

# Modeling Movement of Tourists: Tools and Application in São Miguel Island, Portugal

Armindo Frias<sup>1</sup>, João Cabral<sup>2,\*</sup>, Álvaro Costa<sup>3</sup>

<sup>1</sup> ADVANCE-Advanced Research Centre in Management, CINAV-Naval Research Centre, ISEG/UTL-Lisbon School of Economics & Management, Lisbon, Portugal,

<sup>2</sup> CIMA/UE-Research Centre in Mathematics and Applications of Évora University, UAC- Azores University, Ponta Delgada, Portugal

<sup>3</sup> Research Centre for Territory, Transports and Environment, FEUP- Faculty of Engineering of the Porto University, Porto, Portugal

\*Corresponding author's email: jcabral [AT] uac.pt

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**ABSTRACT**— *Tourism contributes to the development of many regions. Different factors affect the movement of tourists within a destination. Those factors are related to the tourist characteristics, like the time budgets, preferences or destination knowledge, and to the destination features, like the attraction characteristics or accessibility level. Tourist decisions aren't always done in a rational way. Emotions add further complexity to the human decision process. The use of footpaths can play an important role in the satisfaction of tourists, helping them discover the territory and giving them access to different types of attractions.*

*The existence of a mathematical model that integrates the main factors related to the movement of independent tourists within a destination, in a dynamic way, will make possible the creation of an adaptable software tool. This tool will meet the specific needs of tourists, allowing the use of the network in an optimal way by the different tourist profiles, and the needs of the regional government and business, permitting better decisions and the offer of relevant tourism products.*

*This article identifies the main tourists' mobility criteria in the São Miguel island territory, Azores, Portugal, recognizes the necessary modelling process and identifies the basis for the construction of the mathematical model that explains the movement of tourists within the destination.*

**Keywords:** logistics, mathematical modulation, networks, regional development, tourism

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## 1. INTRODUCTION

Tourism is a complex activity that joints multiple stakeholders and socioeconomic interactions (Costa & Baggio, 2009). We can identify stakeholders from the private and public sector, singular and collective, service providers and consumers, with direct or indirect involvement. Between them, different relationships are carried out over space and time. Beyond great complexity, tourism is also a dynamic network system. A network event is never an isolated thing, it is always influenced by the players' characteristics, the kind of relationships established among them and the surrounding context. But in turn, the event will influence stakeholders and the relationships that are established in their neighbourhood.

Networks, especially social networks, aren't isolated systems and are impossible to identify unequivocally its boundaries (Costa & Baggio, 2009). Different political decisions can affect a network and a player can interact and perform different roles in different networks (Dredge, 2006). Because networks theoretical construct is adapted to the analysis of complex problems, with many variables interconnected in a dynamic way, it is suitable to study tourism activity in multiple approaches. One of the main advantages of studying tourism with the networks approach refers to the ability to analyse the event of a phenomenon in several distinct networks and the interconnection among them (Dredge, 2006). This position enlarges the tourism study perspective to the existence of multiple parallel networks superposed at multiple levels and with the existence of different interactions among them. This idea is the basis for the initial construction of our model.

The importance of tourism to the national and regional development, in its different forms, is recognized by many studies (Debbage, 1991) (UNWTO, 2015). The Azores region is no exception, quite on the contrary, since it integrates the specificities of an island located at the outermost territory of Europe. The existence of footpaths can be an important instrument in tourism development, particularly in green sustainable tourism. Footpaths are an important tool to promote environmental and social education, endorsing a greater knowledge and respect of our heritage. The use of footpaths attracts and provides a better access from foreign in to rural areas, contributing to the socioeconomic development of that area, minimizing human desertification and giving benefits to a set of different support facilities like eating and accommodation places (Braga, 2006) (Midmore, 2000). We can say that footpaths are an important factor for the tourism activity and to the development of many regions.

The understanding of the tourist movement within a destination has significant consequences for the tourism product improvement, allowing local stakeholders to develop a better customized offer to the different needs of tourists (Zoltan & McKercher, 2015). To understand the use of footpaths, we must identify the factors that influence the mobility of tourists in the region. From the literature analysis, the mobility associated with the tourist movement has been widely investigated, but the mobility within a destination denotes some scarcity of study (McKercher & Lau, 2008). As mentioned by Kitazawa and Batty (2004), there is a clear need to develop new models that can explain the movement of pedestrians.

The choice of the São Miguel Island territory to carry out this study is due to the combination of several factors associated with the unique characteristics of the region, in particular the fact that the territory integrates a large number of natural, social and cultural attractions, the fact that the population is dispersed all around the territory and the high level of security in the region. These features allow tourists to walk freely through the territory, according to their preferences, in interaction with local populations. Another element relates to the advantages that isolated territories, including islands, have to carry out scientific studies, providing scientists the delimited ideal microcosm to conduct their studies, with high levels of success in the past (Baldacchino, 2008) (Deschenes & Chertow, 2004).

Based on the authors' previous research (Frias & Cabral, 2013) (Frias, Cabral, & Costa, 2014) this article aims to identify the theoretical bases that allow to carry out the mathematical modeling of the movement of tourists in the area under study. Through this model it will be possible to create computer tools that improve the mobility of the tourists, to develop the tourism offer and, at the same time, provide the development of the region as a whole. This study is organized as follows: section 2 analyses the movement of tourists, identifying the main factors that influence their decision-making process in the choice of sites to visit; section 3 presents the mathematical modelling process; section 4 explains the basis for the model; finally, section 5 presents some conclusions.

## 2. FACTORS THAT INFLUENCE TOURISTS' MOVEMENT DECISIONS

The tourist decision-making process has two different stages, namely: (1) a previous travel planning, to define the destination and the general trip parameters; (2) a travel modification, during the journey to adjust and define the details (Bansal & Eiselt, 2004). In both cases, there are a large number of factors that influence the tourist destination attractiveness. Those factors can be divided into two main components, the ones related with tourist site attributes and factors related to the tourist intrinsic condition. According to Lau and McKercher (2007) the factors related to the human condition push tourists to the destination and the physical site conditions pull the tourists.

The perceived pull motives to choose a destination to tour are core attractions, landscapes and facilities. Since tourists may have previous information about the destination, they want to have not just landscapes, but a tourist service that includes core attractions and support facilities (Correia, Valle, & Moço, 2005). The importance of facilities to support tourism is reinforced by several authors. In this line of thought, Khadaroo and Seetanah (2007) claim that it isn't possible to develop tourism without ensuring the existence of transport infrastructures that enable access of tourists in the territory, such as the existence of airports, seaports and roads. Another development element relates to the availability of a set of basic infrastructure, such as electric, sewer, fresh water, communications, health services and security.

There are many factors that can influence the choice of a destination, each studied author had synthesized them in different categories. In order to summarize them, it was compiled by the authors the main categories factors that influence tourist destination attraction, in figure 1. Each one of the five categories that we found can be related to tourist condition or with physical conditions. Categories like *nature* and *cultural and social events* have a bigger relation to tourism main activities, *leisure and adventure* to the travel motivations and, *socioeconomic environment* and *tourism and support facilities* to the conditions that support the tourism activity.

From the analysis of the previous factors and their relationship with the footpaths, we can say that exists a strong connection between them, namely: (1) *socioeconomic environment*, because it is an activity that doesn't involve a significant financial spending and contributes to the civic formation; (2) *nature*, by allowing direct contact with nature in a sustainable way; (3) *cultural and social events*, for providing a closer relationship with the local population, thus enabling a strong interaction with the local cultural and social events; (4) *leisure and adventure*, the different paths allows a diversity of new experiences and the possibility of relaxation; (5) *tourism and support infrastructure*, of which the tourists are dependent such as accommodation, food and transport routes. Considering that the footpaths have a direct connection with the main factors of tourist destination attractiveness, it may be assumed that the footpaths have an influence on regional tourist attraction.

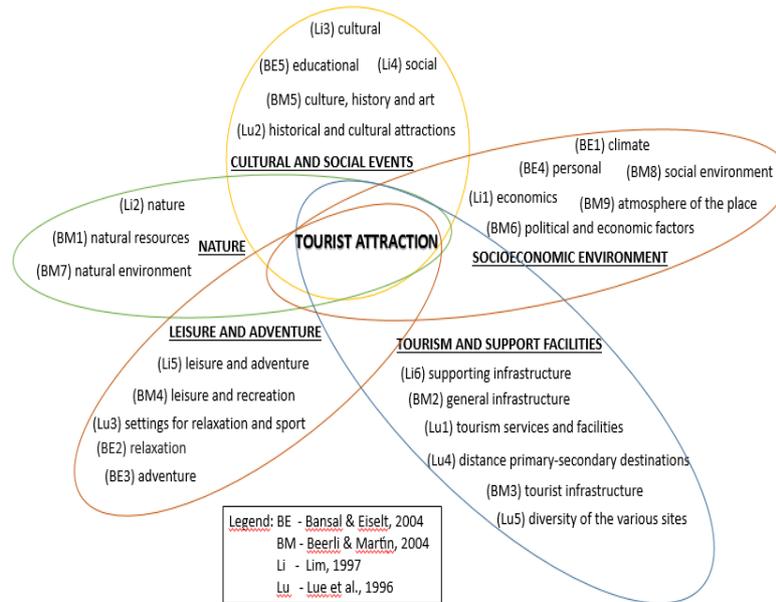


Figure 1: Our composition organizing factors that influence tourist attraction

Looking now for the movement of the tourists within a destination and factors that influence their movement, it turns out that only a small share of world tourism is done to meet a specific interest (Deng, King, & Bauer, 2002). In this sense the tourist tends to seek different experiences, meet different kinds of attractions. In this regard, Lue et al. (1996) conclude that tourists are more likely to choose a multi-attraction circuit, where there are secondary tourism attractions from a different type, compared to the journeys that have similar secondary destinations.

Considering that classify tourist attractions allow to categorize, evaluate and compare the various possible choices, helping tourist with the task of deciding (Fileri & McLeay, 2014), the literature was analyzed to identify factors that influence the tourist decision when they are traveling along the territory, in search of possible classifications for these factors. The authors Lew and McKercher (2006) classify those factors in two large groups, one related to the destination characteristics and other regarding the tourists intrinsic characteristics. The destination characteristics refer to: (A1) trip origins and accommodation location; (A2) trip destinations and attraction locations; (A3) transportation accessibility. Tourists' intrinsic characteristics were divided into: (B1) availability of time (time budgets); (B2) motivations, interests and composition; (B3) destination knowledge and emotional value.

With the intent to understand the spatial behavior of the tourists that visit confined resorts on Paradise Island (Bahamas), Debbage (1991) had identified temporal, spatial, socioeconomic factors and different personality typologies. Of these, he had concluded that the temporal and spatial characteristics have greater explanatory power than the socioeconomics features. In a similar way, studying the movement of tourists that visit the region of Hong Kong, with an independent and individual way, Lau and McKercher (2007) identify a set of factors that they aggregate into human, physical and time factors.

In the study carried out by McKercher and Lau (2008) that attempts to identify the patterns of movement of tourists in the urban environment, it was considered that these are affected by the travel modification, temporal extension of the visit and the level of aversion to risk.

In the bibliography related to the study of the transport mode choice, Masiero and Zoltan (2013), analyzing the correlation between various factors associated with the movement of tourists, including the choice of transport mode and the extension visited in a tourist area of Switzerland. They had clustered the most significant factors in individual characteristics and mode of transport used. According to these authors, the choice of transport mode is influenced by demographic variables and level of knowledge of the territory.

In another study, carried out by Zoltan and McKercher (2015), where the movement of tourists was recorded with the use of an electronic card, they had identified several factors that can influence the movement of tourists, in particular transport mode, familiarity with the destination, origin of tourists, group composition, travel features, destination features, tourist personality and reason for travel.

To summarize the several factors identified in the literature and arrange a clustering method, we have compiled the table 1.

Table 1: Original table composition, which organizes the factors that can influence the movement of tourists

Factors	Debbage (1991)	Lau & McKercher (2007)	Lew & McKercher (2006)	Masiero & Zoltan (2013)	McKercher & Lau (2008)	Zoltan & McKercher (2015)	Our classification
<b>A. Tourist characteristics</b>	---	---	---	---	---	---	---
<b>1. Time budgets</b>	x					x	
Trip length and/or length of stay		x	x		x		x
Time value (allowing to visit ...)			x				
Outcome (destinations) or process oriented (travel) profile	x		x				
Variation along the stay (first day, second ...)		x					
<b>2. Motivations, interests and group composition</b>			x				
Profile (organised mass, individual mass, explorers, adventurous)		x					x
Allocentric or psychocentric profile	x		x	x			
Special interests or generalists			x	x		x	x
Recreation or education oriented			x				
Age and physical disabilities	*		x	*			
Existence of children in the group				*		x	x
Travel group dynamics	*	x	x				
Tourist origin	x					x	
Cultural distance	*						
Level of education, culture	*						
Financial capacity - annual household income	*						
Occupation (white / blue collar)	*						
Travel arrangement (independent, packaged tour)	*						
Personal motivation for the trip	x	x		x	x	x	x
Security perception (risk aversion)				x	x		x
<b>3. Destination knowledge and emotional value</b>			x				
Information sources, gatekeepers			x				
First time or repeat visit, familiarity with the destination	*	x	x	x		x	x
Primary or secondary destination		x	x				
<b>B. Destination characteristics</b>	---	---	---	---	---	---	---
<b>1. Trip origins/accommodation locations</b>			x			x	
Clustered or dispersed			x				x
Type accommodation: hotel, resort, home, other	x		x	x			
Clientele / market segments category			x				
<b>2. Trip destinations/attraction locations</b>			x				
Geomorphology/destination configuration		x					
Number, diversity / types and hierarchy		x	x				x
Clustering or isolated			x			x	
Intervening or substitutable attractions		x	x				x
<b>3. Transportation accessibility</b>			x				
Transport network characteristics		x	x				x
Quality, congestion, cost and affordability, information			x				
Limitations, barriers, distance decay			x			x	
Transportation modes: walking, car, public, tourism	x		x	x		x	x
Choice of transport mode				x			

Note: x - identified with relevance, \* - identified but, not significant in the case study

According to the study carried out by Howley et al. (2012), on the existence of footpaths in rural Ireland, it was concluded that the tourists do not have homogeneous interests. This points out that it is important to recognise the tourist's preferences.

In this particular study, tourists come to the island by air or sea. In the first scenario, most of them came from Europe and North America, and in the second, tourist came from the other Azorean islands or cruise vessels that are accomplishing the transatlantic crossing. Depending on several factors, the movement of tourists on the island is performed using different means of transportation, such as car, bicycle, walking, public transport or specific tour services for tourists. Based on the study of tourism conducted by the Government of the Azores Autonomous Region (RAA) (RAA, 2009) about the tourists that had visited the region in the years of 2005 and 2006, the main age group had between 25 and 54 years old, for an average of 44 years old. As regards to their origin, the majority, 60%, was from Portugal. The North American countries, associated with the Azorean diaspora represent 14.2% and the Nordic countries 14%. The composition of the traveling group is mainly single people or couples, 31.6% and 33.7%, in that order. As a motivation to take the voyage, most of them point out the need to rest and leisure (54.1%), followed by business or work (31.6%) and visiting family or friends (13.2%). Compared to a similar 2001 study, it has increased the number of tourists from the rest and leisure group and reduced the other two groups. In regard to determining the destination characteristics, the first

choice was the nature, peaceful environment and the islands' exoticism. Concerning the activities executed during the stay, only 19.4% walk-through the footpaths. This represents a regression compared to 2001 (30.4%).

It is possible to see that despite the large proportion of tourists that identifies nature, peaceful environment and the islands' exoticism as determinants in the choice of destination, only one fifth used the footpaths, which may represent some contradiction, because a part of the attraction points associated with nature is only possible to visit using the footpaths.

### 3. THE MODELLING PROCESS

Researchers such as Samuelson and Nordhaus (2005) define model as a formal instrument to represent the essential aspects of a complex system, through some fundamental relationships. As for Mooney and Swift (1999), the model is an intentional representation of the reality and when it comes to models built with mathematical principles and tools they are called mathematical models. When applied to the real economy, they transform the complex real world into simplified schemes that allow its study. Chiang and Wainwright (2005) consider that an economic model needs to use a structure that is analytically simplified. This need for simplification is motivated by the extreme complexity of the real economy and because it's impossible to understand all its interrelations at one time. For this reason, Kaewsuwan (2002) supports that economists use models to explain economic processes, to examine an economic issue or to develop a new theory.

Not all economic models assume the traditional mathematical form of equations. Economic mathematics is an approach to economic analysis, where the economists use mathematical symbols and theorems to formulate problems and as an aide to structure the thinking process (Chiang & Wainwright, 2005). The models can take a wide range of layouts, including graphs, charts and diagrams, which can be translated into mathematical equations and then used as the basis of the programming language, in order to produce computer applications (Mooney & Swift, 1999).

The modelling process, according to Mooney and Swift (1999), has four steps, but we can summarize them into three. The first concerns the design of a simplified representation model of the real world. The second relates to the conception of the problem's model, in a practical application and in the case of mathematical models, it refers to the mathematical expression and restrictions. The third step refers to the application of the model to reality, obtaining results to confirm their suitability. This last step undertakes an interactive and dynamic cycle to adjust the model to the real world requirements.

In order to measure the changes that happen in the economy, Kaewsuwan (2002) believes that there should be a development in economic theory, in order to be possible to anticipate the evolution of the economic system itself. To achieve this goal, it is important to make a good historical data analysis, making use of mathematical knowledge and the application of the scientific method. Then, economists apply the modelling process to obtain a model that explains the specific problem. Finally, they test the model and, if confirmed, it may be used as a new economic theory. In the urban traffic management modelling, the most common model used to predict the mobility of pedestrians is the shortest path model. This model can't fully explain human mobility because there are other factors that should be identified in order that the model can interpret the reality of the object under study as closely as possible. Therefore, the models assume a greater explanatory power of reality (Kitazawa & Batty, 2004), whether in urban or rural environment.

To make the present study, several footpaths were identified, official and non-official, independent of the label (footpath, walking trail, trail, rail, pedestrian path, increase to a path, etc.) and it was made its geographical representation using a GIS tool. The beginning and the end of the footpaths were connected using the network of roads and paths. The choice of roads and paths was based on practical knowledge that the authors have from the territory, combining safety with the minimization of the distance and effort spent by the pedestrians. This way it was considered a network that integrates all the island footpaths.

Using the documentation provided by the Regional Government and Travel Agencies that operate in the region, it was carried out the identification of the several nature, culture and social tourist sites available on the São Miguel Island. After that we pinpointed them on the map and drew the network that unites them. The same task was fulfilled for the support infrastructures, namely feeding and accommodation places. The figure 2 gives the example of the accommodation points and the existing footpaths on the island.

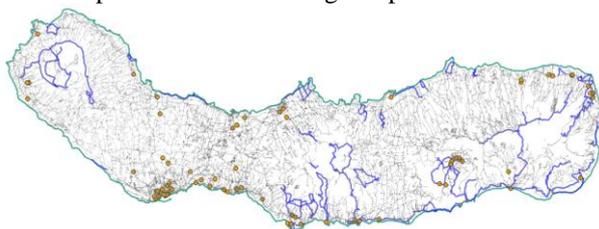


Figure 2: Footpaths and accommodation sites on the São Miguel Island

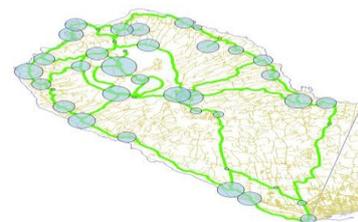


Figure 3: Clustering the vertices

For the networks identified above, we built tables with the identification of its nodes and lengths between edges, as well as adjacency and the distance matrix.

Before starting his walk, a pedestrian tourist that wants to enjoy a particular footpath must calculate the time he needs to do it. To optimize his tour, reduce the time spent on it or to enable the visit to further footpaths or sites, the tourist can

complement his walk with other means of transportation. Therefore, it was also identified the public transportation network on the island and their closest stop points to every footpath. Then, we developed a set of simulations to evaluate the possibility of the walking tourist enjoy the footpaths. To build these simulations, we define some restrictions: the tourist has a fixed location of accommodation, walk for the daylight period and can use the available public transports (bus, taxi, rent car), available either on weekdays or on weekends.

Each of the previously identified networks (footpaths, natural, cultural and social attractions, accommodations, feeding and public transport support facilities) can be represented by a matrix that contributes to the global tourism matrix of the São Miguel Island. We intended to build our model based on a linear combination of matrices that support different levels of the global network structure. Each level generates a graph, from where it will be extracted the corresponding matrix.

#### 4. OUR FORMULATION

To achieve the mathematical formulation that explains tourist mobility, it is necessary to identify the factors that contribute to that movement and their relative weight. The network generated by each variable will be only one dimension of the matrix that will represent the entire model (Dredge, 2006). These partial networks refer to the territory, roads and paths network, logistical support points, public transport and tourist attraction. The connection between the different networks is accomplished through the geographical overlapping of its vertices.

In order to simplify the data processing and to meet the proximity factor and the sense of opportunity, a simplification of the tourism network was performed by clustering points with distances closer than 250 meters from each other. This work permit to identify main vertices, squares, that include several vertices from the partial networks, having a greater power to attract tourists, see figure 3.

Each vertex  $V_n$ , from the global tourism network, will have a value of attractiveness given by the sum of the values of the various vertices of partial networks that exist physically in that place, more or less 250 meters. That value of attractiveness is weighted by the probability value assigned to the preferences of the tourists. The tourist preference is given by the level of utility that tourist perceives that can achieve with the use of the vertex. We can express the value of each vertex (1) as follows:

$$\hat{f}(v_n) = \rho_1 P_{T_n}^2 + \rho_2 P_{N_n} + \rho_3 P_{C_n} + \rho_4 P_{S_n} + \rho_5 P_{R_n} + \dots + \rho_m P_{X_n} \quad (1)$$

Where:

$\hat{f}(v_n)$  – Is the maximum utility that the tourist can achieve with the use of the  $V_n$  vertex;

N - Natural attraction points;

T – Is for the pedestrian paths starting points. Because it is considered that the pedestrian paths have a higher attractiveness value, compering to the other factors, it takes a value with quadratic expression ( $P_{T_n}^2$ ) in the function (1);

C - Cultural attraction points;

S - Social attraction points;

R – Feeding (restaurants) attraction places;

P – Is the weight of each component or set of components in the vertex  $P_{X_n}$ . It's the weight of X category points that exist in the vertex  $n$ . If there are more than one, its weighted is sum. If none exists, it will be assumed that the value is zero;

$\rho_m$  – Represents the utility value assigned to the consumption of each vector, that is, the preference probability assigned by the tourist to each point or set of points;

n - Index assigned to each vertex.

Because the accessibility level to each vertex must be taken into account, as Lew and McKercher (2006, pp. 405-413) theorize, we should incorporate this value into the expression (1), becoming as expression (2).

$$f(v_n) = \hat{f}(v_n) + \sum_{j=1}^k \rho_{m_j} P_{A_j} \quad (2)$$

$P_{A_j}$  – Is the weight given to accessibility.

This becomes because of the integration in the  $n$  vertex of the value of the edge existed between the individual and the location of the vertex in question. It represents the effort that the tourist has to accomplish to reach the vertex  $n$ .

Considering that the goal of the tourist is to maximize the utility level obtained in the throughout the travel, we have to add all the vertices where the tourist will pass. A possible path is identified by the function (3). After obtaining all possible paths, with the implementation of the Dijkstra algorithm, or other, will be obtain the best route.

$$\sum_{j=1}^k f_j(v_n) \quad (3)$$

Each vertex of a subnet (N, T, C, ...) is subdivided into several lower-level categories, each one of them have different specific weights and distinct utility values to each tourist. Considering as an example, the weight of the natural attraction point's network can be express as follows in the expression (4).

$$P_{N_n} = \alpha_1 P_{NM_n} + \alpha_2 P_{NL_n} + \alpha_3 P_{NP\alpha_n} + \dots + \alpha_\tau P_{NPr_n} \quad (4)$$

Where:  $P_{NM_n}$  - Is the  $n$  viewpoint weight;  $P_{NL_n}$  - Is the  $n$  lagoon weight;  $P_{NP\alpha_n}$  - Is the  $n$  natural park weight;  $P_{NPr_n}$  - Is the  $n$  beach weight;  $\alpha_\tau$  - Is the utility value assigned to each consumption vector,  $\tau = 1, 2, \dots, 7$

Within each subcategory of attractions, the weight is defined as the product of factors such as reputation, proximity to other points of interest or the cost of its use.

Because individuals are different, based on initial preferences, possible options can be restricted, therefore achieving a system simplification. As an example, if the tourist had hired accommodation for the whole stay in one place, all other accommodation places assume a null value. Another situation of initial simplification is when the tourist assumes that doesn't intend to visit points of a specific characteristic, in that case, all the points with this feature will take null value. In mathematical terms, if the tourist state that doesn't want to visit churches, every churches points assume a utility value equal to zero and can be imposed the following condition.

$$\sum_{j=1}^n \alpha_{n_j} P_{C_{g_j}} = 0 \quad (5)$$

By its importance, as a scarce resource, the analysis of the viability of each travel must be studied in terms of temporal availability. Consequently, each vertex and edge have an associated time value, that represents the number of time units ( $t$ ) required for tourists to enjoy the total points associated with that vertex or to go through an edge. At the end, the sum of the time units spends on the edges and on the vertices can't exceed the total time assigned by the tourist to the travel.

$$\sum_{j=1}^k t_j \leq t_{max} \quad (6)$$

Where:  $C_g$  - Cultural attraction points from the church type;  $t_j$  - Time unit, having been chosen as standard unit the minute;  $t_{max}$  - Maximum time units available to perform the travel.

The mathematical modelling will provide a better understanding of the patterns of tourists' movement, identifying motivations and limitations. This knowledge, as part of a strategic sector for regional development, allows economic agents and politicians to make better decisions, leading to an optimization of existing resources according to the tourists' real expectations. On the other hand, the mathematical model will allow to build tools that will help tourists to optimize their experience.

## 5. CONCLUSIONS

The small remote island territories are susceptible to natural disasters and suffer from a particular disadvantage in their economic development capacity (Briguglio, 1995). The same properties that put island populations in disadvantage make the islands a useful study site for scientists. The islands are preferred study units, becoming the foundation for significant advances in many scientific areas, because it is a system that can be controlled / constrained in many ways (Deschenes & Chertow, 2004).

It is recognized that tourism triggers a sustained positive effect on economic growth of small countries or regions (Schubert, Brida, & Risso, 2011). The São Miguel Island is located in a remote region of Europe, where tourism is recognized as a strategic aspect of its development; therefore, it makes sense to study the mobility of tourists within the region.

The creation of a mathematical model that enhances the development of the region through customized tourism assumes a great importance in the regional economy and allows building tools that will help tourists, individually, to optimize their experience.

The model that will be developed for the São Miguel Island, because it is based on universal scientific basis, will be applicable to other similar regions, whether island or not, by its adjustment to any region with similar characteristics or an indirect application to regions with different characteristics, after an adjustment process. The authors hope, therefore, to contribute to the advance of scientific knowledge in the area, providing a useful tool for real-world operators, towards regional development.

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