Design of a tracking bracelet for high-risk explorations in remote areas of Colombia

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Abstract– Colombia has experienced a notable increase in tourism in recent years, reflected in a significant increase in visitors, especially foreign tourists. However, many of the country's tourist areas present risks and challenges that can compromise the safety of visitors, especially in remote and little-explored places such as the Tatacoa Desert, the Sierra Nevada del Cocuy, the Alta Guajira, and the Amazon. In this context, this paper presents a comprehensive approach to improving the safety of tourists in these areas by implementing innovative technology. High-risk areas are characterized, and technological alternatives are proposed, culminating in the design of a tracking bracelet, "Wilbone". This bracelet protects 75% of visitors in dangerous areas, promoting safe and sustainable tourism. In addition, the economic feasibility of producing the bracelet is analyzed. In summary, this study highlights the importance of ensuring safety in tourism for sustainable development and the well-being of visitors and local communities.

Keywords-- Tracking, Tourism, technology, GPS, GSM/GPRS.

I. INTRODUCTION

The tourism industry in Colombia has experienced remarkable growth in recent years, reflected in impressive visitor numbers. According to DANE data, in 2022 the country received more than 4 million tourists, with more than 3 million non-resident foreigners, representing an increase of 239.1% over 2020. This substantial increase underscores Colombia's attractiveness and popularity as a tourist destination at the international level.

During the period from January to July 2023, a total of 947,062 visitors were registered, marking an increase of 13.1% compared to the same period of the previous year. Destinations such as Corales del Rosario, Tayrona, El Cocuy, Farallones de Cali, and Flamencos stand out among the most visited. In addition, the number of employees in tourism activities in 2022 reached 709,263, evidencing an increase of 61.1% compared to the previous year, according to statistics.

These employees represented approximately 3.2% of the total number of employees in the same period [1]. Likewise, domestic tourism among Colombian residents has experienced significant growth, with an average of 10.5% dedicated to excursionism activities in 2022, in contrast to the 6.8% recorded in 2020.

Such an increase in tourism activities leads to the need for travel agencies and experiences to seek new alternatives to maintain the attractiveness of their activities under the initiative to promote safety and have a greater response time, due to this emerged tools such as Garmin inReach Mini which allows the user to interact through text messages in areas that have no mobile networks, in addition to sending an SOS signal and keep track, this connectivity is maintained thanks to the Iridium satellite network [2], [3].

Somewear Global Hotspot also offers location tracking and weather forecasting services, offering greater control in the planning of experiences [4], [5]. Also, OceanSignal rescueME PLB1 has the functionality to send a rescue signal while its compact, lightweight, and waterproof design makes it useful for water activities in boats [6], [7].

Garmin GPSMAP 66i is an instrument that presents great versatility in large expeditions, in open spaces due to the presentation of topographic maps, Global Positioning System (GPS) navigation, and satellite communication [8], [9].

The McMurdo FastFind 220 device offers high location accuracy via GPS signal, a floatable design, and a long battery life [10], [11].

Using the above devices as a guide, we proposed the creation of a rescue bracelet with the ability to track location and add functions to measure the user's health, such as temperature and heart rate monitoring, to comply with the Sustainable Development Goals (SDGs) [12]:

1. Health and welfare (SDG 3).
2. Industry, Innovation, and Infrastructure (SDG 9).
3. Deduction of inequalities (SDG 10).
4. Sustainable cities and communities (SDG 11).

II. Methodology

Phase 1: Characterization of high-risk areas.

In the initial phase of the study, the geographic delimitation of the tourist areas in Colombia is carried out, as well as a detailed description of the tourist activities that take place in these regions. At the same time, an exhaustive evaluation is carried out to identify possible risks or hazards that could affect the safety of visitors to these places. This analysis includes factors such as adverse weather conditions, the presence of dangerous fauna, geological risks, or any other element that may represent a threat to the integrity of tourists, consider that these are limited to persons of legal age who are in good health, have the time and determination to carry out this activity, ranging from 18 to 44 years of age. The main objective of this stage is to provide a comprehensive understanding of the tourist areas in Colombia, highlighting both their attractions and possible associated risks, to inform and guide visitors adequately to ensure their safety and well-being during their stay in the country.

Phase 2: Description and identification of feasible technology alternatives.

A literature review is conducted covering a variety of resources, such as scientific articles, products, and technologies that operate without the need for internet connectivity and facilitate the efficient distribution of information. This analysis includes the exploration of tools and devices that allow accessing and sharing data independently of online connectivity, thus addressing the needs of those contexts where internet availability may be limited or unstable.

Phase 3: Proposal for the design of a bracelet-type tracker.

This characterization is important because it shows the type of interest that the end-user has and whether it presents an innovative advance compared to other devices. The characterization includes identifying the respondents' age range, gender, and main occupation at the time of the survey.

According to the survey conducted, taking a sample of 54 people, we can define that our target audience is young people between 18-24 years old and 25-34 years old, representing 36 and 11 young people with 67% and 20% of the total sample, being men who mainly associate this type of activities in a 2 to 1 concerning the female gender.

Young people, being more assertive to risk, are mostly university students (with 70% participation), while the rest are employees and independent professionals.

The follow-up of the results also helps to identify the familiarity with smart devices in general and if they participate in different ecotourism activities and outdoor activities, which can give an insight into the type of frequent activity in arid areas in Colombia and if the device can be suitable for the accompaniment of different users in their physical activities.

According to the respondents, 100% (54 people) have experience using technological means, being expected of this millennium, therefore the use of watches and cardiac devices is in their vocabulary, 26%(14) of them answered that they engage in outdoor activities while (occasionally 35%, rarely 35%, never 4%), taking these activities minimum once a year and maximum once a month, within these participants who do moderate exercise we can say that 57%(31 of the total) use a smartwatch, bracelet or APP to monitor their health in any day to day activity, the remaining 43% said they are interested in trying a smart device for the first time in their life that takes care of their physical integrity.

For the usability analysis and wearable style design comparison, the user is asked about the consideration of the usefulness of wearing a smart bracelet in areas where there is no traditional mobile network coverage, the most relevant features, and if they consider it important that a tour company monitors their location in real-time during excursions

18 young people (33% of the total) said that the most outstanding features of a device with GPS or satellite connectivity, are ease of use, health monitor (heart rate - BPM), water and dust resistance; other functions such as measurement of ambient temperature, long battery life and connection to a smartphone are qualities that they consider second-rate, ease of use leaves them in second need.

In addition, the voices of this survey said that sustainable tourism and companies that promote this type of high-risk activities should promote this type of personal devices, to anticipate risks in areas of difficult access, temperatures, road closures, and other unforeseen events.

Finally, for the functionality issue, it is analyzed if the environmental temperature measurement is considered useful to anticipate risks during excursions and if the practical design with a plastic strap and magnetic link is pleasant. This then gives a picture of the appearance of the device itself. Also, consider whether the touch screens are useful to the user when using the supplied tracking device and the economic proposition that may be in consideration to be paid for if it is an entrepreneur.

According to the proposal made to 54 out of 54 people said that this device must be durable, high-level drop proof, with good aesthetics and quality materials, and willing to withstand arid areas, high heat as well as high humidity. magnetic link and plastic strap, The price is an important detail so 20 young people aged 18 to 24 years (published average target) answered that they are willing to pay the 100 U.S. dollars.

Phase 4: Proposal for the design of a bracelet-type tracker.

Based on the findings obtained in the previous stages of the process, we proceed to implement the identified solutions for the development of a wristband that is economically accessible and has adequate features to collect data about the user. The main objective of this wristband is to provide relevant information about the person who wears it.

Fig. 1 Methodology flowchart.

Phase 1: Characterization of high-risk areas.

Visitors may face challenges related to difficult access and extreme geographic conditions, such as high temperatures, desert terrain, and tropical rainforests. More specifically, the trend is concentrated in the following remote areas that are high-risk within the country:

● Tatacoa Desert,
● The Sierra Nevada del Cocuy
● Alta Guajira
● Amazon

These places offer unique adventure experiences, but they can also expose tourists to risks associated with microscopic agents and changes in water properties and affectations caused by climate variations, which may require immediate medical attention and generate environmental insecurity [13].

This situation has a direct impact on the country's development and the quality of life of its citizens, as well as on its international positioning. Therefore, it highlights the importance of variables such as communication and real-time location to ensure the safety and physical integrity of tourists in these remote and challenging areas. Addressing these challenges is essential to promote sustainable tourism and economic development in Colombia.

Phase 2: Description and identification of feasible technology alternatives.

According to the review, the use of different technologies in devices that offer safety and reliability when making tours is evident. They are responsible for measuring different variables of the person, to safeguard his life and determine feasibility at the place of travel.

These alternatives include the following:

GPS: The Global Positioning System (GPS) is a satellite navigation system that allows determining the exact location of a receiver anywhere on the planet. It works through a network of satellites in orbit around the Earth that emit radio signals. These signals are received by GPS receivers on the Earth's surface, which calculate the receiver's position by triangulating signals from multiple satellites. GPS is used in a wide variety of applications, ranging from vehicle and maritime navigation to asset tracking, mapping, geolocation of mobile devices, and aiding in search and rescue operations, among others [14].

GSM: the global system for mobile communications. As its name indicates, the global system for mobile communications was born under the need to obtain a greater amplitude in the transfer of data, and to obtain improvements in the quality of sound, as well as replacing the analog systems before it, thanks
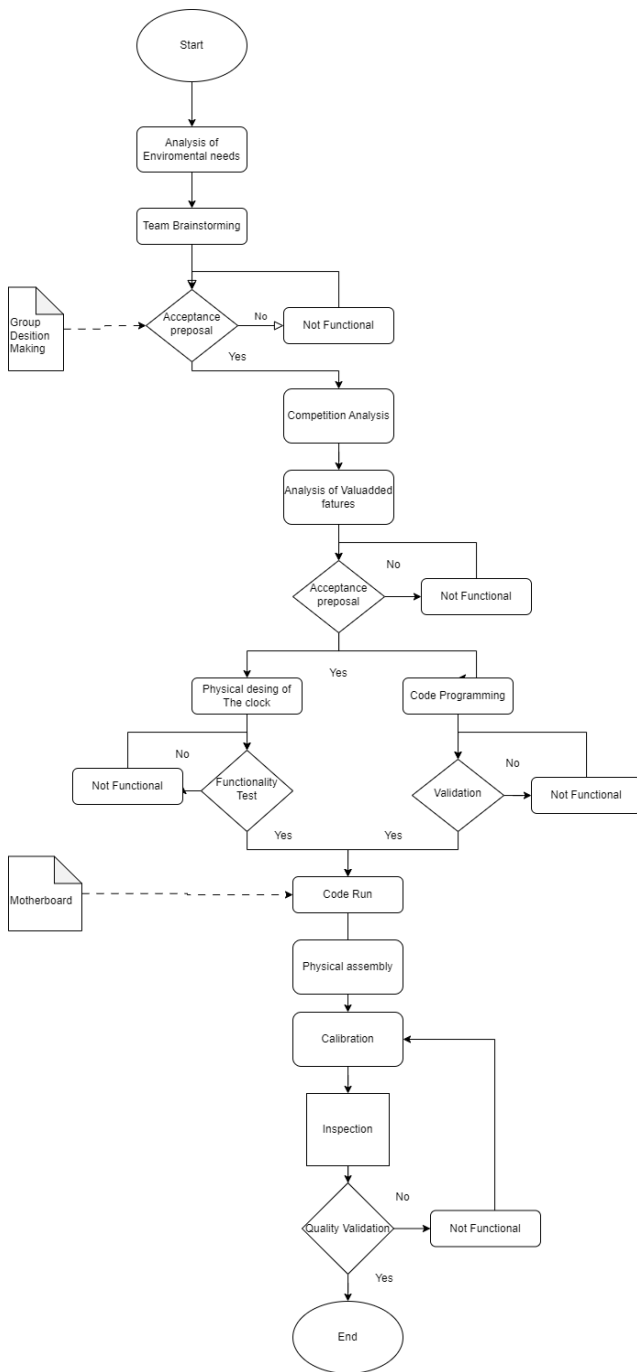
to these capabilities it works as a standard for cellular communications in sending text and voice between cell phones [15,16].

GPRS: General Packet Radio Service (GPRS) works as an extension of the global system for mobile communications, providing greater efficiency and speed in sending data by attaching data in small groups and sending them, thus optimizing the use of the network bandwidth and an extension of GSM that allows more efficient and faster data transmission. It uses packets of data instead of continuous connections, which means that data is divided into smaller packets and transmitted more efficiently, allowing higher transfer rates and more efficient use of network bandwidth [15,16].

LORA: It is a long-range, low-power wireless communication technology designed specifically for Internet of Things (IoT) and Machine-to-machine (M2M) applications. It uses radio frequency to transmit data over long distances with very low power consumption. It is based on spread spectrum modulation that allows transmission distances of up to several kilometers in dense urban environments and up to several kilometers in rural areas. This is achieved thanks to obstacle penetration capability and efficient power management, making it ideal for applications requiring long battery life and wide coverage [17].

MEMS. The MEMS are sound capture devices that use microfabrication technology to integrate mechanical and electronic components into a single microscale structure. These microphones are built using semiconductor manufacturing processes and consist of a sound-sensitive mechanical diaphragm and electronic circuitry to convert the vibrations of the diaphragm into electrical signals. MEMS technology enables the creation of extremely small, efficient, and cost-effective microphones, with miniaturization capabilities that make them ideal for applications in portable devices, smartphones, headphones, wearables, and in-vehicle audio systems, among others [18].

IoT: It is the interconnection of physical devices, objects, and systems over the internet, enabling the remote and automated collection and exchange of data. These devices, which can range from household appliances and vehicles to industrial sensors and medical devices, are equipped with sensors, software, and connectivity technology that allows them to interact with the physical environment and send data over a network [19], [20].

According to the technologies described above, a market study is carried out through a literature review and analysis of devices of different brands, to make a comparison to determine needs considering the contexts and offers of the different competing brands, for the column of the row of cost are mentioned in dollars (USD).

TABLE I

COMPARISON BETWEEN DIFFERENT MODELS ON THE MARKET, WITH SIMILAR FUNCTIONS AND WEARABLE DESIGN

Marca	Modelo	GPS	Conectividad	Monitoreo Salud	Otras Funciones	Costo (USD)
Souyie	Souyie Modern1	Si	Bluetooth 4.0	Ritmo Cardiaco	Brújula, diseño moderno y resistente, carga de 7 días, iOS y Android.	$99.99
Garmin	Instinct 2	Dual	Bluetooth, ANT+	Ritmo cardíaco, oxígeno, Temperatura, Estrés	Durabilidad extrema, navegación GPS avanzada, iOS y Android,	$441
LandAir Sea	LandAir Sea 54	Si	Wif	No	Rastreo GPS en tiempo real, resistente al agua, Duración de Batería duradera.	$29.95
Apple	Watch Series 8	Dual	Bluetooth 5.3 y wifi 4	ECG, oxígeno en sangre, caídas.	Integración profunda con iOS, bateria 18 a 36 horas	$399
Samsung	Galaxy Watch 6	Si	NFC,Bluetooth v5.3, WiFi	Composición corporal, ritmo cardíaco	Integración con Android/Samsung, batería 30 horas	$286.86
Coros	COROS APEX 2 PRO	Si	Bluetooth, WiFi.	Ritmo cardíaco, altitud	Batería de larga duración, métricas avanzadas, bateria 66 horas	$599.59

The feasibility of the market study on smartwatches for outdoor activities is based on its ability to provide up-to-date and accurate information on competition, technological trends, and specific market niches, thus allowing the validation of concepts and strategies. To be able to establish the technologies, design, and cost ratio for the proposed 'Wilbone' device.

Phase 3: Proposal for the design of a bracelet-type tracker.

In total, the analysis of the design and characterization of results was carried out with a total of 54 results. Regarding audience segmentation, the following results are obtained:

Age Range: The majority of participants are in the age range of 18 to 24 years, indicating a significant interest in this young population for the device. There is a notable presence of participants under the age of 18, suggesting that there is also interest among adolescents in the device. Although there is representation in the 25-34 and 35-44 age groups, their numbers are lower compared to the 18-24 age group.

Gender: The majority of participants are of male gender, which may reflect certain trends in survey participation or interest in this type of device.
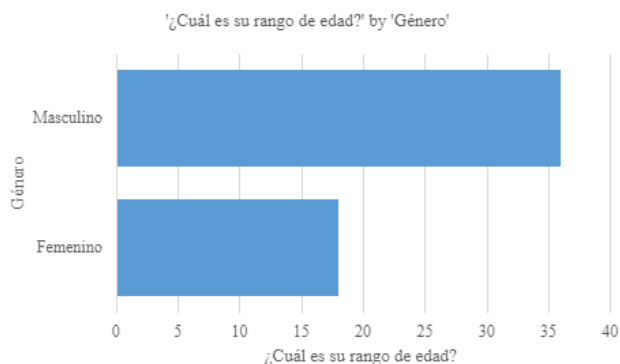
Fig. 2 Gender and age.

However, female representation is also significant, indicating that the device may be relevant to both genders.

Primary Occupation: The majority of participants are students, suggesting strong potential interest among this demographic. The presence of freelancers and employees is also notable, indicating that the device may have utility not only for students but also for those working in various fields. Regarding familiarity with smart devices and survey participants' relationship with outdoor activities, the following results are obtained.

Familiarity with smart devices: Most participants are familiar with the use of smart devices, either occasionally or frequently. This suggests that the target audience is comfortable with technology and is likely to be open to additional smart devices.

Participation in outdoor activities: There is a variety of responses regarding participation in outdoor activities. Some participants report participating regularly, while others participate less frequently. This indicates that interest in the device may vary depending on the level of participation in outdoor activities.

Current use of devices to monitor health or physical activity: Some participants report using devices to monitor their health or physical activity, such as apps on their phones or smartwatches. This shows that there is some interest in tracking

health and physical activity, which could increase receptivity to the proposed smart wristband.

Frequency of tours or excursions in desert or remote areas: Most participants report taking tours or excursions in desert or remote areas once a year or several times a year. This indicates that there is a potential demand for a device that provides communication in areas without traditional mobile network coverage.

Opinion on the usefulness of a smart wristband in areas without traditional mobile network coverage: The majority of participants consider a smart wristband that allows staying in touch in areas without traditional mobile network coverage to be useful. This suggests that there is a perceived need for this type of device in travel or adventure situations.
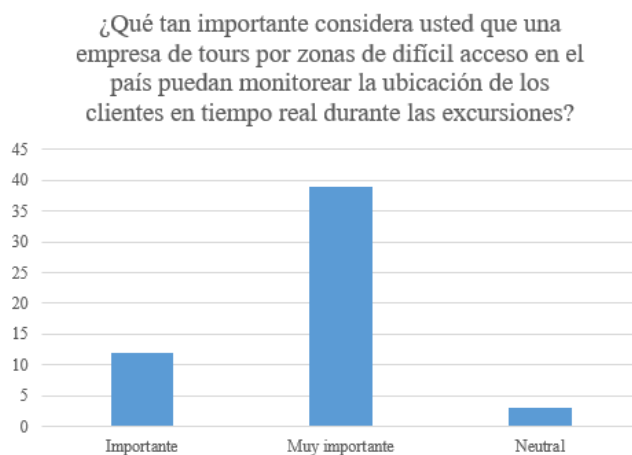

Fig. 3 Importance of rural location.

For the usability analysis and wearable style design comparison, the user is asked about the consideration of the usefulness of wearing a smart bracelet in areas where there is no traditional mobile network coverage, the features of most relevance, and whether they consider it important for a tour company to monitor their location in real-time during excursions.

GPS: GPS is a highly valued feature by most participants, as it allows for precise location during excursions.

Non-conventional connectivity (WiFi or cellular data): Non-conventional connectivity is also considered very important, suggesting that participants desire the ability to stay connected even in remote areas without traditional cellular coverage.

Health monitor (heart rate - BPM): Health monitoring, specifically heart rate, is another important feature for participants, indicating an interest in tracking health during outdoor activities.

Long battery life: Battery life is a key concern for participants, suggesting that they value devices that can operate for extended periods without needing to be recharged.

Water and dust resistance: Water and dust resistance is a very important feature, indicating that participants want durable devices that can withstand adverse conditions while hiking.

Ease of use: Although not mentioned in all responses, ease of use is also an important factor for some participants, suggesting that they value devices that are intuitive and easy to use.

Finally, for the functionality theme, the following results were obtained:

Ambient temperature measurement function: Most participants find this function useful for anticipating risks during excursions, indicating that they value the ability to monitor environmental conditions.

Magnetic link and plastic strap: Most participants seem to agree that they like this feature, suggesting that they prefer the convenience and practicality of a magnetic link and plastic strap.

Touchscreen: No direct responses were provided on the usefulness of the touchscreen, as some responses are blank. However, we can infer that a significant portion of participants value this feature, as it is common in modern devices and can facilitate visual monitoring.

Fig. 4 Cost.

Aesthetic design and durability: The vast majority of participants consider the smart wristband to be aesthetically pleasing and durable, suggesting that they value both the appearance and quality of the product.

In summary, participants appear to value the functional features, affordability, and durability of the smart wristband, indicating an interest in devices that offer useful functionalities for outdoor activities at a reasonable cost.

Phase 4: Proposal for the design of a bracelet-type tracker.

The integration of several modules in a compact smart wristband, such as GPS, LoRa, GSM/GPRS, MEMS microphone, and a microcontroller like ESP32, is a challenge that requires an optimal design [15], [21]. The first step is the creation of a printed circuit board (PCB), which accommodates all these components efficiently in the limited space of the wristband. This includes strategic placement of components to ensure optimal performance without interference. The connections and tracks on the PCB must be designed to interconnect the components effectively, considering strategies to make use of power optimization to maintain longer battery life. It is considering the integration of antennas for the communication modules.

The programming is done in Python language with an interface that displays data by data of those previously discussed. These data are received at the same time by the control panel that tracks the tours.
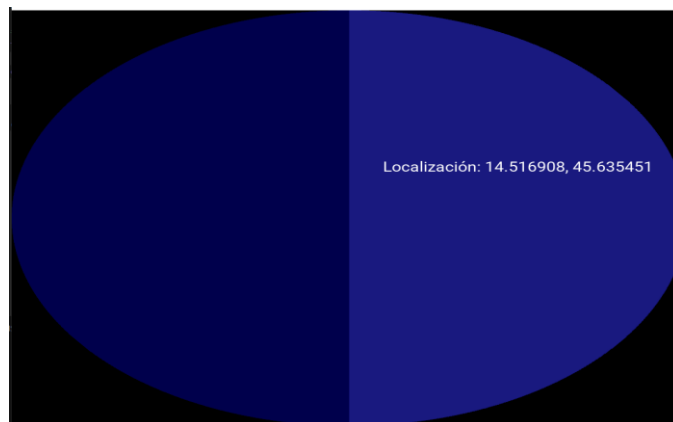

Fig. 5 Code.

Fig. 6 Simulation.

The circuit design includes all the modules listed above. This is incorporated and connected without the need for large gauge wiring and the size of the modules does not exceed that of a common everyday smartwatch.
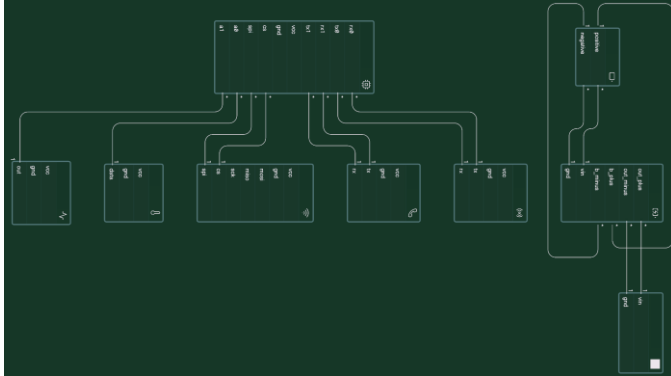

Fig. 7 Circuit diagram.

Once the PCB design is completed, it is necessary to carry out extensive tests to verify the correct functioning of the components and to avoid any unwanted interference [16]. The 'Wilbone' bracelet is designed to be manufactured according to the PCB and the battery is kept safe, ensuring resistance against possible terrain, and protection against damage due to adverse weather conditions or impacts.

It stands out, presenting a scalable modular approach, which adapts to different environments, being portable and aesthetically pleasing. Using Nylon as support material, while maintaining correct anthropometric and ergonomic design data [22].
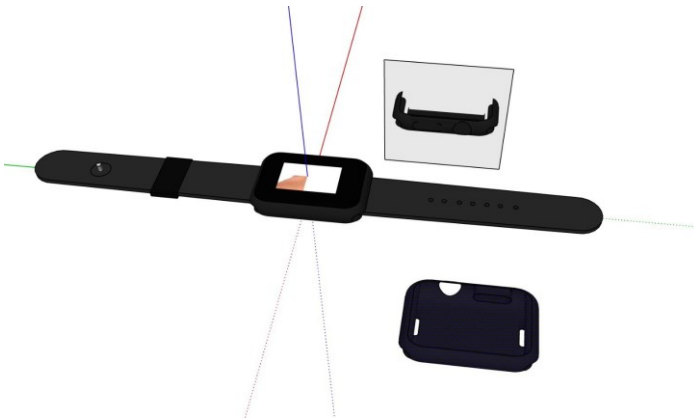

Fig. 8 Prototype design of Wilbone.

With the implementation of "Wilbone" as a high-security preventive system, the aim is to protect more than 75% of visitors in areas exposed to environmental hazards. This approach represents a crucial measure to mitigate potential hazards in wild natural environments. In addition, this system provides a significant opportunity for local communities located in these remote areas, allowing them to align themselves with the needs and expectations of visitors while promoting local economic development and improving the quality of life of their inhabitants.

It is important to note that attracting tourists to the country not only benefits these communities but also has a positive impact on various industries. In addition to fostering economic growth in the areas of lodging and food services, public services, transportation, and warehousing, tourism contributes to diversifying the national economy and generating employment in multiple sectors. Thus, sustainable tourism development not only protects visitors and promotes local development, but also strengthens the national economy as a whole.

Socially, it generates responsible and safe tourism which encourages economic activities increasing the tourist attractiveness of the regions, focused on those communities that are far from urban centers due to their proximity to these hostile environments, in this way this project can extend to various regions of the world, while helping to meet the objectives of sustainable development [12], [23]. Therefore, it generates an economic benefit for the local tourism industry and its inhabitants; while decreasing response times to accidents or emergencies by responsible agencies and provides real-time information on the status of users, due to this it can indicate more specific needs that require medical attention and a current and accurate location of users [24], [25].

TABLE I
BUDGET ESTABLISHED FOR BRACELET BASED ON ESTIMATED COSTS FOR THE YEAR 2023

Description		Quantity	Price
Arduino Nano ESP32	Amazon	1	$ 85.419
Modulo GPS NEO-6M	UALTRONICA	1	
Módulo LoRa (RFM95W)	One.Dollar.Store	1	$ 30.000
Módulo GSM/GPRS (SIM800L)	Amazon	1	
Sensor LM35 (Sensor de Temperatura)	AlliExpress	5	$ 15.375
Sensor de Pulso SEN-11574	SparkFun	1	
FYIOGXG Batería de repuesto	Amazon	1	$ 38.396
TP4056 Lithium Battery Charger	AlliExpress	1	
Human talent			$ 5.416
Services cost			
Packaging			$ 115.102
Manufacturing cost			**$366.594**
Sales price			**$458.242**

"Wilbone" is a wristband designed with a retail price of less than USD$115.71 for the tourism market, making it affordable for visitors and adaptable for local communities seeking to promote safe tourism in the target region. This bracelet not only offers a search and rescue assistance system but also provides support for managing eventualities and mishaps in outdoor environments.

In terms of production, Wilbone demonstrates high profitability by breaking even after exceeding 5237 units sold, which allows for a leveling of production costs. However, there

is the possibility of reducing costs by purchasing the bracelet in bulk. It is important to note that, due to its accessibility and functionality, "Wilbone" represents an economical and practical solution to strengthen the safety and well-being of tourists and local communities in the region.

IV. Conclusions

The final design has proven to be effective in meeting the economic, communication, and operational needs of both tourism businesses and the users who make use of these services.

A real client is being contemplated between 22 years and 31 years of age. According to statistics, they are people who seek to socialize through sports, in search of activities that involve risk, extradition, impulsivity, personal fulfillment, and focus on the relationship with nature. [26],[27].
An association is observed between the degree of familiarity with smart devices and the use of tools to monitor health or physical activity. Those with a higher level of knowledge tend to make greater use of such devices for fitness monitoring purposes.

Most respondents sporadically participate in outdoor activities, suggesting the possibility of deriving benefits from devices designed to monitor their physical activity during such activities.

Although the majority of participants go on excursions or tours in desert or remote areas at least once a year, there is also a sizeable group that never does so. This indicates a diversity in outdoor activity patterns among the respondents

The importance of variables such as communication and real-time location to ensure the safety and physical integrity of tourists in these remote and challenging areas is highlighted. Production costs will depend on the variation of the acquisition price of inputs.

The development of new technologies, known as "wearables", demonstrates the crucial role that technology can play in promoting safe tourism in Colombia. The "Wilbone" bracelet offers not only an emergency assistance system in remote areas of the territory but also supports the management of information and contributes to improving the safety and well-being of those who use it.

The future development of new technologies mustn't be dependent on the traditional network and the different terrains since the signal transmitted by the device will depend on this. Without leaving aside, an extensive study of the various challenging environments, with possible strange humidity or high temperatures, is also important.

It is essential to consider that at the date of this study, the values indicated in the market are a feasible option in the economic field for the manufacturing process of the bracelet. Still, considering the dynamics of global prices, these necessary materials can increase or decrease their price, which generates a margin of variability.

The development and implementation of the proposal could have limitations regarding its distribution and commercialization. As well as the initial investment for prototypes and scale-up designs.

On the other hand, positioning in a market as volatile as the current one is also a limiting factor since it would significantly affect the profitability percentage of the product.

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