



# Article Maritime Transportation Dynamics in the Azores Region: Analyzing the Period 1998–2019

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Abstract: The geography over which maritime transportation operates is unique, combining physical, strategic, and commercial imperatives. Physical issues are stable across time, but strategic, especially commercial, considerations continually shift with the ebb and flow of the globalization process. Contextually, the distance that isolates different locations in many cases plays a vital function in these interactions. Distance is the primary element that affects the values of interaction intensities. In fact, the issue is how the intensities were reduced with distance since this reduction is generally not linear. In this regard, this article intends to pursue the issues of the shape and parameters of the distance-decay functions based on the travel time value between islands. In this regard, almost all the Azores Islands were used as a case study. The study results show that the distance-decay functions established the unique dominance of Faial Island, Pico Island, and São Jorge Island, all in the Azores central group; in addition, there was an increase in the number of passengers in those. Moreover, the dominant position is the central islands, and their coexistence with others in the environment makes them more accessible than other islands, showing Terceira Island as a potential maritime passengers' hub in the Azores. So, with this study, it becomes clear which are the main accessibility issues within the Azores archipelago as well as efficiency should be promoted through the design of policies in maritime passengers' transportation.

**Keywords:** accessibility; planning; maritime transport; regional studies; transportation; ultra-peripheral territories

## 1. Introduction

The distance that isolates different locations in many cases plays a vital function in these interactions. Distance is the primary element that affects the values of interaction intensities. In fact, the issue is how the intensities were reduced with distance since this reduction is generally not linear.

In fact, if we look closely at some pieces of recent research, as is the case of the study of Fratila et al. [1], where the relevance of maritime transport for economic growth in the European Union was analyzed, it is easy to understand the significance of this issue. Another relevant issue to consider when we approach this topic is the disruption occurrences in liner shipping functions that influence the schedule, consequently increasing



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**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). cargo delivery costs at ports [2–4]. Furthermore, there are several other topics to consider about the success of maritime transportation; according to Dui, Xiaoqian, and Wu [5], "(...) the ability of the ports to send and receive goods can be easily destroyed by political and natural interferences (...) causing a significant negative socio-economic impact such as port operation suspension and route disruption. Effectively implementing resilience management in MTS can improve its ability to handle interruptions and minimize losses."

Based on the exposed issues, the current work seeks the problems of the form and parameters of the distance–decay operations based on travel time between islands. Therefore, the principal goal of this article is to construct a distance–decay function for travel time between each of the eight Azores islands by sea transport in Portugal. Each island has its specific position and the number of passengers and travel time to get there. The paper attempts to describe the universal distance–decay role for these islands generally based on the following straightforward and easily accessible variables: the number of passengers and the travel time to the studied places.

#### 2. Maritime Transportation: A Brief Overview

According to Rodrigue [6], we comprehend that, "The geography over which maritime transportation operates is unique, with its combination of physical, strategic, and commercial imperatives. Physical issues are stable across time, but strategic, especially commercial, considerations continually shift with the ebb and flow of the globalization process". Although oceans account for 71% of the earth's surface, maritime transport mostly takes place only along specific routes that are regularly used in itineraries. These routes are a function of obligatory points of passage, which are strategic locations, of physical constraints and political borders [6].

Numerous scholars view maritime transport as an environmentally rational approach, mostly due to the low energy consumption and air emissions per transport work compared to other transport modes. Thereby, it becomes evident that there are many efforts in the maritime sector in policy, technology, and research to achieve specific sustainability goals [7]. In fact, maritime transportation is seen as materializing human interactions in a globalization era. Nonetheless, for Ng and Wilmsmeier [8], "(...) *beyond being a tool bridging different regions, maritime transport is a direct and indirect driver of economic development with possibilities to consolidate, induce and interpose*". Consequently, the performance of maritime transportation as a derived demand through its organization, processes, and functioning has simplified and potentially pushed space-time reduction [8].

To understand the present structures, strategies and developments in maritime transport, it is very important to reflect on the networks along with multi-level hierarchies connecting the two-dimensional surfaces of the Earth [9]. Hubs and maritime transport passages, manifested by transportation infrastructure and services, can be located in the close spatial distance to underdeveloped and peripheral regions. Additionally, according to Wilmsmeier [10], "(...), the group of linkages drives spatial integration, integration does not follow egalitarian patterns but has created an uneven configuration of space of physical networks - consequently, pushing centrality and peripherality".

While the maritime transport configurations have expanded significantly with the globalization of the maritime industries, the main drivers being cost efficiency exploiting the principles of economies of scale, scope and density as one of the major pillars of sustainability [11]. Furthermore, the physical properties constituted in border lands and islands create path dependency and canalize the action space in maritime transportation. At the same time, mentioned areas project the political and economic regimes or dominating power that have led to their construction, as manifested in the prevalent operational models and rationales in border lands and islands service provisions. Transportation infrastructures in these regions contribute to the current path-dependent spatial maritime transport patterns and dynamics [12].

The spatial trends and patterns of fixed infrastructures assemble differing action areas by covering the distances interpreted in costs, time, or similar. Here, the increasing institutionalization of the inter-disciplinary character of maritime transport also dilutes the 'geographical' nature of maritime geography investigation [8].

The considerable increase and significant variety of theoretical reflections and practical projects regarding the maritime transportation field make it a time-consuming and demanding task to determine the main study topics and tendencies properly. However, research endeavors have been assembled to rethink specific subjects, trends, and methods in maritime transportation domains such as shipping and service management, intermodal transport, maritime risk and safety, maritime cluster and regional development, environmental issues, and sustainability [13].

Major concerns of maritime transport are related to transport infrastructure management, and maritime spatial planning and analysis. The research directions and dynamics also shifted from regulations and policy management to efficient, integrated and sustainable maritime transport over the past few decades. Furthermore, it could be easily understood that the emerging research trends are related to transportation and infrastructure sustainability including environmental, social and economic perspectives of maritime management [14].

Accessibility is a concept used in various fields such as transportation planning and regional studies. It plays an important role in the planning process and policy making. According to Iacono, Krizek and El-Geneidy [15], "(...) it has been applied to transportation studies since the 1950s when it was defined as the ease of reaching desirable destinations. Improving accessibility has recently re-emerged as a central aim of regional planners and aligned disciplines".

Generally, accessibility is a combination of two positions, one expressing the activities or prospects to be achieved and the other describing the action, time, distance, or cost required to reach them [16].

Additionally, if we focus on the Maritime Transportation and the Insular Territories, it is possible to understand that islands have been considered particular cases of accessibility studies. Determinative factors that play a key role in the islands' accessibility are isolation and small area. A private transport system, especially in continental regions, can be an alternative way to cover for the absence of public transportation. However, the geographical discontinuity that exists in islands makes it difficult to achieve this purpose. The fact that most islands, especially in Europe, are located in the geographical periphery, has resulted in a low level of accessibility. That is why we call them insular territories. This issue is more recognizable in smaller islands that are not able to possess air services, so that they can only be accessed by maritime transportation [17].

Insular territories are not only about "boundedness" but also about "connectedness". The habitats of all insular territories and islands depend on the world outside. Connectedness issues of a small island and its communities are concerned with the level of established linkage and extent of accessibility and communication under the constraints of scale economies, micro-climate, and spatial reach of networks [18].

The main spatial approaches that most accessibility assessments employ are one of the reasons for considering insular territories as different from large scale or regional transportation infrastructure studies. Furthermore, these studies could not examine the performance of the actual public transportation and infrastructure. For instance, accessibility is measured as if all modes of transport services are available at any time of any day, a fact that simply is not true for islands. As a result, when a specific transport service or infrastructure on the island is not properly provided or supported, the time or cost required to access it is disproportionately high compared to the same on the mainland [19].

Multimodal accessibility index (MAI) is a substantial instance that has been used frequently in literature to evaluate the accessibility of different regions of the EU from a perceived European center, including insular territories and islands. However, this method basically relies on accessibility indicators that do not take the discontinuities of space into account. Consequently, island realities, including additional time and cost due to geographical limitation such as remoteness and insularity, along with a lack of various transport modes, could not be properly considered in accessibility assessments [20].

As we discussed, accessibility reflects the ease of access between two points in units of time. Island regions, such as the Azores Islands archipelago, form an interesting case study for analyzing accessibility measures. This is a very fragmented geographical space, comprising islands of multiple size and socio-economic dynamics. The economies of insular territories are organized in a system of economic poles that are particularly interesting to study as population composition and administrative structures vary between the islands [21].

Contextually, the economic, social, and demographic dynamics that stem from this geographic particularity are associated with economic and social isolation, resource scarcity, land limitation, and high operational costs. At the same time, insularity characterizes the general 'atmosphere' that determines the experiential identity of the 'islander' and the distinct environment and trends created in these geographic regions [22].

As long as isolation constrains transportation services, the analysis regarding the accessibility and infrastructure assessment of insular territories come up with measures resulting from the islands' social, economic, and transport infrastructure characteristics. Based on these characteristics, accessibility of insular territories can be referred to as a function of a combination of hierarchies in accessibility, strategic transport infrastructure, congestion effects, travel time and behavior analysis, along with insularity in particular, peripheral region transport planning, level of accessibility, and socio-economic issues. In the geographical context of insularity, transportation, and logistics, infrastructure has a fundamental function in accessibility, territorial cohesion, and socio-economic growth and development. A destination's remoteness only seeks to amplify its dependence on transport connections, and transport services are critical for the local population's sustainability in the insular regions. The barrier formed by the sea prevents the use of private vehicles, and inter-island transport is limited [23].

Therefore, it is vital to consider accessibility measures that allow us to achieve an accurate comparison framework of the resulting accessibility dynamics, along with particular regional settlements of insular territories. In this way, we can implement measurement approaches that include necessitated indicators of transport infrastructure performance to analyze level of accessibility regarding insularity characteristics. So, first of all, the implemented method of accessibility assessment has to be comprehensive and sensitive to challenges, features and trends in insular territories, and related transport infrastructure and systems [24].

While the declared guidelines and evaluations enclose transport infrastructure and accessibility, this study aims to identify and fill the gap regarding the practical analysis accessibility and significant geographical limitations of insularity in the Azores archipelago along with socio-economic issues.

### 3. Materials and Methods

### 3.1. The Case Study Area

The selected case study for this article was the Azores Autonomous Region. Contextually, through Figure 1, it is possible to evidence that the Azores archipelago is part of the Macaronesia Region—along with the archipelagos of Madeira, Cape Verde, and Canary. The archipelago, inserted in the North Atlantic, comprises nine islands and a total surface area of around 2300 km<sup>2</sup>, corresponding to approximately more than 2.5% of the Portuguese territory (more than 92,000 km<sup>2</sup>). Their geographical proximity groups the archipelago islands in eastern, central, and western groups.



Figure 1. Azores Islands-geographical location [25].

The three biggest islands are São Miguel, Pico, and Terceira—and they represent approximately 68.5% of the total area and about 85% of the Azores population. Population densities per km<sup>2</sup> fluctuate between 184 inhabitants on the biggest island and 27 inhabitants on the smallest island. Amongst the 19 municipalities in the Azores, the largest is Ponta Delgada in São Miguel Island. Contrarily, the smallest is Vila do Corvo in Corvo Island, which registers a variation in population density in 230 inhabitants per km<sup>2</sup>.

Generally, the landscape of the Azores is marked by a strong orography, where the high altitude is associated with the hardy relief. The different islands' maximum altitude ranges between 405 m in Graciosa and 2351 m in Pico, the highest point in Portugal. The islands' landscape is usually overwhelmed by the magnificent lagoons that occupy the abatement craters of extinct volcanoes.

Additionally, in the Azores, the production systems represent the primary income and employment generation's primary sources, reflecting the endogenous capacity for economic support.

In this archipelago, the urban and rural systems represent urban occupation and rural settlement patterns and dynamics. Urban and rural settlement dynamics stand out in this context, and the location, shape, and structure of urban agglomerations harmonize with urban expansion and housing dynamics. In addition, it is possible to verify a tendency of slight population growth, the persistence of a high index of rurality in the population's residence, and average values in Portugal.

Additionally, this region presents a significant increase in urban areas in evolutionary terms, reflecting the urban growth that has been witnessed in recent years. The agricultural and pasture areas have decreased in recent years, considering that in the 1990s they represented more than 50% of the Azores area. Contrarily, there was an increase in forest areas and natural environments, when in the middle of the 1990s decade, they represented near 30% of the Azores' territory.

According to Castanho et al. [26], "(...) accessibility and equipment systems are part of the infrastructure, transport, communications, energy, and collective equipment networks". Additionally, according to the above-mentioned authors, we should emphasize "(...) the need to provide a set of services (utilities, communications, and energy) and mobility conditions to populations, tourists, and economic agents, as a privileged instrument of cohesion and competitiveness policies". The area of execution of the research is the Azores islands since data were obtained on the number of passengers received by each of the islands traveling using a ferry. Data were obtained from Regional Statistical Service of the Azores (SREA). Data on inter-island movements within the Azores archipelago provide crucial information on space mobility and spatial interactions.

Likewise, the travel times between the islands were obtained from the company Atlanticoline S.A. and the website https://www.ferrylines.com/en/search/, (accessed on 1 July 2021). In methodological terms, on the Euclidean expression of distance, units of time have been used because they represent an excellent approach to the problem of distance. Thus, there was no need to differentiate between modes of transport in the analyzed case since only ferry transport was analyzed, and there was sufficient data [27–29].

Once the travel times between islands had been determined, using the ferry and the number of passengers arriving at each island as a means of transport, the probability of interaction between the islands connected by ferry was possible to calculate. As a consequence, the associated interaction force could be determined. In this regard, one can formulate the possible interaction distance of each island that results in a continuous and monotonically decreasing curve, and which is called the distance–decay function [30].

While it is true that each individual may present different perceptions of what may be near or far from their position, the curve to be obtained will take into account the aggregate distance that will result in the average value of the probability of interacting for each distance. In this case, the willingness of passengers to travel from one island to another by ferry is determined based on the number of passengers registered in the years 1998 and 2019. For this reason, except for the island of Corvo, where there were no data, for the remaining islands, the distance–decay functions for these years were calculated since they are the initial and final years for which data were available.

Subsequently, it is related to the distance measured in hours recorded to reach each of the islands of the Azores archipelago. Thus, the resulting curve will be a linear composition of all the individual interaction functions.

Therefore, the distance–decay function for a particular island has been constructed as follows: the travel time on *x*-axis shows distance in hours from a given island to each one of the remain islands. At the same time, the intensity of interactions on *y*-axis offers the portion of annual travelers from the different islands to a given island, given by:

$$I_{d,o} = \frac{Pax_{d,o}}{Pax_d} \tag{1}$$

where  $I_{d,o}$  is the intensity of interactions to destination island *d* from origin island *o*;  $Pax_{d,o}$  represents the passengers to destination island *d* from origin island *o*; and  $Pax_d$  represents total annual passengers arrived to island *d*.

Intensity of interaction values occur in the range between 0 and 1 and are called interaction intensity. Islands are "close" if interaction intensity falls between (0.5;1), "close to far" if interaction intensity fall between (0.1;0.5) and "far" if interaction intensity fall between (0;0.1). Of course, the intensity of interaction on the islands cannot be measured. Additionally, we postulate that the value of the intensity of interaction on the same island, that is, at the zero distance, is 1 or 100% [31]. Additionally, each origin island of the path is represented by a single point in the graph. Regarding the location of these points (islands) in the coordinates of the graph, the optimal decay functions for each of the islands were expressed.

#### 4. Results

The flows of trips, made by ferry, from each of the islands of the Azores archipelago to a given island have been used to calibrate the essential functions of distance reduction. All 16 estimated power functions highly fit data with explained capacity no lower than 78.55%. All decay factors are statistically significant at 95% confidence interval. Its shapes and

parameters are presented below. The research uses only flows between primary spatial units of the islands since the intra-unit flows are not available. Two variable parameters must be used to emphasize the optimal distance–decay function for the islands. All functions for all islands are graphically presented in subsequent figures and tables. Inter-action intensity is in the range between 0 and 1. Contextually, the intensity of interaction on the islands cannot be measured.

# 4.1. Faial Island

For Faial Island, from 1998 to 2019, the distance from neighbor Pico Island has an interaction intensity "close to one" for distance–decay function, being the only one with "close" accessibility. Nearby, at only 1.5 h travel time, São Jorge Island returns a spatial interaction intensity below 0.03, being thrown into a "far" accessibility. The 2019 interaction intensity is a little lower than in 1998 for Pico Island and double higher for São Jorge Island. These are islands with the most significant number of travelers to Faial Island. Remaining islands are farther away with low interaction intensity and no significant change between 1998 and 2019 (Table 1 and Figure 2).

**Table 1.** Data for maritime connections to Faial Island from the rest of the archipelago—for 1998 and 2019.

Destination	Travel Time (Hours) —	Passengers	
		1998	2019
Santa Maria	17.7	36	9
São Miguel	14.0	301	377
Terceira	6.5	629	999
Graciosa	5.0	185	369
São Jorge	1.5	3879	16,965
Pico	0.5	129,766	205,483
Flores	9.0	1029	245



**Figure 2.** Intensity of interactions and travel time to Faial Island from the rest of the archipelago—for 1998 and 2019.

# 4.2. Pico Island

From the distance–decay function for Pico Island, Faial Island is the only "close" accessibility island, with an interaction intensity around 0.9, even decreasing between 1998 and 2019 (from 0.94 to 0.87). Far away interactions take place with São Jorge Island, at 1.5 h travel time distance, increasing from 0.045 (1998) to 0.107 (2019) and turning into "close

to far" range. These two destination islands show the most significant total number of travelers to Pico Island. Similarly to the Faial distance–decay function findings, the 2019 interaction intensity is a little lower than in 1998 for Faial Island and double for São Jorge Island. Concerning the remaining far away islands, the distance–decay function shows very similar behavior with low interaction intensity and no significant change between 1998 and 2019 (Table 2 and Figure 3).

**Table 2.** Data for maritime connections to Pico Island from the rest of the archipelago—for 1998 and 2019.

Destination	Travel Time (Hours) —	Passengers	
		1998	2019
Santa Maria	15,7	40	19
São Miguel	12,0	325	1204
Terceira	5,5	1544	2947
Graciosa	3,0	191	633
São Jorge	1,5	6276	25,550
Faial	0,5	130,054	207,240
Flores	12,0	141	132



**Figure 3.** Intensity of interactions and travel time to Pico Island from the rest of the archipelago—for 1998 and 2019.

# 4.3. São Jorge Island

For São Jorge Island, a 1.5 h travel time distance from Pico Island is the only "close" accessibility island, with an interaction intensity around 0.54, increasing from "close to far" range (from 0.43 to 0.54) in 1998. Faial Island, also with a 1.5 h travel time distance, follows at "close to far" accessibility, with an interaction intensity around 0.36, even decreasing between 1998 and 2019 (from 0.43 to 0.36). Far away interactions take place with Terceira Island, at 6 h travel time distance, decreasing from 0.11 (close to far) to 0.06 (far) between 1998 and 2019. These three origin islands show the most significant total number of travelers to São Jorge Island. For the remaining far away islands, the distance–decay function shows very similar behavior with low interaction intensity and no significant change between 1998 and 2019 (Table 3 and Figure 4). From all distance–decay functions for all islands, São Jorge Island is the only one that decay factor decreased between 1998 and 2019, even total travelers raised more than 200%.

Destination		Travel Time (Hours) —	Passengers		
			1998	2019	
San São Te Gi	ta Maria Miguel erceira raciosa Pico Faial	14.7 11.0 6.0 2.7 1.5 1.5	3         20           135         564           1598         2980           317         971           6306         25,371           6323         16,932		
0.6		10.0	/1		
0.5	•		y <sub>2019</sub> = R <sup>2</sup>	= 0.9179x <sup>-2.301</sup> = 0.9046	
of interac 0.3			y <sub>1998</sub> = R <sup>2</sup>	$0.9965x^{-2.336}$ = 0.9339	
Intensity 0.1		•			
		<sup>1</sup> 11			

**Table 3.** Data for maritime connections to São Jorge Island from the rest of the archipelago—for 1998 and 2019.

**Figure 4.** Intensity of interactions and travel time to São Jorge Island from the rest of the archipelago—for 1998 and 2019.

Travel time

8

10

12

14

16

• 1998 • 2019

## 4.4. Graciosa Island

0 4

2

4

6

The distance–decay function for Graciosa Island shows no "close" accessibility and only three with "close to far" accessibility coming from Terceira, Pico and São Jorge, which are all around 3 h travel time distance range to Graciosa. The interaction intensity maximum is 0.37 from Terceira Island (1998) followed by 0.36 from São Jorge Island (2019) and 0.20 from Pico Island (1998). Those three islands account for more than 85% of all travelers to Graciosa Island. Interaction intensity did not change much through time from 1998 to 2019, related to all islands. That intensity is slightly higher for São Jorge, São Miguel and Flores Islands and slightly decreased for Terceira, Faial, Pico and Santa Maria Islands in 2019 (Table 4 and Figure 5).

**Table 4.** Data for maritime connections to Graciosa Island from the rest of the archipelago—for 1998 and 2019.

Destination	Travel Time (Hours) —	Passengers	
Destination		1998	2019
Santa Maria	11.7	29	14
São Miguel	8.0	49	126
Terceira	3.0	844	1769
São Jorge	2.7	681	1854
Pico	3.0	461	962
Faial	5.0	210	383
Flores	13.0	71	114



**Figure 5.** Intensity of interactions and travel time to Graciosa Island from the rest of the archipelago—for 1998 and 2019.

## 4.5. Flores Island

Flores Island only shows "close" accessibility for Corvo Island's 1.4 h travel time distance range, with the highest interaction intensity of 0.70 recorded in the more recent year. For 2019, all remaining islands stay at "far" range, totaling 30% of all travelers to Flores Island. Indeed, Corvo Island only receives travelers from Flores and that is why no distance–decay function for Corvo was possible to estimate. In contrast, 1998 shows no "close" accessibility and four islands in "close to far" range, namely, Corvo, Faial, Pico and Terceira Islands, which account more than 85% of all travelers to Flores Islands. From 1998 to 2019, interaction intensity strongly increased for Corvo, and decreased mainly for Faial, Pico, Terceira and São Jorge Islands (Table 5 and Figure 6).

**Table 5.** Data for maritime connections to Flores Island from the rest of the archipelago—for 1998 and 2019.

Destination	Travel Time (Hours) —	Passengers	
		1998	2019
Santa Maria	27.2	1	1
São Miguel	23.5	162	173
Terceira	19.0	464	210
Graciosa	14.0	16	45
São Jorge	13.0	255	99
Pico	12.0	355	103
Faial	9.0	578	266
Corvo	1.4	1282	2058

## 4.6. Terceira Island

If we focus on Terceira Island (Table 6 and Figure 7), it is possible to verify that if a hub should be addressed in the Azores, Terceira Island would be the chosen one. Five in seven islands are "close to far" and only Flores and Santa Maria Island are far away accessibility. Graciosa Island, with a 3 h travel time distance, has the highest interaction intensity (0.28) and Flores Island's 19 h travel time distance has the lowest interaction intensity (0.02). In 2019, all five "close to far" accessibility islands accounted for 95% of all travelers to Terceira Island. Intensity interaction did not change much between 1998 and 2019 for Terceira Island.



**Figure 6.** Intensity of interactions and travel time to Flores Island from the rest of the archipelago—for 1998 and 2019.

**Table 6.** Data for maritime connections to Terceira Island from the rest of the archipelago—for 1998 and 2019.

Destination	Travel Time (Hours) —	Passengers	
		1998	2019
Santa Maria	10.0	501	293
São Miguel	4.5	937	1581
Flores	19.0	492	200
Graciosa	3.0	1923	2666
São Jorge	4.6	1504	1971
Pico	5.5	1253	1534
Faial	6.5	987	1125



**Figure 7.** Intensity of interactions and travel time to Terceira Island from the rest of the archipelago—for 1998 and 2019.

# 4.7. São Miguel Island

São Miguel Island has the highest interaction intensity with Santa Maria Island at 3.7 h travel time distance, being the only one with "close" accessibility, even losing 22% in

interaction intensity between 1998 and 2019, from 0.78 to 0.56. Terceira Island, at 5.5 h travel time distance, remains at "close to far" accessibility, even increasing 18% in interaction intensity between 1998 and 2019, from 0.11 to 0.29. Those two origin islands account more than 85% of all travelers to São Miguel Island. For the remaining islands, all far away, the distance–decay function shows very similar behavior with low interaction intensity and no significant change between 1998 and 2019 (Table 7 and Figure 8).

**Table 7.** Data for maritime connections to São Miguel Island from the rest of the archipelago—for 1998 and 2019.

Destination	Travel Time (Hours) —	Passengers	
		1998	2019
Santa Maria	3.7	8281	9753
Terceira	5.5	1170	5082
Flores	26.0	149	192
Graciosa	8.0	49	279
São Jorge	11.0	162	487
Pico	12.0	359	1199
Faial	14.0	471	427



**Figure 8.** Intensity of interactions and travel time to São Miguel Island from the rest of the archipelago—for 1998 and 2019.

## 4.8. Santa Maria Island

The highest interaction intensity from all distance–decay functions is found in Santa Maria Island, considering travelers from São Miguel. For sure, being the only two islands in the Azores oriental group, 3.7 h travel time apart from each other, and more than 10 h away from the remaining Azores islands are the main factors for interaction intensity higher than 0.96. With the remaining islands, Santa Maria has minimal or almost no interaction. However, there were no significant changes between 1998 and 2019 interaction intensity, and the estimated decay function factor increased from 1998 to 2019, denoting the effect of higher demand from travelers for Santa Maria Island (Table 8 and Figure 9).

Destination	Travel Time (Hours) —	Passengers	
		1998	2019
São Miguel	3.7	8281	9836
Terceira	10.0	101	291
Graciosa	14.0	29	10
São Jorge	14.7	3	35
Pico	15.7	40	18
Flores	29.7	1	1
Faial	17.7	36	18

**Table 8.** Data for maritime connections to Santa Maria Island from the rest of the archipelago—for 1998 and 2019.



**Figure 9.** Intensity of interactions and travel time to Santa Maria Island from the rest of the archipelago—for 1998 and 2019.

# 5. Discussion

Estimated decay function factors increase from 1998 to 2019 in all cases, except for São Jorge Island which slightly decreased, showing that over the 21 years travelers have intensified their demand to neighboring destinations with low travel times. In fact, from all distance–decay functions we can see that the closest islands in 1998 got even closer in 2019, being Pico Island to São Jorge Island and Corvo Island to Flores Island, respectively, which is a clear example. In these two particular cases this was, at least in part, due to the improvements in transportation infrastructure and equipment completed on both islands between 1998 and 2019, making connections more reliable. Additionally, the most distant islands in 1998 got even further apart in 2019. This evidence is more prominent for Flores and Santa Maria Islands, the western and eastern islands of the Azores archipelago, respectively.

The two more populated islands, São Miguel and Terceira, account for 80% of the Azores inhabitants, and seem to play different roles in terms of accessibility. Terceira Island's central position, interaction intensity and estimated decay functions, shows that if a passenger maritime hub should be addressed in the Azores, Terceira Island would be the chosen one. São Miguel Island, the most developed with roughly 55% of the Azores inhabitants, plays the economic motor of the Azores and is the main air gateway to and from outside the Azores archipelago, being the only ones with low costs airlines, became

more accessible mainly to Terceira Island, Graciosa Island, São Jorge Island and Pico Island, all from the Azores archipelago central group.

All year operations between Faial, Pico and São Jorge for sure contributes to higher interaction intensity between them. Connections with remaining islands are seasonal and just took place in the summer months. Data indeed show more travelers from "close" and from "close to far" islands between 1998 and 2019, compared to "far" islands, as is the case of the triangle formed by Faial Island, Pico Island and São Jorge Island. São Jorge became more accessible from Faial, Pico, Graciosa, Terceira, São Miguel and Santa Maria. On the other hand, and considering the most significant changes, São Jorge increased its accessibility with Pico and decreased with Terceira and Faial.

#### 6. Conclusions

The analysis of distance–decay functions confirmed the unique dominance of some central islands of Faial, Pico, and Sao Jorge over others, and their spatial impact depends on the central location, small travel time values between islands, and an increasing number of passengers. As we can see, both years analyzed show very similar behavior for most of the islands. The dominant position is the central islands, and their coexistence with others in the environment makes them more accessible than other islands. Here, results shows that Terceira Island could claim a rational maritime passengers' hub in the Azores.

As Flores Island is the most western and Santa Maria Island the most eastern of the Azores archipelago, they play opposites, whose positions are "far" from the central group islands, but "close" in terms of accessibility to Corvo Island (second most western) and São Miguel Island (second most eastern), respectively. This geographic condition is responsible for high interaction intensity between Flores Island and Corvo Island, and between Santa Maria Island and São Miguel Island, but significantly reduces interaction with other islands, which results in low accessibility.

Between 1998 and 2019, the number of travellers rose 72,5% in the Azores, increasing on average 2,63% per year. Travellers to São Jorge raised 218% and only to Flores it lowered 5%, with all remain island facing travellers increases. This evidence and research results regarding lower decay factors estimated between 1998 and 2019, with travellers intensifying their demand to neighbouring destinations with low travel times, cannot be disassociated from the role of improvements in transportation infrastructure and equipment completed in all the Azores islands between 1998 and 2019, making passengers' maritime transportation more reliable.

Regarding research contribution to the literature, as far as our knowledge goes, this is the first time this approach and decay functions were estimated to the Azores islands. We intend to contribute to clarify accessibility issues within the Azores archipelago and promote efficient and consequent policies in maritime passengers' transportation.

Additionally, there are important to decision makers to sort/prioritize future improvements in transport infrastructures and equipment, according to the potential increases in travelers between Azores islands. Those improvements could also benefit travel time savings between islands, reducing waiting time at departure and arrivals, in addition to that associated with faster ships.

The main research limitation is related to the coexistence of all year operations with summer months only operations, but we believe this was a lesser evil considering the importance of knowing the reality of maritime accessibility in the Azores archipelago as a whole.

Future research on this topic should include the impact from changes in travel time and consider their value, considering that business, commute and leisure trips are not worth the same.

#### 7. Limitations of the Study and Prospective Research Lines

Although this research extends the experience and knowledge about the main accessibility issues in some insular areas, as is the case of the Azores Islands, substantial opportunities for prospective studies are still required. In fact, to have a comprehensive understanding of all these maritime transportation and efficiency issues in ultra-peripheral territories, we should consider several other factors, besides the ones studied in this article, which might affect traveling trade, the importance of port infrastructure or other activities that could be found in some recent research papers (see: [32,33]). Moreover, for future research, it is also possible to perform correlations related to specific factors which might be necessary for traveling patterns towards the islands—i.e., demography or economy are just a few examples. Furthermore, more years should be analyzed in future research related to this specific territory; thus, a better picture of all these maritime transportation problems will be revealed.

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