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# The Importance of Automatic Counters for Sustainable Management in Rural Areas: The Case of Hiking Trails in Historic Villages of Portugal

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**Abstract:** The dynamics of territorial planning, the management of its tourism products, and the monitoring of demand flows and their impact on the territorial structure (social, economic and environmental) require tools that support the acquisition of reliable quantitative data, as far as possible in real time, that are easy to manage and allow immediate analysis. In the case of structures and equipment anchored in the nature tourism segment, in particular hiking trails, in addition to determining the demand indices in a network of hiking trails and understanding their territorial and temporal dynamics, the data collected through automatic counters is a crucial tool to support territorial management and evaluate the patterns and flows of tourist demand. Based on these assumptions, this research seeks to analyse demand data observed on eleven hiking trails in the Historic Villages of Portugal, collected through automatic monitoring systems (counters). In four years, between 2020 and 2023, the trails analysed generated a demand of almost 190,000 passages, which translates into an annual average of 47,500 passages in the tourism product "Historic Villages of Portugal" (more than 4800 passages for each trail), mostly in the spring and autumn months, mainly on weekends.

**Keywords:** rural territories; sustainability; hiking trails; automatic counters; historic villages of Portugal

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## 1. Introduction

In a global context characterised by concern about the inherent problem of climate change, linked to the impacts generated by society and economic activities, with latent effects in the near future and, in many cases, in the present, the sustainable management of resources appears to be a crucial factor in mitigating the effects of these activities, especially in the tourism system [1–3].

On the other hand, it is essential to ensure that tourism makes a fair contribution to the territories where it takes place, to the economic actors [4] and the resident population [5,6], without jeopardising the link with their cultural roots, beliefs, and physical and emotional well-being, guaranteeing harmony between economic interests and the community [7,8].

The key to fair, lasting, and sustainable tourism is balancing development, resource management, and local communities [9–12], in line with the Sustainable Development Goals set by the United Nations (UN) in 2015.

Given that nature-based tourism activities are mainly concentrated in rural and/or mountain areas [13,14], some of which coincide with classified biotopes (protected natural areas) or are environmentally sensitive and which also face demographic and economic problems, tourism is seen as a driving force for the development of these destinations, although it is crucial to ensure their sustainability.

In order to facilitate continuous monitoring of tourism demand and its adaptation to territorial planning policies and tourism supply, there has been a growing discussion about the importance of intelligent demand monitoring systems and the analysis of the data generated by this equipment.

The rapid evolution of the global tourism system and its interconnection with the constant evolution of available technologies has increased the importance of data as a very important tool for defining planning strategies, supporting decision-making, improving operational efficiency, adapting communication and marketing strategies, adopting measures to mitigate the environmental impact of tourism [15–18], and helping to increase the strategic competitiveness of businesses, tourism products, and territories [19,20]. The data generated by three main sources (users, devices, and operations) generate information flows from online publications (social networks and others), the positioning system (GPS), mobile roaming, Bluetooth use, automatic monitoring devices, transactions, activities or events (in the tourism market), bookings, purchases, among others [16].

The global increase in demand for tourism and leisure activities in rural and/or mountain areas, especially in the hiking and cycling segments, mostly in recent decades, has led to growing concern about the impact of this demand on the environmental structure of territories [21–28], some of which are associated with protected areas or have some protected status [29–32].

In fact, hiking tourism is an essential part of the global tourism system [33,34] and the most important activity within nature tourism [4,35,36], especially in rural and/or mountain areas [33,37–41]. This constant demand has led to a growing interest in research and application projects that focus on monitoring demand [42], using different tools and methodologies: field observations [43–46], interviews [47], digital footprints [45,48–51], dedicated geocaching networks [52], GPS tracking [47,53–56], mobile data [57–60], camera recordings [44,61], or automatic counters [44–46,50,62–66] are among the most widely used [67] by researchers and managers of tourism areas or products around the world.

Among the various tools used to monitor demand on trails, automatic counter systems are increasingly being used due to factors such as reliability, remote data collection, real-time demand management, long battery life, management of a complete trail network using multiple counters through a single digital platform, the interconnectivity between automatic counters and the transmission of data to the digital platform (via GSM—Global System for Mobile Communications), the ability to store data internally in the event of a prolonged loss of connection to the GSM network, the possibility of programming the organisation of the data collected (time interval, day, month, year), among others [65,68,69].

On the other hand, given the current state of available technology, monitoring systems also face a number of challenges. Increased vulnerability to vandalism or theft of equipment; loss of equipment and data due to extreme weather conditions or natural disasters (floods, forest fires, etc.); average price of software, hardware, and online management platforms; operating costs due to the use of GSM network connectivity; and inability to distinguish the passage of a human being or a large animal are some of the challenges in managing these devices [62,65,70].

The monitoring of trail users using advanced technologies allows the generation of a set of data that is easy to collect and analyse, which is crucial for land-use planning policies and the management of tourism products integrated into the walking and cycling segments [71], with particular implications for the sustainable management of trails and hiking activities [66,72,73]. Reliable data, with a continuous flow, in real time and broken down by itinerary, allows dynamic and proactive management, providing essential data for measuring demand patterns; defining the hot and cold spots of a network of hiking trails; measuring the ratio of investment in the creation and maintenance of each trail per user; adapting the communication and promotion of certain trails according to the greater or lesser demand observed; implementing possible measures to condition the use of trails according to the defined load limits; provide reliable data for analysing the market for possible investors (accommodation, catering, tourist entertainment, etc.); provide supporting data to improve the definition of samples for questionnaires or other forms of research.

In this way, the set of data provided by the automatic counters, in line with the technological standards prevailing on the market, makes it possible to obtain extremely important data for the definition and evaluation of public policies for investment in tourism, for the constant monitoring of demand, for the continuous collection and storage of data, and for the easy analysis of data without the need to use complex tools.

On the other hand, the data collected by automatic counters are easier to analyse using simpler tools (directly on the dashboard of the application that manages the collected data or through Excel software, for example), with practical application and the possibility of collecting and analysing in real time [74].

Based on these assumptions, in an attempt to understand the dynamics of tourist demand on the hiking trails of the Historic Villages of Portugal, one of the most consolidated tourism products in Portugal, the demand is analysed using data collected from the network of trails using automatic counters.

Thus, considering the scarcity of studies analysing the data collected by automatic counters on hiking trails integrated into national and international tourism products, this article seeks to respond to the following objectives: (1) determine correction factors for the data collected by automatic counters; (2) analyse the demand on the hiking trails of the Historic Villages of Portugal; (3) understand its temporal evolution; (4) identify the geographical and temporal patterns of demand; and (5) determine the use of each hiking trail for future analysis of carrying capacity.

## 2. Materials and Methods

### *2.1. Research Area*

The network of Historic Villages of Portugal (HVP) has a complex territorial framework, mainly developed in low-density areas, comprising 12 places, villages, and towns with multiple ecocultural resources (cultural, natural, and landscape), spread over 10 municipalities in the interior of the Central Region of Portugal (NUT II), mostly close to the border with Spain (Figure 1, Table 1).

In order to respond to the widespread decline in the importance of a significant part of rural and/or mountain areas, especially since the second half of the 20th century, the pilot project for the creation of "Historic Villages of Portugal" sought to respond to the main challenges faced by these areas through a bottom-up strategy, based on a new logic of territorialisation of public policies for the development of areas with growing structural difficulties.

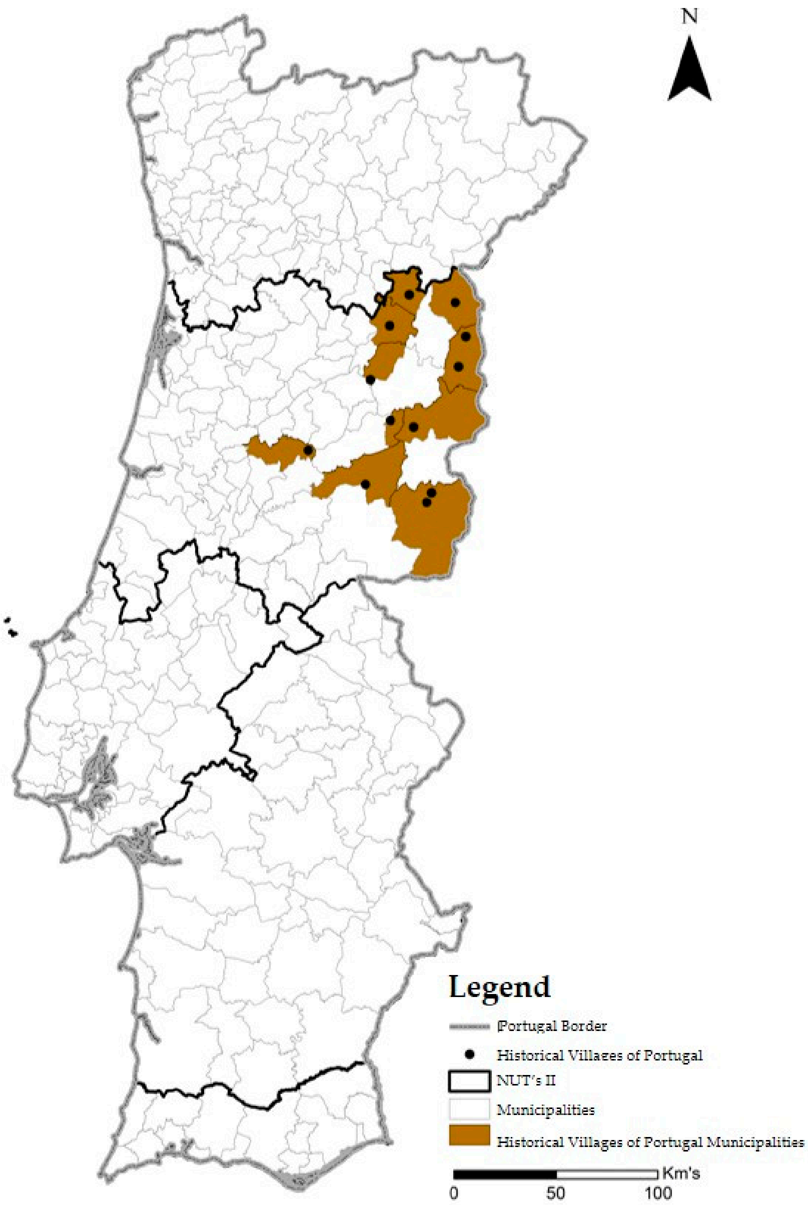


**Figure 1.** Geographical framework of the Historic Villages of Portugal.

**Table 1.** Geotourism profile of the municipalities of the Historical Villages of Portugal.

| Historical Villages of Portugal | Municipality | Resident Population (2021) | Hosting Capacity (2023) | Guests in Tourist Accommodation (2023) |
|---|---|---|---|---|
| Almeida | Almeida | 5.887 | 254 | 11.500 |
| Belmonte | Belmonte | 6.205 | 285 | 21.521 |
| Castelo Mendo | Almeida | 5.887 | 254 | 11.500 |
| Castelo Novo | Fundão | 26.503 | 829 | 69.128 |
| Castelo Rodrigo | Figueira de Castelo Rodrigo | 5.148 | 241 | 7.096 |
| Idanha-a-Velha | Idanha-a-Nova | 8.355 | 657 | 23.730 |
| Linhares | Celorico da Beira | 6.583 | 371 | 19.602 |
| Marialva | Mêda | 4.630 | 247 | 14.195 |
| Monsanto | Idanha-a-Nova | 8.355 | 657 | 23.730 |
| Piódão | Arganil | 11.065 | 313 | 18.968 |
| Sortelha | Sabugal | 11.280 | 275 | 13.927 |
| Trancoso | Trancoso | 8.413 | 262 | 11.597 |
| Total | | 94.069 | 4.645 | 246.494 |

The internal context, with continuous cycles of population loss (especially to the coast of Portugal and abroad), the difficulty of attracting and retaining population, the renewal of the demographic structure (very marked by population ageing), the decline of agro-sylvo-pastoral production activities, the difficulty of creating new businesses and jobs, the lack of basic services (basic sanitation, accessibility, etc.), and gaps in the provision of neighbourhood services to the population, among others [75], were challenges that needed to be addressed and, if possible, reversed.

Based on this set of challenges, linked to the importance of the existing heritage and its potential as a driving force for social and economic development, the Network of Historic Villages of Portugal (strategically identified as a valuable tourist resource in the first National Tourism Plan—1985/1988) emerged as the first integrated initiative in Portugal, with technical and financial support under the Programme to Promote Regional Development Potential of the Community Support Framework II (1994–1999), followed by the Operational Programme for the Centre Region—Integrated Territorial Action 'Innovative Actions to Boost Villages' in the Community Support Framework III (2000–2006).

The process of selecting the places that would be part of the Historic Villages of Portugal began with the identification of settlements with special characteristics in the field of historical, architectural, archaeological, and environmental heritage, as well as socio-cultural territorial relations, with the aim of enabling the creation of thematic tourist and cultural circuits that would generate benefits for the territories and their communities, in order to reverse the negative cycles they faced through tourism and related activities [76–78].

With the exception of Piódão, the other places that make up the Historic Villages of Portugal are considered fundamental landmarks in the history of the formation of the nationality, which assumed great geostrategic importance, mostly located on the border (with Spain), where castles and fortifications that were part of the defensive lines still stand [76,79,80].

Between 1994 and 2006, the implementation of the Programme for the Recovery of Portugal's Historic Villages resulted in a total financial investment of 44.6 million euros, invested in the protection and enhancement of the heritage (mainly in urban rehabilitation and upgrading or basic infrastructure), the promotion and publicity of the network, and the stimulation of the local economy—with 2.3 million euros dedicated to the creation of micro-enterprises [78,81]. In the following programming cycles (2007–2013 and 2014–2020), through the Collective Efficiency Strategies (EEC PROVERE Programme for the Economic Enhancement of Endogenous Resources), public investment of around EUR 7 million followed between 2007 and 2013 and around 5.4 million euros of public investment between 2014 and 2020, specifically dedicated to communication and marketing, animation, and innovation. This was complemented by private investment of 17.8 million euros between 2007 and 2013 and around 66 million euros in project intentions between 2014 and 2020.

As a result of the various cycles of public investment, the Historic Villages of Portugal have specialised in, among other things, a strong tourist offer in the walking and cycling markets: (a) a structured network of 14 approved short-distance hiking routes (Table 2); (b) a 700 km cycle route in the discipline of cyclo-tourism (road cycling), which can be divided into two loops (north and south); and (c) a large circular hiking and cycling trail (GR 22—Grande Rota das Aldeias Históricas de Portugal) of about 600 km, certified with the Leading Quality Trails—Best of Europe label, awarded by the European Ramblers Association, which recognises the best hiking destinations in Europe.

**Table 2.** Characteristics (average time to complete and distance) of hiking trails in the HVP.

| Historical Village of Portugal Hiking Trail | Average Time (Minutes) | Distance (km) |
|---|---|---|
| Almeida | 200 | 14.1 |
| Belmonte | 140 | 9.5 |
| Castelo Mendo | 95 | 6 |
| Castelo Novo | 110 | 2.7 |
| Castelo Rodrigo | 191 | 11.31 |
| Linhares | 50 | 3.1 |
| Marialva | 75 | 3.8 |
| Monsanto | 120 | 4.5 |
| Piódão | 280 | 10 |
| Sortelha | 135 | 7.4 |
| Trancoso | 420 | 21 |
| Total | 1816 | 93.41 |

In addition, the Historic Villages of Portugal's growing concern to differentiate itself as a sustainable destination and the adoption and promotion of strategies in line with this goal led to the destination being certified under the Biosphere Destination label, making the HVP the first network destination in the world to receive this recognition, a major factor in its participation in the Climate Summit—COP26—held in 2021, as the only Portuguese destination invited.

### *2.2. Data Collection*

Historic Villages of Portugal installed a series of monitoring systems on 11 short-route trails, using automatic counters that use passive infrared technology in combination with a high-precision lens to detect the heat emitted by the human body, installed about 1.5 m above the ground (to minimise wildlife counting).

The data collected by the automatic counters is stored in the device's internal memory, and every hour it transmits the data on the passages recorded to a server that can be accessed via a digital platform (hosted on a website that can be accessed via user accreditation) using GSM (Global System for Mobile Communications) mobile network technology.

The equipment is small, stored in a waterproof box to protect it from water and moisture, and concealed in beacons made from 100% recycled plastic. The automatic counters are powered by batteries with an autonomy of more than two years.

To optimise battery management and guarantee more than two years of autonomy, the system has been formatted to store data in the internal memory for periods of one hour, which is then sent to the servers once a day. In the event of GSM network unavailability or communication failure, the system is able to store up to 45 days of counting data, attempting to reconnect to the server every hour.

### *2.3. Data Analysis*

The monitoring systems were installed and became fully operational in 2019, and this first year was used to test the equipment, fine-tune the ideal location for the physical installation, and adjust the data collection platform. For the purposes of this research, data collected between 1 January 2020 and 31 December 2023 on the 11 short hiking trails in the HVP equipped with automatic counters was taken into account.

In terms of data management, once the data had been collected and sent directly to the servers via the automatic monitoring systems, it was collected individually for each of the 11 trails analysed and extracted from the digital platform in Excel format.

Once organised, the data were analysed using IBM SPSS Statistic software (v 29.0), and statistical analysis was carried out to understand the key dynamics of demand, including totals, averages, variations, percentages, standard deviation, or average deviation.

## 3. Results

### *3.1. Primary Data and Correction Factor*

Considering that the trails under study are located in natural areas, some of which are part of natural and/or protected areas, and despite the fact that the equipment is installed at a height of approximately 1.5 m above the ground, the presence of large animals (such as deer—*Cervus elaphus*, or roe deer—*Capreolus capreolus*) or birds with gliding flight to land on the beacons may disturb the counts, especially at night.

In this way, in order to guarantee the maximum reliability of the data collected, after prior analysis and identification of some night-time passages, and taking into account the peculiarities of the area, which largely prevents pedestrians from walking after sunset, a parameterised correction factor was applied according to the average hours of light in each season, disregarding the data collected between 7 p.m. and 8 a.m. from October to April and between 9 p.m. and 6 a.m. from May to September.

The primary data obtained from the automatic counters, without the application of correction factors, indicated a total of 189,106 passages between 2020 and 2023. With the introduction of the correction factor, which limits the number of night-time counts, 182,845 passages were considered valid for use in this study, giving a margin of error of 6261 passages or approximately 3.3 per cent (Table 3).

**Table 3.** The impact of night passages recorded by automatic counters in HVP hiking trails.

| Historical Village of Portugal Hiking Trail | With Night Records (n) | Without Night Records (n) | Difference (%) |
|---|---|---|---|
| Almeida | 29.630 | 28.327 | −4.4 |
| Belmonte | 17.262 | 16.364 | −5.2 |
| Castelo Mendo | 13.398 | 12.654 | −5.6 |
| Castelo Novo | 6.997 | 6.889 | −1.5 |
| Castelo Rodrigo | 14.823 | 14.201 | −4.2 |
| Linhares | 18.751 | 18.073 | −3.6 |
| Marialva | 8.137 | 7.553 | −7.2 |
| Monsanto | 32.197 | 31.860 | −1.0 |
| Piódão | 25.986 | 25.794 | −0.7 |
| Sortelha | 5.643 | 5.423 | −3.9 |
| Trancoso | 16.282 | 15.707 | −3.5 |
| Total | 189.106 | 182.845 | −3.3 |

Analysing the deviations from the night counts for each route, it can be seen that Piódão (0.7%), Monsanto (1%) and Castelo Novo (1.5%) are the trails with the lowest percentage of night counts. On the other hand, Marialva (7.2%), Castelo Mendo (5.6%) and Belmonte (5.2%) are the trails with the highest percentage of night-time counts by the automatic counters.

### *3.2. Geographical Demand Patterns for Hiking Trails in Historical Villages of Portugal*

In the overall picture of the four years studied, the Monsanto (31,860 passages—17.4% of the total), Almeida (28,327 passages—15.5%), and Piódão (25,794 passages—14.1%) trails are the ones with the highest recorded demand, together accounting for 47% of the total number of passages on the HVP trails (Figure 2). These are also the most visited places in the network of Historical Villages of Portugal, especially by tourists linked to nature and active tourism.

The trails in these areas also have the best annual average number of passages, with 7965 passages in Monsanto, 7965 in Piódão, and 7082 in Almeida.

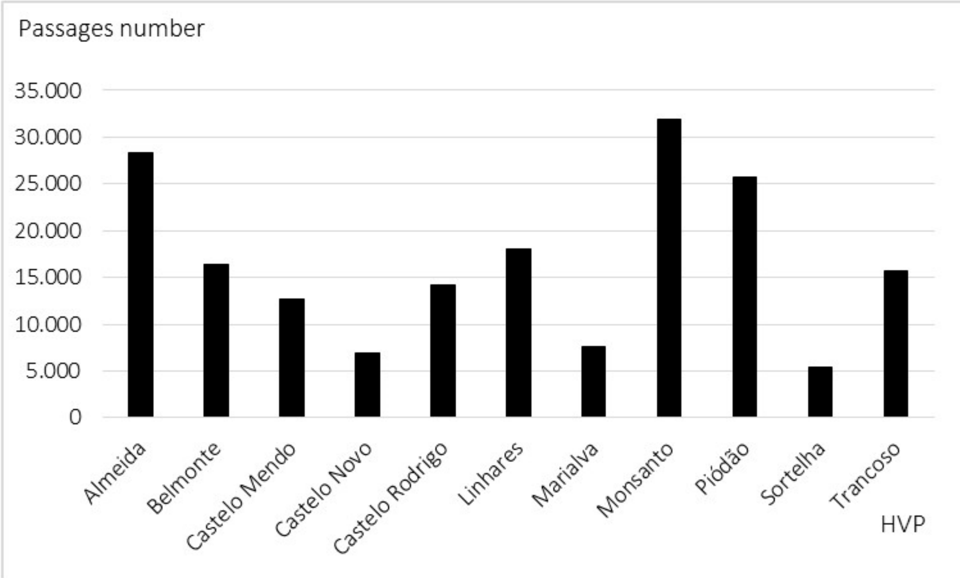


**Figure 2.** Hiking trail passages recorded by automatic counters, by HPV, between 2020 and 2023.

On the other hand, Sortelha (5423 visits—3.0%), Castelo Novo (6889 visits—3.8%), and Marialva (7553 visits—4.1%) have the lowest number of visits. These figures can be explained partly by the location of the automatic counters but mainly by technical problems with the equipment (lack of GSM coverage, destruction by forest fires, etc.).

The highest number of passages in a year was recorded on the Monsanto HPV (16,385—in 2020), and the lowest annual record corresponds to the Sortelha trail (109 passes—in 2023).

The analysis of the average deviation (AD) of the passages shows that the trails of Sortelha (AD = 26.7%), Trancoso (AD = 26.1%), and Marialva (AD = 23.1%) have the greatest variability in the average annual demand.

On the other hand, Belmonte (AD = 3.1%), Piódão (AD = 3.8%), and Almeida (AD = 5.3%) are the routes with the lowest average percentage variation in annual demand. Among the trails with the highest demand, Piódão has an average deviation of only 989 passages, which shows a high balance of annual demand flows (Figure 3).

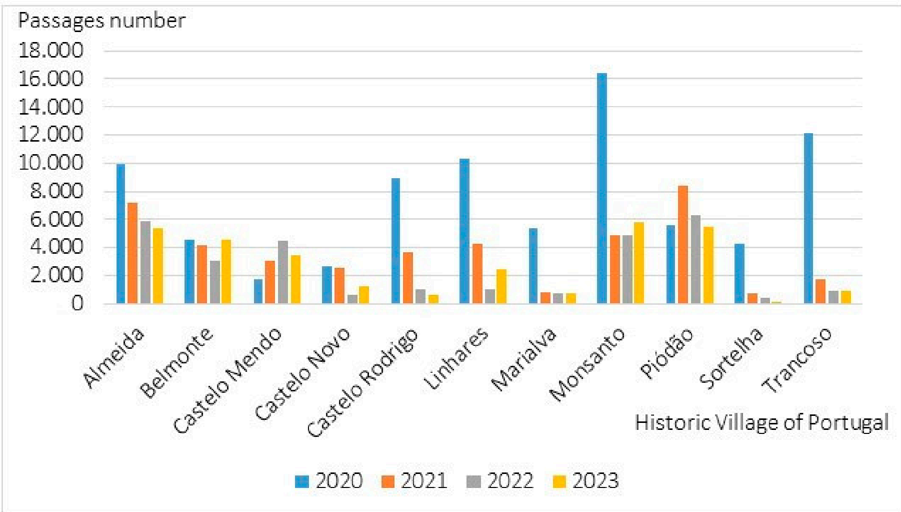


**Figure 3.** Hiking trail passages recorded by automatic counters, by HPV, per year.

Cross-referencing the geographical analysis of demand with its temporal expression shows that for nine of the eleven trails analysed, 2020 was the year in which the maximum number of passages was recorded in the time series between 2020 and 2023. The only exceptions are the HPVs of Castelo Mendo and Piódão, which recorded the maximum number of passages in 2022 and 2021, respectively.

On the other hand, in 2023, five trails of the network recorded the lowest number of passages in the series (Almeida, Castelo Rodrigo, Piódão, Sortelha, and Trancoso), followed by 2022, when four trails recorded the minimum number of passages (Belmonte, Castelo Novo, Linhares, and Marialva). Finally, in 2020, Castelo Novo, unlike the others, recorded the minimum number of passages.

### 3.3. Temporal Analysis of Demand for Hiking Trails

An analysis of demand, as measured by the number of passages on the 11 trails that make up the HVP network, shows that 182,845 passages were recorded between 2020 and 2023, an average of 45,711 passages per year and 4156 passages for each trail in the network.

In the dataset analysed, 2020 was the year with the highest number of passages on the trails, with 81,890 passages, followed by a sharp decline in 2021 (−49.4%) to 41,437 passages, with a further decline between 2021 and 2022, although less marked (−29.8%), to 29,101 passages. In 2023, there was a slight recovery compared to 2022, with 30,417 passages (+4.3%) (Figure 4).

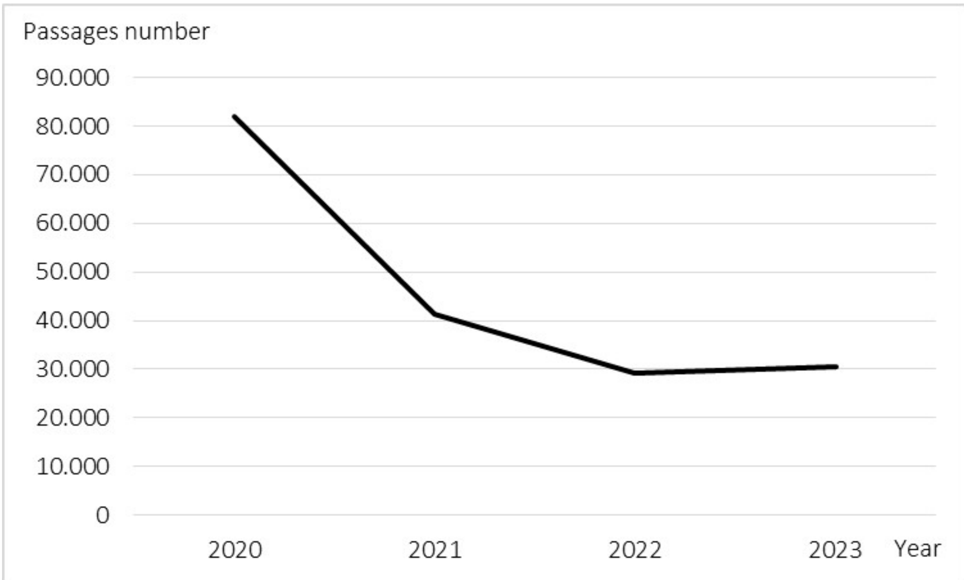


**Figure 4.** Total passages in HVP hiking trail, recorded by automatic counters, per year.

### 3.4. Trends in Seasonality of Demand

An analysis of the demand for walks recorded by the automatic counters shows that spring (between March and June) is the period with the highest number of visitors to the HVP, representing 49.6% of the total number of passages between 2020 and 2023. In this season, the month of May has the highest demand with 15% of all passages (Figure 5).

On the other hand, winter accounts for a smaller proportion of demand (around 16%). Autumn, which is considered one of the seasons with the highest demand from hikers (like spring), has the lowest weight in the HVP (around 17% of the total).

Summer is characterised by a considerable number of passages, higher than in winter and autumn, with the months of July and August (when the average temperature in the area under study is the highest) accounting for 17.4% of passages.

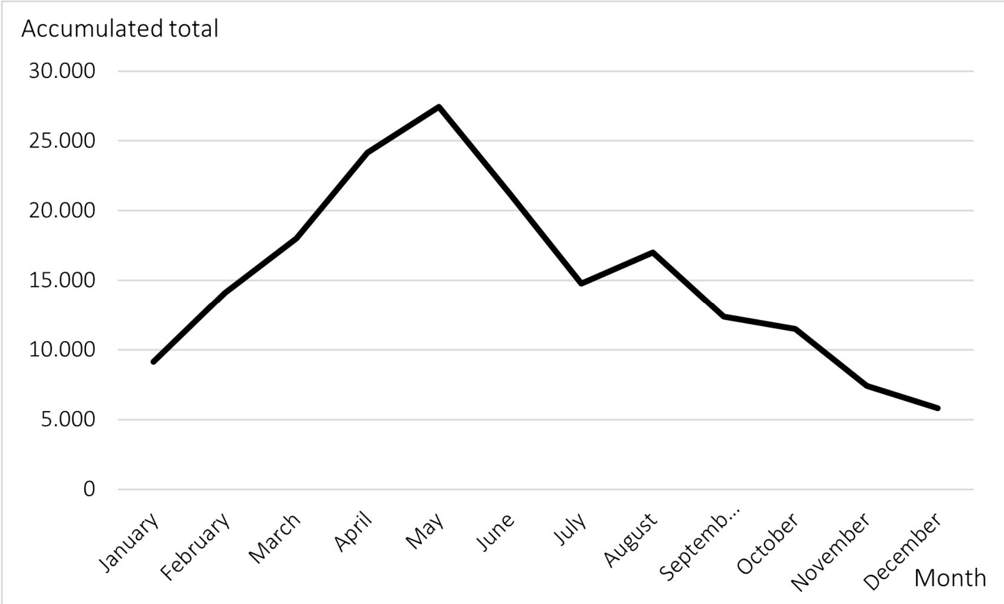


**Figure 5.** Passages recorded on the set of hiking trails in the Historic Villages of Portugal, per month (accumulated between 2020 and 2023).

A more detailed analysis of the level of demand for each hiking trail reveals some asymmetries, although overall most trails show similar dynamics (Figure 6).

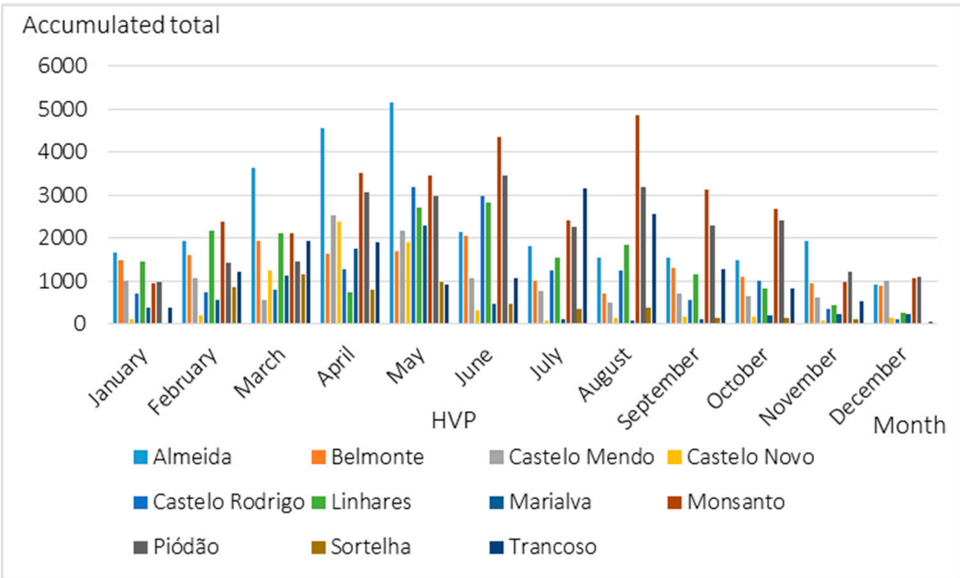


**Figure 6.** Passages recorded on Historical Villages of Portugal hiking trails, per month (accumulated between 2020 and 2023).

Thus, 9 of the 11 routes show that the maximum number of passages occurs in spring, spread over the months of March (Sortelha), April (Castelo Mendo and Castelo Novo), May (Almeida, Castelo Rodrigo, and Marialva), and June (Belmonte, Linhares, and Piódão). Finally, only the Monsanto and Trancoso trails have the highest number of passages in August, at the height of summer.

On the other hand, if we look at the periods of least traffic verified by the automatic counters, we can see that on most of the lines, the least traffic occurs in winter (especially in January and December), in the cases of Almeida, Castelo Rodrigo, Linhares, Monsanto, Piódão Sortelha, and Trancoso. On the other hand, on four of the routes, the lowest frequencies occur in summer (July and August), in the case of Belmonte, Castelo Mendo, Castelo Novo, and Marialva.

Looking at the average variation in demand over the months of the year, it can be seen that the trails located in the HVP of Belmonte (AD = 2.27%), Piódão (AD = 2.98%), and Monsanto (AD = 3.17%) have less variation in average monthly demand. On the other hand, the HVPs of Castelo Novo (AD = 9.18%), Marialva (AD = 7.23%), and Sortelha (AD = 6.6%) show a much more uneven distribution of demand over the months of the year.

### *3.5. Favourite Dy of the Week*

The analysis of demand by day of the week shows a greater concentration of passages during the weekend, corresponding to 32.5% of the total number of passages recorded. The day of the week with the lowest frequency is Tuesday, with 12.8% of the total number of passages recorded (Figure 7).

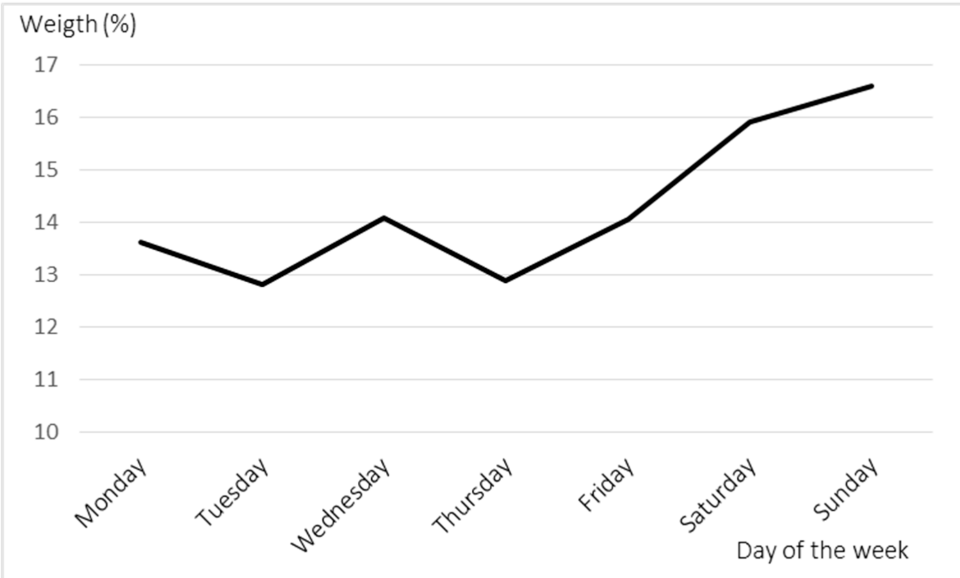


**Figure 7.** Passages recorded on the set of hiking trails in the Historical Villages, per weekday (accumulated between 2020 and 2023).

In an overall analysis, taking into account all the trails studied, the data show a high level of uniformity in the variation of the number of passages throughout the week, with a concentration of passages between 12.8% (Tuesday) and 16.6% (Sunday), with an average deviation of 1.1%, demonstrating a homogeneous distribution of demand.

However, a more detailed analysis of demand for each route reveals some trends that differ from the global average.

Looking at the day of the week with the lowest number of registered passages, Tuesday is the day with the most trails (Almeida, Castelo Mendo, Monsanto, Piódão, and Trancoso). This is followed by Thursday (Belmonte, Linhares, and Sortelha), Wednesday (Marialva), Friday (Castelo Novo), and Saturday (Castelo Rodrigo).

On the other hand, an analysis of daily demand by route reveals a greater heterogeneity in the dispersion of demand over the weekend. In fact, three of the routes have their highest demand on Saturday (Castelo Mendo, Linhares, and Marialva) or Sunday (Belmonte, Castelo Novo, and Monsanto), while Piódão has exactly the same weight on both days of the weekend (18.1%). The remaining four trails reach their maximum average number of passages on Wednesday (Almeida and Trancoso), Monday (Sortelha), or Thursday (Castelo Rodrigo) (Figure 8).

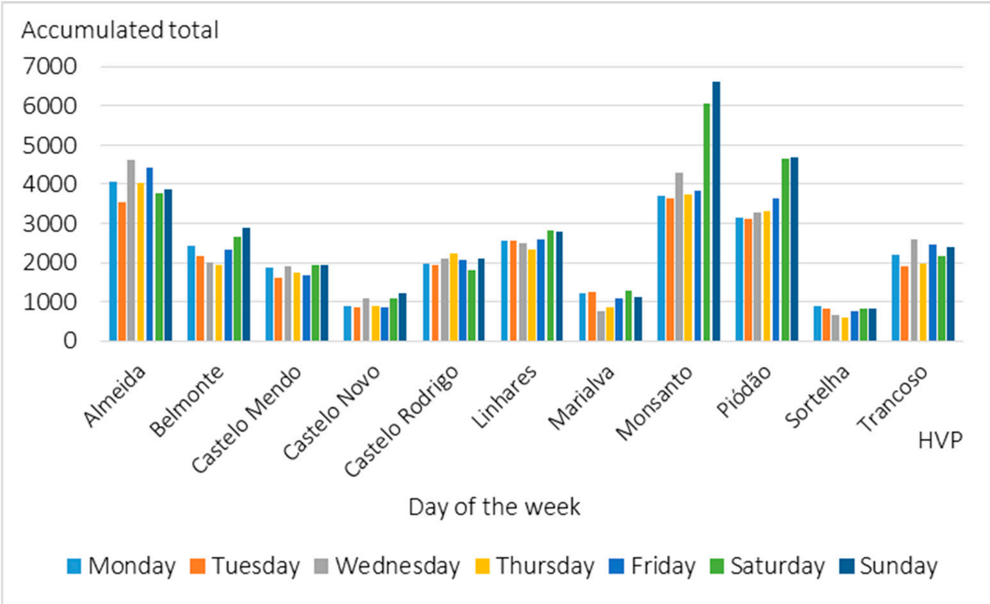


**Figure 8.** Passages recorded on Historical Villages of Portugal hiking trails, per weekday (accumulated between 2020 and 2023).

The analysis of the average deviation by route confirms that the trails with a higher concentration of passages on one or more days, especially at the weekend, have an uneven daily demand, which may reveal a greater seasonality at weekends. The trails located in the HVP of Castelo Rodrigo (AD = 0.7%), Linhares (AD = 0.7%), and Castelo Mendo (AD = 0.9%) show less variation in average daily demand. On the other hand, the Monsanto (AD = 3.2%), Piódão (AD = 2.2%), and Marialva (AD = 2.1%) trails have a greater daily variation in the number of passages. Finally, unlike the other routes with the highest demand (Monsanto and Piódão), the Almeida trail, despite its high demand, manages to maintain a fairly balanced daily flow of demand (AD = 1.0%).

### *3.6. Time of Passage Through Automatic Counters*

Analysing the number of passages on the trails by time interval, and considering that the automatic counters are mostly installed at equidistant points between the start and/or end of each trail, the majority of passages occur between 12 noon and 4 p.m. (56.0%), with 1 p.m. being the time with the highest number of passages (11.62%) (Figure 9).

However, the distribution of the average number of passages per hour varies according to the season. In summer, the cumulative number of passages in the periods 6–9 a.m. and 6–9 p.m. varies between 29.99% in August and 37.57% in July; on the other hand, in winter, the periods closest to the start/end of the day (from 8 to 10 a.m. and from 5 to 6 p.m.) record fewer passages with lower percentages (between 25.80% in January and 19.19% in December).

On the other hand, in summer, the average number of passages during the hours of maximum sunshine (from 12 to 4 p.m.), which reflects the time window with the highest average demand recorded by the counters, varies between 53.54% (August) and 46.48% (July), below the annual average. In the case of winter, this time window (from 12 to 4 p.m.) represents average counts above the annual reference percentage, varying between 71.81% (December) and 66.12% (January), confirming the importance of the number of hours of light and sunshine in the variation of passage times.

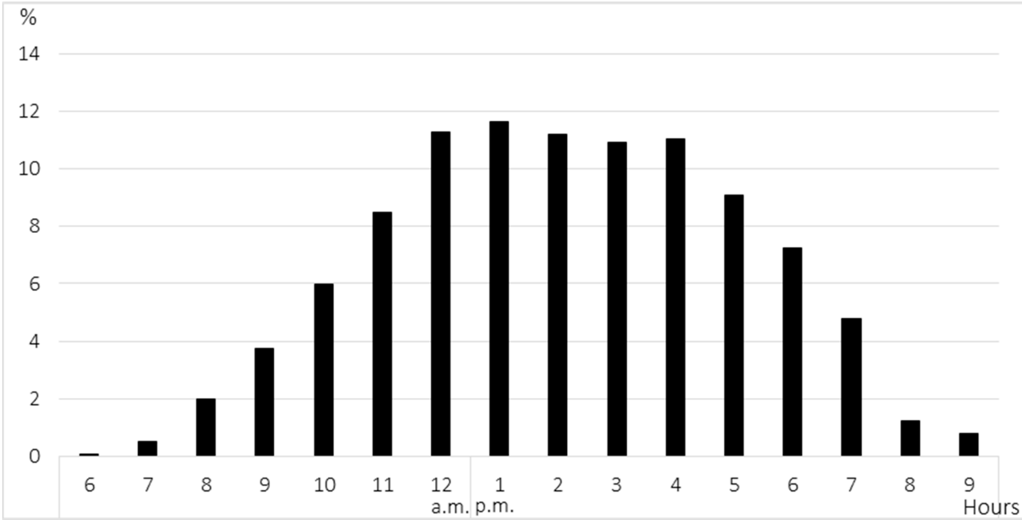


**Figure 9.** Passages recorded on the set of hiking trails in the Historical Villages, per hour (accumulated between 2020 and 2023).

When analysing the hourly demand at the level of each trail, the dynamics are very similar, although there are significant differences in the conditions offered by each trail, especially in the estimated average duration and length.

Although the 11 trails in this study have a total length of 101.9 km, ranging from 2.7 km (Castelo Novo) to 21 km (Trancoso) (Table 2), this amplitude in the differences in length and average time taken is not reflected in the hourly averages recorded by the automatic counters.

The 6 p.m. block has the lowest weight in 10 of the 11 routes analysed, with only Marialva having the 9 p.m. block with the lowest percentage of passages. On the other hand, the 2 p.m. block is the period with the most passages on four routes (Castelo Mendo, Castelo Rodrigo, Marialva, and Piódão), followed by 12 noon (Castelo Novo, Linhares, and Monsanto), 3 p.m. (Almeida and Trancoso), and finally 4 p.m. (Belmonte and Sortelha).

## 4. Discussion

Based on the results obtained, the variations seen in the hourly counts demonstrate the importance of applying parameterised correction factors to the data obtained from the automatic counters [82], allowing a more accurate calculation of hiking flows.

In the overall picture of the four years studied, the Monsanto (31,860 passages—17.4% of the total), Almeida (28,327 passages—15.5%), and Piódão (25,794 passages—14.1%) trails are the ones with the highest recorded demand, together accounting for 47% of the total number of passages on the HVP trails (Figure 2), in line with the demand trends observed in the HVP tourist offices [81].

The lower number of passages on the Castelo Novo (2022), Castelo Rodrigo (2022), Sortelha (2022 and 2023), and Trancoso (2022 and 2023) routes is largely due to technical problems with the automatic counters (the most common being forest fires, battery system failures, hardware failures, etc.).

Particularly in the case of the Trancoso route, the greater variability in the number of passages can be explained in part by the length of the trail (21 km) and the average time taken to complete it (seven hours).

The temporal variation in demand can be partly explained by the evolution of the COVID-19 pandemic and the periods of lockdown and reopening that occurred between 2020 and 2021.

In 2020 and most of 2021 [83], the successive periods of tightening and easing of restrictions on the movement of the population and the severe restrictions on international travel, despite a very sharp drop in foreign tourists, favoured an increase in domestic demand, especially for rural and/or mountain areas with facilities and infrastructure dedicated to the enjoyment of nature, such as hiking trails.

In 2022 and 2023, with the resumption of "normal" dynamics in the world tourism system, the global opening of borders, and the free movement of people, the demand registered on the HVP trails stabilised at around 30,000 registered visits per year, i.e., around 2700 visits for each of the 11 trails.

Comparing the number of visits recorded by the automatic counters with the evolution of tourist demand in the area, the data seem to confirm the importance of the weight of the pandemic in the variations in demand flows on the hiking trails.

Analysing the trends in the three demand variables for each year (passages on hiking trails, overnight stays in tourist accommodation, and guests in tourist accommodation), it can be seen that there is an inverse trend between the number of passages and the two tourist accommodation dimensions (overnight stays and guests).

If, on the one hand, the number of passages registered on the HVP routes decreases between 2020 and 2023, with a slight recovery in 2023 compared to 2022, the trend in the dynamics of tourist accommodation (number of visitors and overnight stays) is the opposite: there was a marked recovery between 2020 and 2022, which continues to grow between 2022 and 2023, although at a slower pace.

This trend is confirmed if we analyse the weight (in percentage terms) of the three demand variables in each year in relation to the cumulative total of each indicator between 2020 and 2023, with 2021 marking the convergence point of the reversal of the dynamics identified.

A longer time series, especially after the period of "full recovery" of tourist activity, will make it possible to obtain more stable data in the future, which will allow us to confirm or not the trend of constant demand for hiking trails in the Historic Villages of Portugal.

An analysis of the demand for hikers recorded by the automatic counters shows that spring (between March and June) is the period with the highest number of visitors to the HVP, representing 49.6% of the total number of passages between 2020 and 2023, in line with the overall demand recorded by the number of entries at the HVP tourist offices [78,81]. On the other hand, winter accounts for a smaller proportion of demand (around 16%). Contrary to the trend observed in other studies carried out in Portugal [84,85], autumn, which is considered one of the seasons with the highest demand from hikers (like spring), has the lowest weight in the HVP (around 17% of the total).

Similarly, contrary to the dynamics observed in other studies [14,85,86], summer is characterised by a considerable number of passages, higher than in winter and autumn, with the months of July and August (when the average temperature in the area under study is the highest) accounting for 17.4% of passages.

The analysis of demand by day of the week shows, as expected and in line with other studies [85,86], a greater concentration of passages during the weekend, corresponding to 32.5% of the total number of passages recorded. The day of the week with the lowest frequency is Tuesday, with 12.8% of the total number of passages recorded.

In an overall analysis, taking into account all the trails studied, the data show a high level of uniformity in the variation of the number of passages throughout the week, with a concentration of passages between 12.8% (Tuesday) and 16.6% (Sunday), with an average deviation of 1.1%, demonstrating a homogeneous distribution of demand.

This research filled the gap in previous research on the use of automatic counters for monitoring hiking trails, integrated into tourism products, but it still has the following limitations:

1. Limitations in data validation. Despite the reliability of automatic monitoring systems, in future studies, it would be important to carry out a parallel in-person collection of data from passages on pedestrian routes, in situ, simultaneously, through daily sampling, to determine the degree of effectiveness of the data collected by the equipment.
2. Sample limitations. This study focuses only on the network of short-route hiking trails in the Historic Villages of Portugal, not analysing demand data observed on the great route trails existing in the tourist product studied.
3. Limitations of demand patterns. The dynamics arising from the pre- and post-COVID-19 pandemic may have changed the dynamics of demand in the Historic Villages of Portugal. The lack of reliable data from the period before the start of the pandemic limits the scope of this study, as it does not allow analysing pre-existing patterns of the pandemic crisis.

## 5. Conclusions

This study analyses the trends in demand for short hiking trails in the Historic Villages of Portugal by analysing data collected by automatic counters.

Considering the scope of the research carried out on the scale of a tourism product with great national and international projection, there are no known previous studies that have analysed the demand for such a complex network of hiking trails using automatic counters.

Therefore, with the aim of understanding the main dynamics and results that can be obtained by analysing passages recorded with this type of tool, this article has made it possible to obtain and discuss some interesting results that open the door to further research. Among the various data analysed, it was possible to (1) determine the importance of the hourly correction factor in the records collected by the automatic counters; (2) identify and discuss the geographical patterns of demand for hiking trails within the Historic Villages of Portugal tourism product; (3) identify and understand the temporal dynamics of demand (annual, monthly, daily, and hourly); and (4) analyse the seasonality of demand for hiking trails.

Determining and applying the correction factor to the night-time passages recorded by the automatic counters resulted in a margin of error of 3.3% of the total for the eleven trails analysed.

Thus, between 2020 and 2023, the trails in the Historic Villages of Portugal have registered a total of 182,845 passages, which means an average of 45,711 passages per year and 4156 passages for each trail in the network, with those with the highest demand corresponding to those with the most visits to the tourist offices installed in the corresponding places (Monsanto, Almeida, and Piódão).

The data analysed shows that spring (between March and June) is the period with the highest number of pedestrians in the HVP, with 49.6% of the total number of hikers, while May has the highest level of demand. Winter, on the other hand, has a lower proportion of verified demand.

Finally, in terms of demand patterns, it can be concluded that demand is higher at weekends, especially in the time window between 12 noon and 4 p.m.

This research systematises the results of the demand verified in the network of short hiking trails in the Historic Villages of Portugal, reflecting a localised analysis, and its further development warrants more future studies, especially in determining the capacity and assessing the conditions of each trail.

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