) is seen as less ideal than one that starts and ends at the exact location without traveling through the same portions again.

Criterion D discourages a path that incorporates sections currently available on existing trails. This criterion aims to reduce overcrowding on current routes and facilities while also increasing the amount of land used for hiking. As a result, the more trail segments used in the path that is not part of the existing trail network, the more suited the trail is.

All criteria have been normalized, and their scores are in the range [0,1]. The maximum score possible with this normalization is 10.

Route suitability = $(4 \times A) + (3 \times B) + (2 \times C) + (1 \times D)$

➢ *Evaluating The Routes' Difficulty*

Each proposed route's viability was determined by its difficulty and expected duration. The viability was determined using the following method presented by Colorado (2001), which is based on the number of hours required to complete a route, the length of the trail, the total elevation gain, and the hiker's expected average speed.

The route's length was calculated using Google Earth Pro software. The elevation profile from Google Earth software was used to obtain the height gain.

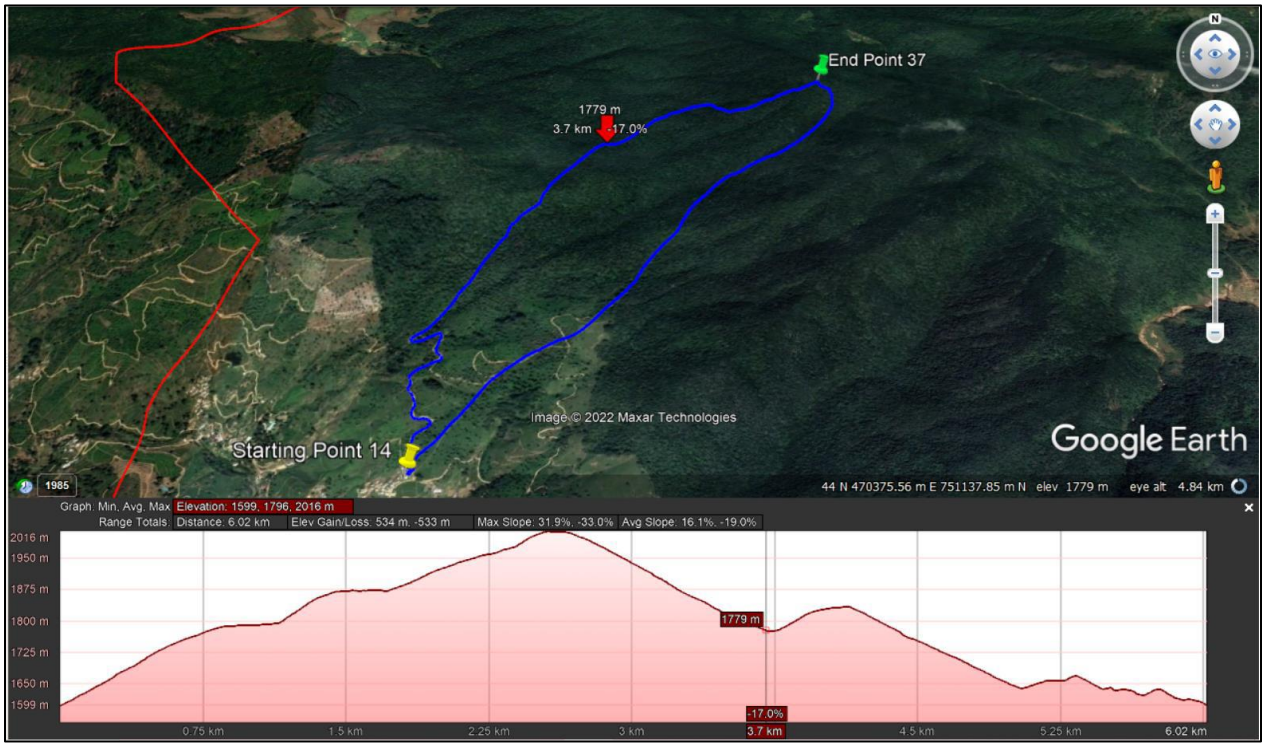

Fig 1: Elevation profile of Google Earth Pro Software was Used to Take the Details of the Trails

A tourist hiker is the prototype user. According to Bohannon and Andrews (2011), a hiker's average speed is between 2 and 6 km/h. A mid-level or tourist hiker has a horizontal speed of 4 km/h and a vertical speed of 400 m/h (values between 2 and 6 km/h for horizontal distance and 0–1000 m/h for vertical step).

The following calculation was used to calculate the total time required to finish the route based on these speeds (Vías et al., 2018):

- $If\ T_V > T_H \rightarrow Time = T_V + (T_H/2)$
- $If\ T_H > T_V \rightarrow Time = T_H + (T_V/2)$

The route's projected time duration is called Time. T_H (horizontal time) is the time it takes to go a specific distance, whereas T_V (vertical time) is the amount of time it takes to achieve a specific height difference.

Table 1: Route's Viability and Degrees of Difficulty, based on its Expected Duration

Time (h)	Difficulty
< 3	Low
3 – 6	Moderate
6 – 9	High
9 >	Extreme (not viable)

C. Mobile Application Development

Mobile application development fulfils this research's second objective: developing a mobile application that consists of the hiking trails of the Horton Plains National Park. Establishing a mobile app is essential because this research focuses on identifying a strategy to support Sri Lankan tourism. The mobile app development process comprises a few stages, including the user interface design, hiring a mobile app developer to build the app, and inserting the research findings into the application.

➢ *User Interface Design*

The mobile app's user interface is vital since the research findings must be understandable. The mobile app consists of the most suitable routes found in this study. The routes will be sorted in descending order according to the suitability score. The routes must be divided into categories based on their difficulty, and the location of the routes must be apparent to the user via a map image. The route's details will include the trail's length, elevation gain, estimated time to complete the route, starting location, and the suitability score. These details

will assist the user in deciding which option to take. The two arrows at the bottom will guide the user through the available trails.

Fig 2: User Interface Design

➢ *Developing the Mobile Application*

The objective of the mobile app would be to show users the hiking trails with their characteristics clearly. Once the user chooses a hiking trail, the "Go to Map" button takes them to the Google Maps application. All the trails are stored at the https://mymaps.google.com. The "Go to Map" button is linked to the stored trail inside google storage. The user can use the Google Maps application to navigate through the trail. Google Maps has an offline map feature incorporated into the app. The user must first download the Horton Plains National Park offline map. This step requires mobile data or wifi. Then the user can use the hiking trail after turning on GPS on the phone without utilizing mobile data or wifi.

IV. RESULTS AND ANALYSIS

A. Assessing the Suitability of the Route

In section *User Interface Design*, the methodology to find the suitability of a route is stated. The graph below summarizes the results of suitability for all the routes. The suitability scores are presented as a percentage.

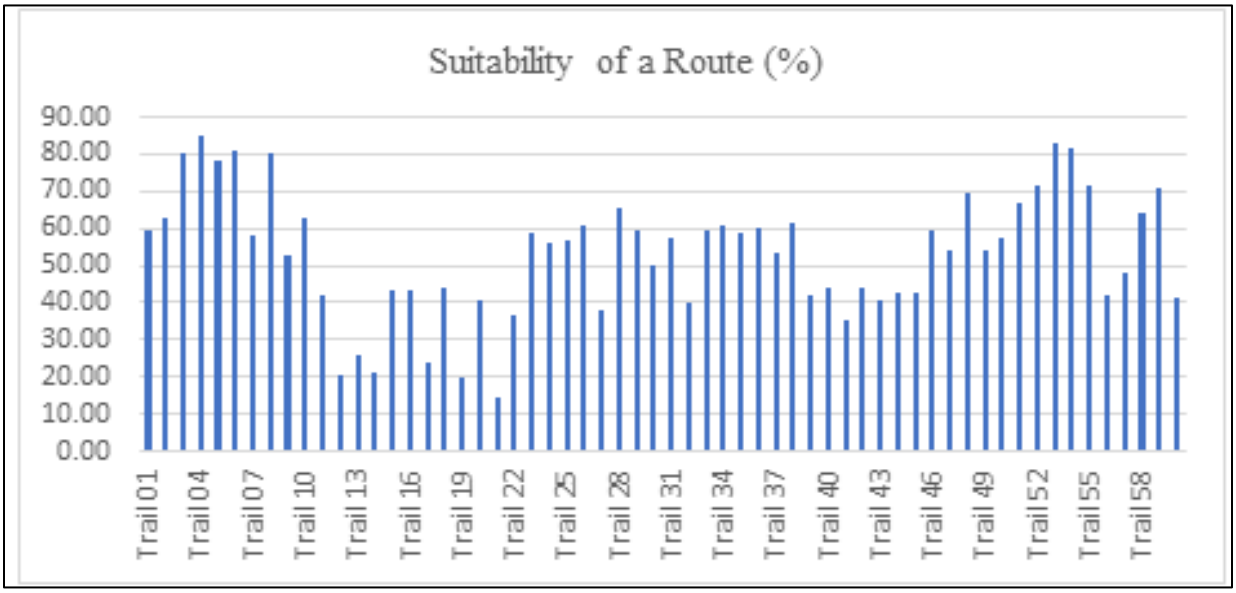

Fig 3: Suitability of the routes

Out of 60 trails, there are five trails with more than 80% suitability score, 14 trails with a score between 80 – 60%, 30 trails with a score between 60 – 40%, and 10 trails with less than that 40%.

B. Assessing the Difficulty of the Route

Following the methodology in section 3.2.2., the results of the trail difficulties are summarized as follows.

Table 2: Summary of Difficulties of Trails

Difficulty	Average Values of the Routes			No. of Routes
	Length (km)	Total Height Gain (m)	Time (h)	
High	0	0	0	0
Moderate	9.87	869.83	3.71	12
Low	5.48	424.77	1.95	48

All identified trails are viable according to the results of trail difficulties. That means there are no trails that are longer than 9 hours. In addition, there is no single track in the high difficulty range. Twelve routes are moderately challenging, and the remainder of the trails (48) is low in difficulty.

Moderately challenging routes have an average length of 9.87 km, an average height gain of 869.83 m, and an average duration of 3.71 hours. Low-difficulty trails have an average length of 5.48 km, an average height gain of 424.77 m, and an average duration of 1.95 hours.

Fig 1: Starting interface of the app

C. Mobile Application Development

➢ *Choosing The Most Suitable Hiking Trails To Include In The Mobile Application*

Ten of the most suitable trails were selected to insert into the mobile application. Five trails from each difficulty group were selected, considering the suitability of the trails. Suitability is represented as a percentage in the table below. Selected trails are as follows.

Table 3: Selected Trails for the Mobile App

Trail Name	Suitability (%)	Time Duration	Difficulty
Trail 04	84.90	2.65	Low
Trail 06	81.27	2.80	
Trail 08	80.20	1.14	
Trail 03	80.12	2.74	
Trail 05	78.44	2.43	
Trail 53	82.74	3.34	Moderate
Trail 54	81.54	4.04	
Trail 59	70.61	4.58	
Trail 51	66.72	3.48	
Trail 58	63.90	4.15	

➢ *Finalization of Mobile Application*

A mobile app developer was hired to develop this app for this study. All the required details were provided to the developer to create the app. The developer built the mobile application to match the provided user interface design in figure 4. The app is named "Map Navigator." Figure 6 shows the starting interface of the app. In this case, the user must select the Horton Plains button to proceed.

After clicking the "Horton Plains," the user is directed to an interface containing all the trail details. First, an image of the route indicates the direction to travel. Then the difficulty of the route is shown on a coloured background. The detail section includes the trail's length, elevation gain, estimated time to complete the route, starting location, and suitability score. These details will assist the user in deciding which option to take. The user can click the "Go to Map" button to open the route in the Google Maps application. The two arrows at the bottom will guide the user through the available trails. Figure 7 shows screenshots of all the ten trails included in the mobile application.

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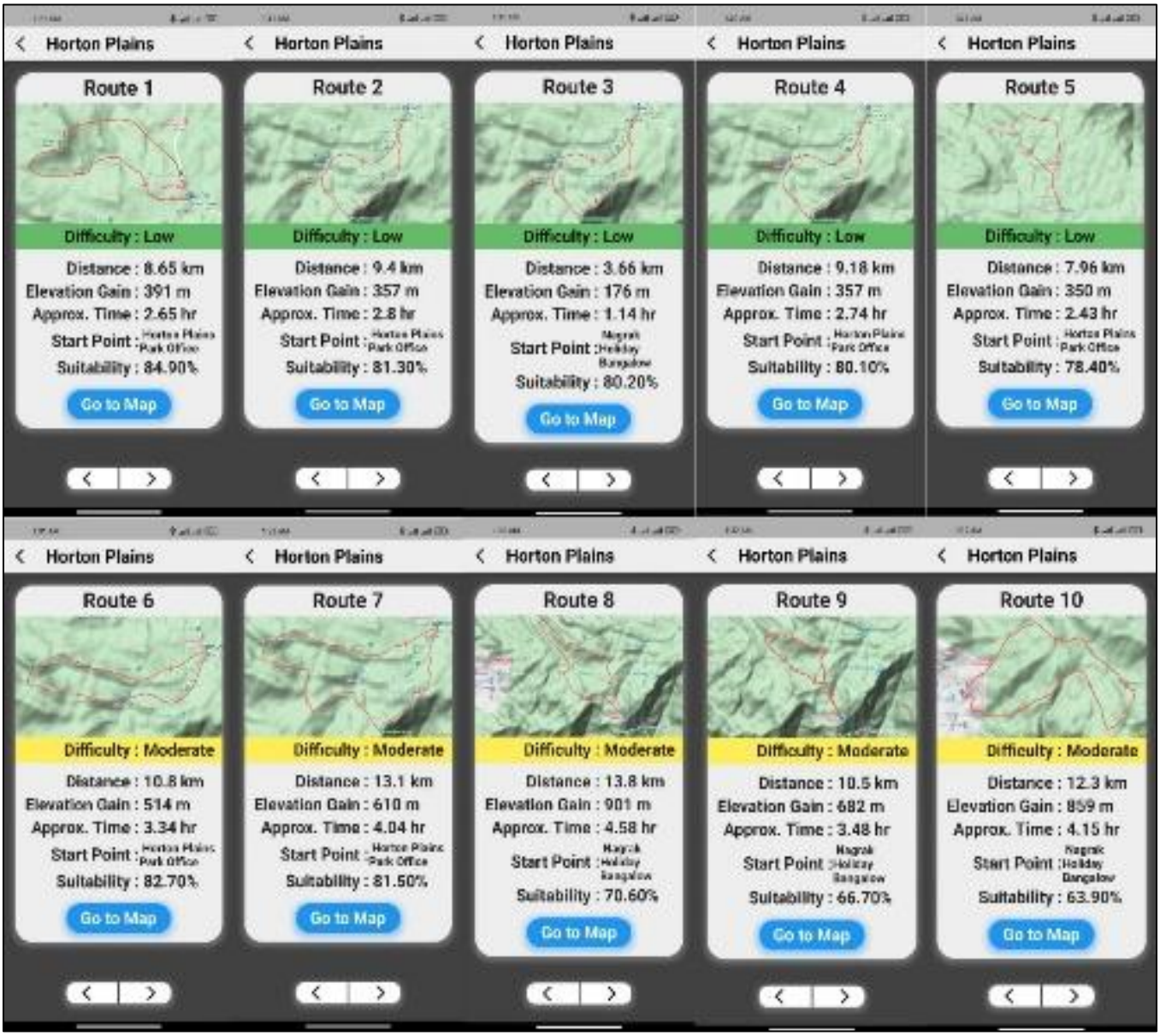

Fig 2: Screenshots of the Mobile Application

The process of the navigation along trails is tested using a test trail. This test trail goes along the John Rodrigo Mawatha, Katubedda, Sri Lanka, and a blue dot indicate the user's real-time location on the map. Figure 8 shows the GPS location testing along the test trail. The mobile application developed for this study can be downloaded via this link. It will operate on any mobile device with an Android operating system.

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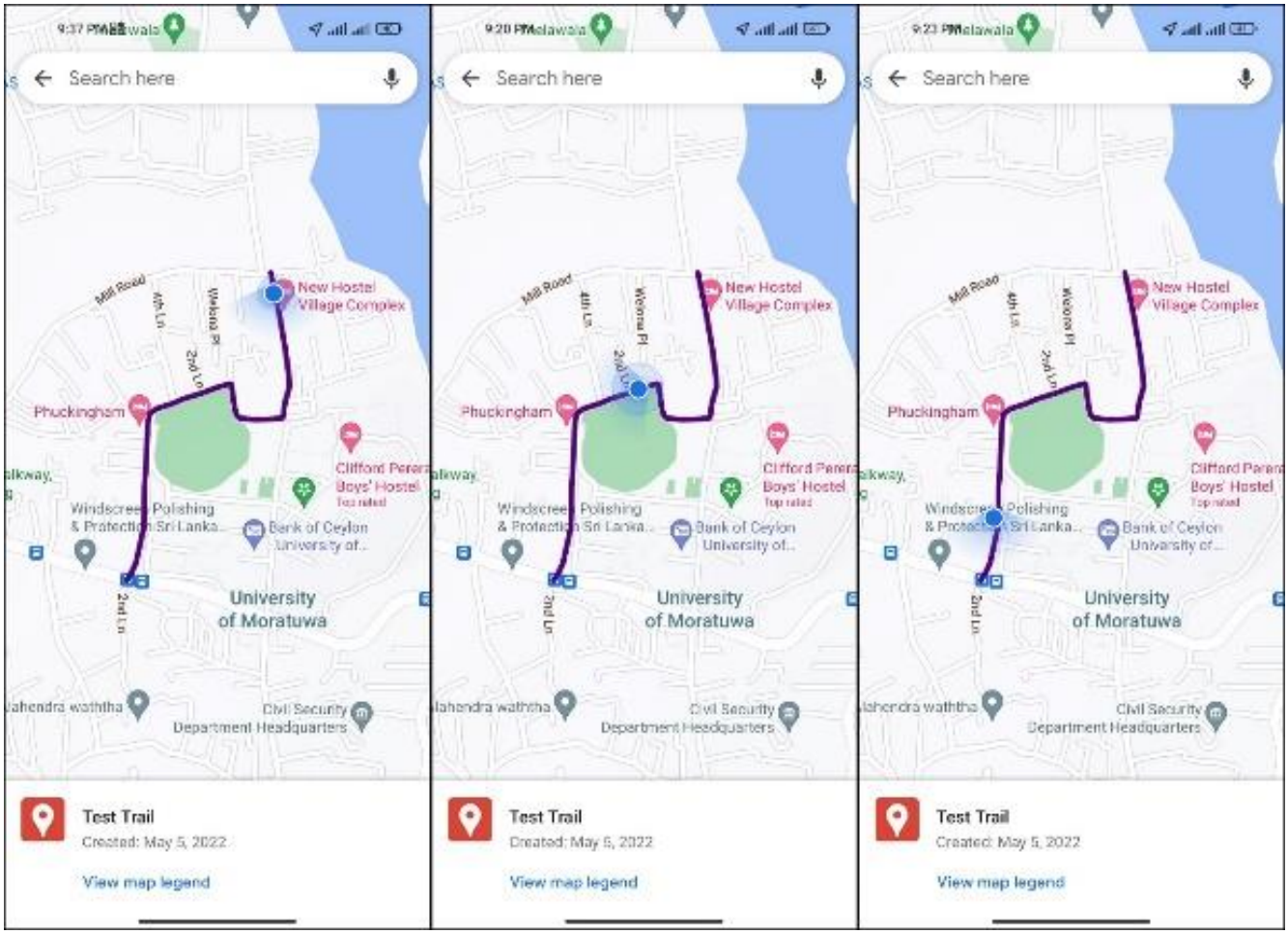

Fig 3: Navigating along the Test Trail using GPS

V. CONCLUSION

Hiking tourism is one of the fastest-growing forms of tourism globally. The number of hikers worldwide is estimated to be over 118.26 million, with global market size of $12.24 billion (Farad et al., 2017). This is an excellent opportunity for local governments to attract more tourists and bring them into their communities by providing hiking routes. The problem is that most tourists do not know what hiking routes are available in local areas, making it difficult for them to plan their trips.

A mobile application with hiking routes would solve this problem by allowing people to find out about the hiking trails near them without asking or searching online. There have been many types of research to find new hiking routes to promote hiking-related tourism. However, in Sri Lanka, there have not been such types of analysis to benefit from it. This research has shown a method to find and analyze hiking trails and utilize them on a mobile application.

The methodology of the hiking trail recommendation system and analysis consists of 3 steps. Identifying hiking trails, assessing the suitability of the trails, and assessing the difficulty of the trails are the critical steps in recommending hiking trails. The following essential step is to present the identified hiking trails with a mobile application. Google Maps application has been utilized to navigate along the hiking trails. The Google Maps offline map feature has been used to operate the trail in an area without mobile data coverage.

In conclusion, the methodology proposed in this research to find hiking trails can be applied to any mountain, hill, or peak in Sri Lanka. The type of mobile application developed in this study can be used to guide the tourists in selecting their desired destination. Since the application will be available online, anyone can get an idea about the hiking destinations in Sri Lanka before coming. Hence, it will support the Sri Lankan tourism industry and, eventually, the country's economy.

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