Journal of Simulation

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjsm20

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JOURNAL OF SIMULATION
https://doi.org/10.1080/17477778.2022.2027826

ORIGINAL PAPER

ABM RoutePlanner: An agent-based model simulation for suggesting preference-based routes in Spain

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ABSTRACT
Spain ranks second in the world for the number of international tourists. These tourists have different preferences, which influence their choice of tourist routes depending on the activities offered by provinces. There are currently no routes customised according to the preferences of a travel party, which makes the supply of tourist packages complex. We propose an agent-based model, named ABM RoutePlanner, which simulates the behaviour of travel parties through provinces of Spain. The model is developed as an application of the ODD protocol. This paper makes two contributions. First, we describe a model applicable to the identification of appropriate routes for different combinations of tourists' preferences in some (hypothetical) environments. Second, we present the actual routes that will allow tour operators to define strategic plans that motivate tourists to visit the provinces included in the routes. The simulation model was calibrated with data extracted from TripAdvisor and Spanish tourist surveys.

ARTICLE HISTORY
Received 25 March 2020
Accepted 22 December 2021

KEYWORDS
Agent-based model; simulation; ODD protocol; tourism; routes; web application

1. Introduction

Suggestions of tourist routes are crucial for customised tourist packages. This is particularly the case in Spain, a country comprising autonomous communities that are, in turn, made up of provinces. According to data obtained from the United Nations World Tourism Organization (UNWTO, 2018), Spain ranks second in the world for the number of tourist arrivals. The tourism sector represented 14.6% of Spain's gross domestic product in 2018, amounting to US$190,519 million according to data from the World Travel and Tourism Council (WTTC, 2019).

A travel party has personal preferences that serve as motivation to visit provinces that offer different activities (Kim et al., 2012). Adopting the UNWTO (2008) definition, a travel party is defined as visitors travelling together on a trip and whose expenditures are pooled. Knowing these preferences provides information that enables companies to offer travel packages with personalised routes consisting of sequences of provinces to visit. In addition, knowledge of preferences allows for improvement of public policies, encouraging tourism development in each province, and reducing the risk of making changes to the supply of services that could negatively alter the number of visits to these provinces (Johnson & Sieber, 2011).

Agent-based simulation has been used to study a wide variety of complex and social systems (Negahban & Yilmaz, 2014). To the best of the authors' knowledge, there is no study that analyses suggested routes for different combinations of travel party preferences. Furthermore, the use of data-based methodologies (e.g., statistics) presents two main difficulties (Libai et al., 2013). The first concerns data availability. Data are not usually found in large volumes and are not available to the public. For example, to access the tourism data of Spain in its entirety, one must request the data from a public institution, but this request is not always granted by the institution. The second difficulty relates to data noise. The data, if available, are subject to circumstances that may directly or indirectly affect tourism in the country of study. For example, the data collected during an economic crisis may be influenced by a factor external to the tourism industry.

Our proposal is to suggest tourist routes that adapt to the preferences (e.g., gastronomy) of travel parties who visit Spain. This is achieved via an agent-based simulation approach. An agent-based model (ABM) is a computational model for simulating a real-world system by representing emergent phenomena that result from the interactions of individual agents (Bonabeau, 2002). The implementation of our simulation, which is called ABM RoutePlanner, does not require data representative of all elements to be analysed, thereby avoiding the difficulties of data availability and data noise mentioned above. For our ABM, only a reduced set of data for calibration is necessary. To suggest routes

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in ABM RoutePlanner, a travel party seeks to maximise satisfaction by comparing its preferences with the activities available in each province, and then considering the travel distance relative to its current location (Figure 1). ABM RoutePlanner allows us to analyse the behaviour of these groups (agents in the model) in different scenarios (Davis et al., 2007) and to obtain travel routes based on combinations of preferences, which influence the travel parties' choices among different provinces in Spain. In this paper, the model description follows one of the most highly developed and often used protocols to define ABMs, namely ODD (Overview, Design Concepts, and Details), as an application to simulate tourist routes. The ODD protocol is described in the original works of Grimm et al. (2006), updated in Grimm et al. (2010). To the best of our knowledge, our proposal is the first application of ODD to ABMs in travel tourism.

For the calibration of our model, we considered 23 provinces belonging to the six autonomous communities with the largest number of visits from international tourists to peninsular Spain in 2018. These provinces represent 62% of all visits by international tourists to Spain and 90% of visits to peninsular Spain in 2018 (National Statistics Institute of Spain, 2019). The selected preferences of gastronomy, culture, and nightlife represent the three most popular activities of tourists according to data collected by the EGATUR survey (Turespaña, 2014).[1] In addition, the choice of these preferences is in line with other studies, such as Johnson and Sieber (2011) and Boavida-Portugal et al. (2017). The selected provinces offer several attractions, which are categorised by the type and number of activities available according to data extracted from the TripAdvisor website (www.tripadvisor.com). This website contains information about 7.3 million hotels, airlines, and activities, and it has received more than 570 million views.

This paper makes two practical contributions. The first contribution is the application of the ODD protocol (Grimm et al., 2006) in a new domain: creation/suggestions of tourist routes based on matching users' preferences with places' attractions. In addition, our proposal is validated with data from Spain. Although we can find studies about applications of ODD in tourism in the body of the literature (Amelung et al., 2016; Balbi et al., 2010; Pizzitutti et al., 2014; Pons et al., 2014; Student et al., 2016; Vinogradov et al., 2020), these studies largely ignore, to the best of our knowledge, the creation/suggestion of tourist routes considering these aspects. The second contribution is the suggestions to tourist companies of travel routes in Spain: the different routes have been customised according to the preferences of travel parties. These routes can be used by any Internet user through the Web application presented in this paper.

2. Literature review

In research related to tourism, commonly used analysis tools are structural equation models (Hasani et al., 2016), factor analysis (Prebensen et al., 2010), and logit models (Meleddu, 2014). In this study, we executed an ABM simulation, which allowed us to analyse the interactions and behaviours of tourists in time and space, considering distances and using a smaller amount of data than other analysis tools would require (Johnson & Sieber, 2011). Thus, this section discusses the concepts of tourism, simulation by ABMs, examples of ABMs in tourism, and it also presents a comparative reference frame of ABMs that address the route issue.

2.1. Tourism in Spain

In 2018, Spain received 82.7 million visits from international tourists (UNWTO, 2018), of whom over 87% visited the country for reasons of "leisure, recreation,

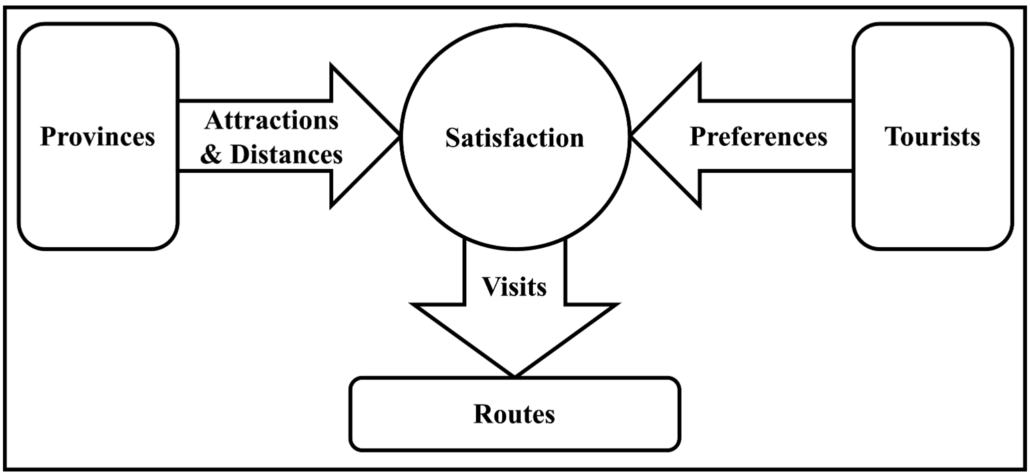


Figure 1. Overview of ABM RoutePlanner.

or vacation", spending US$86.4 million or 87% of the total expenditure by tourists (National Statistics Institute of Spain, 2019).

Tourists' choice of destination is affected by various factors, such as the duration of the stay (Johnson & Sieber, 2008), distance between destinations (Jeuring & Haartsen, 2017), and preferred activities (Boavida-Portugal et al., 2017). Locations and the distance between destinations (Chao et al., 2011) are also factors to consider to attract more tourists (Johnson & Sieber, 2011). In Spain, tourism may be defined by the activities offered by provinces, tourists' preferences, and distances between provinces. When we analysed previous data for Spain, it was possible to identify different levels of satisfaction derived from the connection between the preferences of each travel party and the activities in each province, which motivated visits to different provinces and generated personalised routes.

2.2. Simulation by ABMs

There are many restrictions in modelling using traditional methods; for example, the use of differential equations requires the imposition of unrealistic assumptions, including linearity, homogeneity, normality, stationarity, equilibrium, and rationality (Bankes, 2002; Epstein, 1999). More traditional analytical and regression models have often proven useful because they are computationally efficient. However, as computing power becomes less expensive, it becomes more efficient to employ computational modelling to understand complex systems (Rand & Rust, 2011). The tourism system consists of a large number and variety of actors who interact with each other within a series of natural and socioeconomic systems, and at different spatial and temporal scales. The variety of actors and their various levels of interactions contribute to the complexity of the tourism system (Johnson et al., 2017). Traditional methods of data collection, such as trip diaries, provide a valuable source of micro-level data on tourist behaviour, but the time-consuming nature of collecting even a limited data set makes this an inappropriate source of data for parameterising a model of a broad range of tourist behaviours (Johnson & Sieber, 2011). Simulation approaches, such as ABMs (Neumann & Burks, 1966), make it possible to represent rich behaviour at a micro level, and to derive conclusions at an aggregate level from this micro-level behaviour (Stummer et al., 2015).

Simulation is a technique that allows researchers to generate possible results in (hypothetical) scenarios given a set of parameters. An ABM simulation emulates real-life processes, systems, or events (Davis et al., 2007). To illustrate the main components of an ABM with a concrete example, we can use the simulation of the behaviour of Twitter users (Araya et al., 2019):

- Environment: Space in which agents are located and move. This space, which can be conceptual or concrete, affects the agents' behaviour. An environment can be an urban area, a social network site (e.g., Twitter) or an ecosystem (Nicholls et al., 2017).
- Agent: Representation of autonomous individuals who interact and perform actions that may affect the environment or other agents. For example, each user in Twitter can tweet to its followers to comment about the products or services of a company.
- Action: Act performed by agents in the environment. These acts are guided by a series of rules, and their execution can affect other agents. For example, each user can make a decision to tweet, retweet another message, or just do nothing. If a user (re) tweets a message, other users will receive this message.
- Period: Unit of discrete time in the model. Agents can perform an action for a period equivalent to the unit of time stipulated by the model. For example, in Twitter, a period of time can be one or a couple of hours.

A widely known example of an ABM simulation is the interaction of predators and prey (Smith & Slatkin, 1973). As shown in Figure 2, there is a matrix (environment) in which a specific population of each type of individual (agents; in this example, sheep and wolves) coexists. The objective of predators (wolves) is to feed on prey (sheep), and that of prey is to flee from predators. In period p_0 the population of wolves is two and that of sheep is four. In period p_1, the sheep located in row *a* move one cell to the right and reproduce, while those in row *c* are eaten by the wolves that were previously in *d*2 and *c*4. In this way, the actions of the agents in the environment are represented: that is, the prey's act of reproducing and predators' act of eating prey. In the following periods, when hunting many prey animals, the population of predators increases while the population of prey decreases; this results in an increase in the difficulty of feeding for predators, so that their population decreases, while that of the prey increases. This simulation represents real-life natural processes, which are cyclical because the size of one population affects the size of another.

2.3. ABMs in tourism

There are various ways to simulate tourist decision-making (Nicholls et al., 2017). However, they have in common the intention of ascertaining the level of tourist satisfaction with different destinations. Although an ABM allows us to capture the dynamic individual interactions between tourists

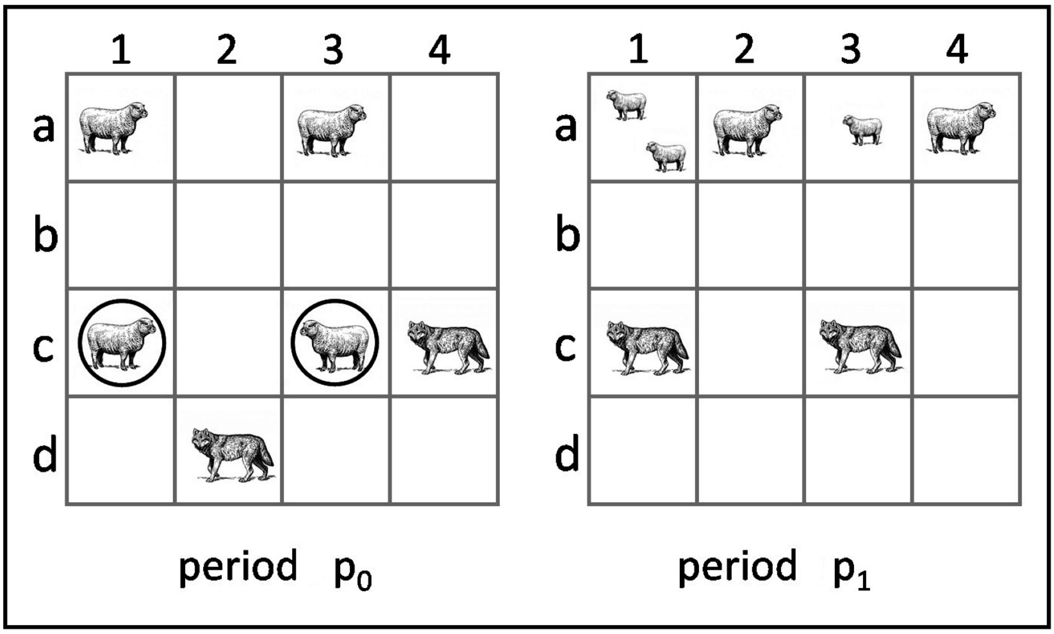


Figure 2. An example of a predator–prey simulation

and destinations, as well as to predict tourist patterns, to date there are few applications of ABMs in tourism research. In the following, we present a series of previous studies that allowed us to create a theoretical framework for ABMs in tourism (Table 1).

Table 1 summarises articles referring to simulations of ABMs developed in tourism, among which are variations in the software used, types of environment (e.g., cities and forests), objectives, types of agents, information used to perform an action, number of destinations, and simulated scenarios. Three examples are described in detail in the following.

Management strategies: Johnson and Sieber (2011) used the TourSim software to examine the impacts of a decline in visits by US tourists to the Canadian province of Nova Scotia. Two different scenarios were simulated. One scenario simulated the effect of a decrease in visits resulting from an economic crisis, and the other considered the use of advertising in response to this lower level of visits. In TourSim, the tourist agent first assessed the level of awareness acquired about the destination, to which the agent had been introduced at random. Next, for an agent to visit a destination, a match between preferences (accommodation and activities) and the potential destination was required. The results showed that by observing how the pattern of tourist visits varies in response to changes in awareness of the destination, it is possible to develop a better understanding of the competition in the destination and the implications of this for the planning of tourism in Nova Scotia. This increased awareness of the destination attracted more tourists to the region, showing the effect of the interactive variables that influence the use of advertising as an adaptation strategy within a competitive tourism environment.

Adaptation strategies to climate change: Pons et al. (2014) analysed the impacts of climate change on winter tourism in ski resorts in the Pyrenees region (Europe) and evaluated the effects of using artificial snow as an adaptation strategy. More specifically, they analysed the interaction between physical variables (accumulated snow and distances between ski resorts) and the socio-economic implications (i.e., possible changes in the number of skiers). In this case, the agents (skiers) carried out a substitution activity and stopped skiing when ski resorts were closed in the area to which they would normally go. The rest of the skiers made a spatial substitution and, by means of a gravity model, were redistributed among the remaining open ski resorts of the region according to the attractiveness of each ski resort and the distance between them. This study shows that ski resorts within the same geographical region can be affected by the response of skiers to poor snow conditions.

Decision-making processes: ABMs have also been developed to improve knowledge about tourists' decision-making processes. Thus, the objective in the study of Boavida-Portugal et al. (2017) was to know where and why tourists take a vacation, using as a case study five cities in the coastal area of Alentejo in Portugal. In this case, the agents were endowed with rationality and their choices obeyed rules that imitated real-life behaviours. For example, the compatibility parameter was based on a match between tourists' motivations and activities in the destinations. They also included more abstract characteristics, such as the influence of tourists' social network sites and the satisfaction the tourists had

Table 1. ABM applications in tourism.

Reference	Environment (No. & type)	Objective	Information used prior to action	Agents	Scenarios
(Li et al., 2021)	China (341 cities and 1,990 attractions)	Understand individual visitors' multi-destination travel patterns and the spatial spillover effects in visitor flows as an aggregate outcome.	Destination duration of stay, agents' time allocation, visitor agents make decisions on attraction choices, detailed information about each attraction.	- Global optimisers - Sequential optimisers - Radial optimisers	Three scenarios are based on 3 different agent categories.
(Vinogradov et al., 2020)	Airbnb in Norway (3 types of properties)	Research different regulatory measures and their specific impacts on Airbnb's growth over time.	Share of properties rented out on long-term basis, total demand for Airbnb services, owners' memory horizon, Airbnb tax, maximum number of nights per month when a property is rented out via Airbnb.	- Properties permanently populated by their owners. -Properties rented out on a long-term basis. - Properties rented out short-term via Airbnb.	(1) Scenario with policy intervention (2) Scenario of no policy intervention
(Alvarez & Brida, 2019)	General destinations (9 destinations)	Introduce a dynamic agent-based model to represent the evolution of destination selections by tourists.	The initial crowding type, destination preference, destination profile, knowledge of individuals about destinations.	- Tourists	Not specified
(Boavida-Portugal et al., 2017)	Alentejo Coastal, Portugal (5 cities)	Measure the effect of individual and social variables to understand the tourist's decision-making process, i.e., where and why they decide to vacation.	Destination preference, individual motivations, last experience at destination, social influence (social networks).	-Tourists (mobile agents) -Destinations (non-mobile agents)	(1) Change in the level of consciousness of the destination. (2) Change in the tourist's individual preferences on the destination.
(Reintinger et al., 2016)	Europe (109 cities)	Estimate future changes in demand and its consequence for European destinations.	Travel distance, destination type, budgetary considerations.	-German tourists -Destinations -Regions of origin	(1) Normal society (trend). (2) Flexible and mobile society (significant consumption of resources). (3) More limited society (scarce resources and importance of environmental concerns).
(Qiu et al., 2016)	Sichuan, China (41 tourist sites)	Forecast the direction and distribution of the tourist flow.	Accessibility of the tourist site, lodging, level of overcrowding, quality of installations.	-Long-distance tourists -Short-distance tourists -Tourist managers	(1) High presence of tourists on the route from Leshan to Panzhihua. (2) High presence of tourists within Zigong. (3) High presence of tourists on the route from Chengdu to Ya'an.
(Li et al., 2015)	Wallonia, Belgium (6 forests)	Know the effect of distance to destination on the dates on which the visit takes place.	Group composition, length of stay, travel distance, land use, level of visits to destinations.	-Single tourists -Couples -Families -Groups	(1) Calculation of the number of visitors. (2) Assessing changes in the travel distance. (3) Assessing changes in the allure of forests.

(*Continued*)

Table 1. (Continued).

Reference	Environment (No. & type)	Objective	Information used prior to action	Agents	Scenarios
(Pizzitutti et al., 2014)	Galapagos Islands, Ecuador (4 Islands)	Identify, through a complex web of interactions, the tourist market system in the Galapagos Islands.	Tourists' individual features, number of tourist activities, features of the accommodation offer (hotels and cruises).	-Tourists -Tourism providers -Market operators	(1) Opening of a new airport. (2) Decrease in tourism from 180,000 to 100,000 visitors per year. (3) Increase in the park fee for tourists.
(Pons et al., 2014)	Pyrenees region, France, Andorra & Spain (41 ski stations)	Explore the change in the skiers' distribution among ski stations due to adaptation of people's behaviour to snow conditions as a result of climate change.	Current snow conditions, travel distance between ski stations, one special feature of each ski station, maximum daily lodging capacity.	-Skiers (winter tourists)	(1&2) Increase in mean winter temperature of + 2 C & +4 C, considering only natural conditions of the snow. (3&4) Add the effect of artificial snow on the base scenarios of + 2 C & + 4 C.
(Johnson & Sieber, 2011)	Nova Scotia, Canada (35 cities)	Measure the impact of a decrease in the US visitors to destinations within Canada.	Accommodation preferences, available activities, maximum travel distance, length of stay.	-US tourists -Domestic tourists -Foreign (non-US) tourists	(1) 10% decrease in visits by American tourists. (2) Increase in publicity by destinations.
(Chao et al., 2011)	Hakone, Japan (5 cities)	Understand the development process of recreational Commercial Districts in tourist areas during planning of sustainable tourism.	Availability of public installations, tourist sites, transportation, number of people.	-Tourists -Residents -Government	(1) Low tolerance to building. (2) High tolerance to building.

with their vacation experience. Two experiments were conducted to explore how variations in knowledge about a destination and in the individual preferences of tourists change the selected destination.

Therefore, it is seen that ABM is an emerging approach in tourism research (Johnson et al., 2017). ABM has much to offer tourism, and indeed the tourism research community has been quite forward looking in its historical investigation and adoption of new techniques, particularly in exploring complexity and systems approaches from a theoretical perspective.

2.4. Comparison of ABMs for routes

The use of ABMs for routes has been studied in diverse fields, such as logistics and transport (e.g., Badland et al., 2013; Batet et al., 2012; Dia, 2002; Elbert et al., 2020; Nasir et al., 2014; Nguyen-Trong et al., 2017; Ukkusuri et al., 2017). In relation to ABMs in tourism (or movement of individuals within a fixed area), Table 2 compares 10 aspects of different ABM proposals. This table compares articles about ABMs on routes, indicating that the articles adopt different approaches and use different types of information sources (e.g., activities, preferences) to generate or assign routes. In order to deepen the analysis, we present a more detailed comparison with three of the papers in Table 2.

Zhang et al. (2013) proposed an ABM to represent large-scale transport dynamics in the city of Shanghai, China. Agents (citizens) were characterised by socio-demographic variables and their employment status. They used routes for the journey from home to places of work and rest. These agents chose a means of transport (e.g., subway) and could, according to certain criteria, such as the probability of transport saturation, change routes.

García-Magariño (2015) proposed software to simulate the assignment of predefined cultural routes to travel parties typified by their composition (e.g., families, friends, couples) in the centre of the city of Madrid, Spain. The results of the simulation were numbers of groups assigned to each route, which established a ranking of routes for each type of travel party. In ABSTUR, routes were not generated or mixed, and only previously defined routes were ranked.

Xiong et al. (2018) showed the use of their proposal in White Flint, Maryland, United States, with the goal of integrating and predicting changes in the travel behaviour of people and in traffic dynamics. In this simulation of an ABM, the agents based their decisions on their personal characteristics and their knowledge of the traffic flow or transport network. The choice of routes varied over time because, as a general rule, agents learned from their own experiences. As a result, the search for new routes was reduced and, in turn, changes occurred in the departure schedules in order to avoid traffic congestion.

Table 2. Comparison of ABMs for routes.

Aspects/Software	(Raney et al., 2003) *No name*	(Kim et al., 2012) *No name*	(Zhang et al., 2013) MatSim	(García-Magariño, 2015) ABSTUR	(Xiong et al., 2018) AgBM-DTALite
1. Generate routes	✓	✓	✓		✓
2. Calibrated with databases	✓	✓	✓	✓	✓
3. Consider activities		✓	✓	✓	
4. Consider agent's preferences		✓	✓	✓	
5. Agents with memory	✓	✓	✓	✓	✓
6. Route scoring	✓	✓	✓	✓	✓
7. Considers agent's learning	✓		✓		✓
8. Validated with real data	✓		✓		
9.Web application				✓	
10. Software used in business		✓		✓	✓

Furthermore, Table 2 highlights two aspects that are still little covered in the tourist route literature. The first is validation with real data. Owing to the absence of standard validation procedures for ABMs in tourism, few studies have validated models (Raney et al., 2003; Zhang et al., 2013). This raises issues for researchers and stakeholders regarding the reliability of the models. Models of complex systems are inherently difficult to validate as a result of the unpredictability of complex systems and the lack of suitable independent data sets for comparison. With an increasingly instrumented world pushing the availability and use of "big data", the challenge of appropriate data for both parameterisation and validation may be partially solved (Amelung et al., 2016). The second aspect is the creation of a Web application. To add value, the creation of an agent-based recommendation Web application is vital to suggest personalised routes to tourists to bring our theoretical model to practice. García-Magariño (2015) took several features of tourist profiles into account for a Web application that recommended a ranking of routes for each type of travel party.

In summary, the literature in tourism does not propose the generation of new routes; rather, it only mixes previously defined routes, and decisions about changing routes are not based on the preferences of agents but on changes in the environment. Agents make decisions based on the type of group/party to which they belong and not on their preferences. In contrast, this paper describes a model applicable to the identification of appropriate routes for each combination of tourists' preferences in some (hypothetical) environments. Moreover, this model is validated with data from Spain, and our work includes a Web application that allows tourists to enter their preferences and the number of stays (no days) to obtain route recommendations.

3. Methodology

This section presents the ABM RoutePlanner proposal as an application of the ODD protocol (Grimm et al., 2006) to describe ABM simulations of tourist routes. First, this section presents our proposal and how it is described using the three components of the ODD protocol. Then, it presents the software architecture of our proposal and its implementation details.

3.1. Overview: Purpose and variables of ABM RoutePlanner

We describe the purpose and variables of ABM RoutePlanner using the ODD protocol. ABM RoutePlanner is graphically summarised in Figure 3(a), which shows how travel parties travel among different provinces (destinations) to define tourist routes. The selection and order of provinces to travel to are determined according to the parties' preferences, distances between provinces, and provinces' attractions. Next, we briefly describe the concepts (variables) used in the simulation:

- Environment: Map of Spain, where agents (travel parties) and visitable provinces (destinations) are. This map shows a journey in kilometres that has to be considered by agents when travelling between provinces.
- Agents: Each agent represents a travel party in real life and has a defined combination of preferences. An agent moves between provinces according to the probability of the agent's satisfaction. This probability is defined through the preferences of gastronomy, culture, and nightlife, and the activities in each province.
- Action: Agents act by assessing their preferences and the travel distance, and then moving from one province to another in order to maximise their satisfaction.
- Period: A period represents an agent's stay in one province.

Grimm et al. (2006) defined a protocol to design ABMs, which is widely used in the existing literature (Amelung et al., 2016; Pizzitutti et al., 2014; Pons et al., 2014; Vinogradov et al., 2020). This protocol comprises three different stages: Overview, Design

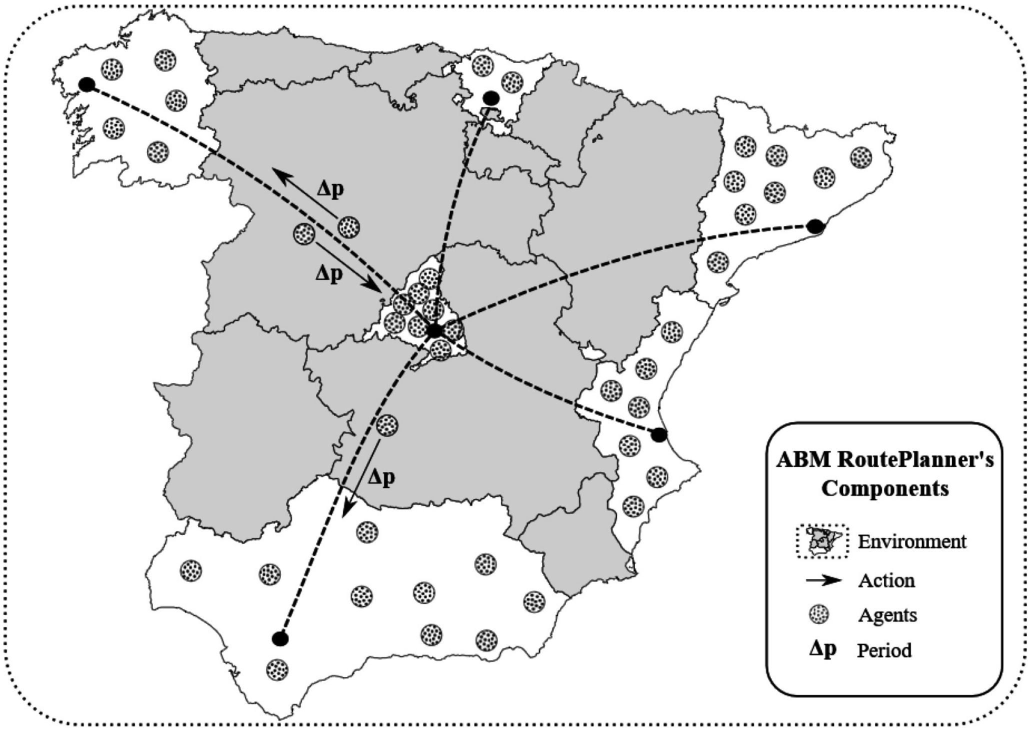
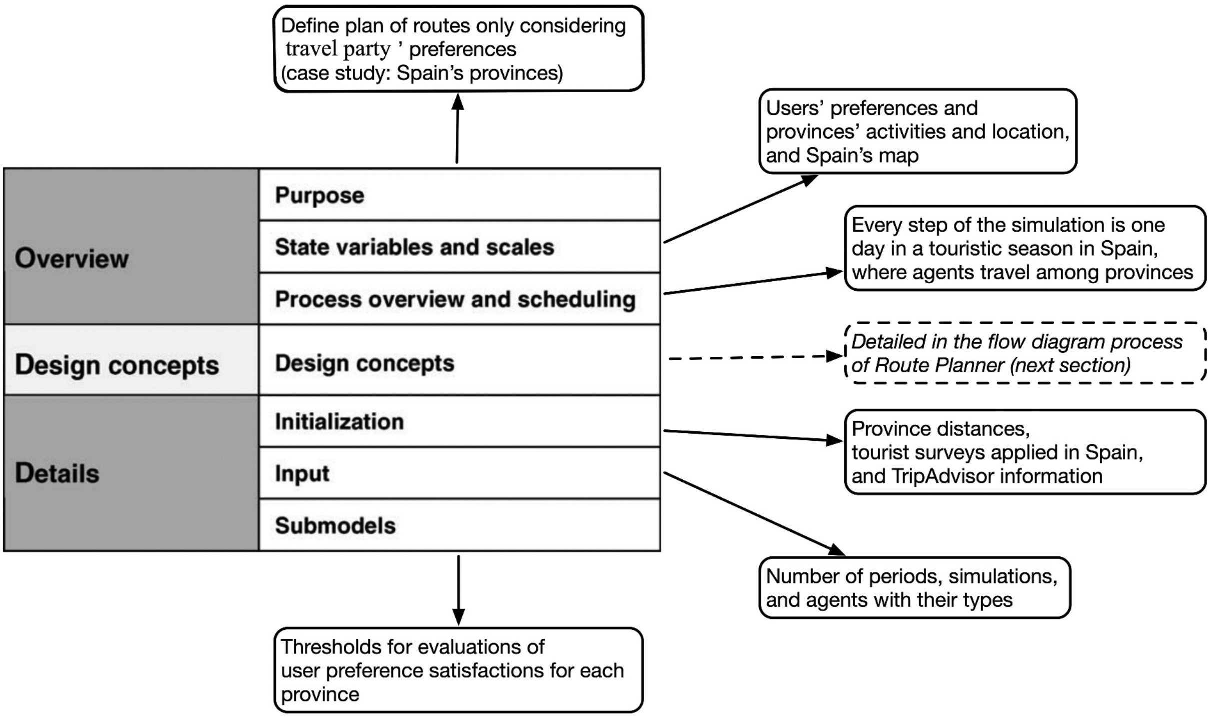


Figure 3. (a): ABM RoutePlanner and its definition model based on the ODD protocol. (b): ABM RoutePlanner and its definition model based on the ODD model.



concepts, and Details. There are three elements of Overview: purpose, state variables and scales, and process overview and scheduling. The first element describes the ABM's purpose, the second establishes the variables that will be used in the ABM, and the third specifies how the environment works and agents interact. In Design concepts, designers express how the ABM algorithm works (e.g., a flow diagram). There are three elements of Details: initialisation, input, and submodels. The first element specifies the data required to calibrate the model (e.g., environmental information), the second one defines inputs required to start a simulation (e.g., periods), and the last one is used to declare particular features of the model. Figure 3(b) shows how ABM RoutePlanner (or other ABMs in travel tourism) is expressed in the ODD protocol. In Overview, ABM RoutePlanner specifies its purpose of defining tourist routes using variables like preferences of users (or agents) and the map of Spain. In Details, we can see that the tourist surveys

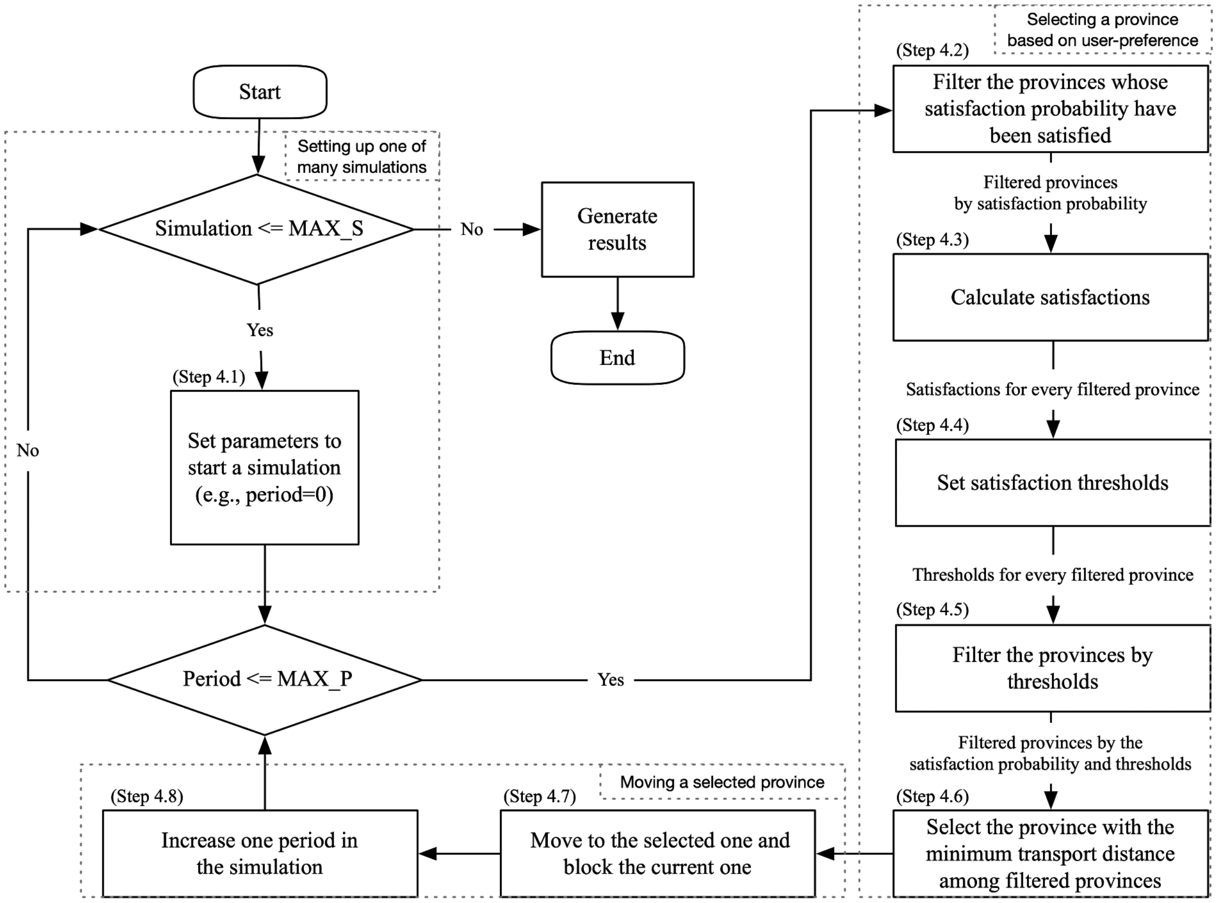


Figure 4. ABM RoutePlanner flow diagram

and TripAdvisor information are used to calibrate the model. In addition, the submodel element is used to specify the particular behaviour of ABM RoutePlanner using three thresholds (high, medium, and low) to rank users' satisfaction regarding their preferences and the activities each province offers. Regarding Design concepts, the next section describes in detail the flow diagram of the main process of ABM RoutePlanner.

3.2. Design concepts: The ABM RoutePlanner's main process

The main process of our proposal is presented in the flow diagram shown in Figure 4. This flow diagram shows the three major steps of the main process in dashed rectangles: setting up one simulation, selecting the province based on users' preferences, and moving towards the selected province. This diagram includes] each action taken by agents, who use equations (1) to (3) to make decisions. Next, we explain each step of this flow diagram, including these three equations.

$$FilteredProvinces = p \in Provinces / P_{satisfaction}(p) \text{ is satisfied} \tag{1}$$

$$Satisfaction(prov_j, a_i) = \sum_{k=1}^{3} preference_k(a_i) * attraction_k(prov_j) \tag{2}$$

$$Threshold(prov_j, a_i) \begin{cases} HighforSatisfaction(prov_j, a_i) \exists_{maximum} \\ MediumforSatisfaction(prov_j, a_i) \exists_{middle} \\ LowforSatisfaction(prov_j, a_i) \exists_{minimun} \end{cases} \tag{3}$$

- Step 4.1 – Set up the simulation. The required parameters are set up to start one of many simulations. This step corresponds to the input element of the ODD protocol.
- Step 4.2 – Filter provinces by satisfaction probabilities (Equation 1). According to the satisfaction probability of each province, a set of viable provinces is selected for each agent. We use this step to remove from the selection a set of provinces that do not satisfy an agent's preferences according to the information provided by TripAdvisor.
- Step 4.3 – Calculate satisfaction by province (Equation 2). Through a weighted sum and following the guidelines of other authors (Li & Liu, 2008; Wu, 2002), each agent calculates satisfaction using its preferences and the province's activities.

- Step 4.4 – Set satisfaction thresholds and assign them to provinces (Equation 3). Three class intervals are defined by measuring satisfaction, resulting in the number of provinces ranging in the categories high, medium, and low in accordance with the satisfaction and travel party. To define these thresholds, we use a range between 0 and the number of activities per 100,000 habitants,[2] where a rule of three sets limits for each threshold. The rationale behind the definition of these three thresholds is based on the psychometric Likert scale (Albaum, 1997), which uses 5 levels (from "strongly disagree" to "strongly agree") of the responses of a qualitative question. We shrunk to 3 levels to group "agree" levels into only one group.
- Step 4.5 – Filter provinces by threshold. Provinces that belong to the highest available interval of thresholds to every agent are filtered.
- Step 4.6 – Select a province. Using filtered provinces, each agent selects the shortest distance from the agent's current location.
- Step 4.7 – Travel to a province. An agent travels to a province to restart the process during the *n* periods established by the simulation.
- Step 4.8 – Increase the simulation by one period, and start a new cycle of interactions between agents of the simulation.

According to Table 2, we can see that ABM RoutePlanner satisfies all aspects described in this table, excepting *Route scoring* and *Agent learning*. The former aspect is not considered because agents use their preferences to define a route and not the route evaluation made by other agents. The latter is not considered because the agents do not repeat a route to generate a learning process and preferences are not learned.

3.3. Details: The calibration of the model

This section presents the initialisation and inputs for the model; that is, data calibration to run a simulation in ABM RoutePlanner. Given that our proposal aims to determine the effects of tourist visits based on preferences, we mainly consider variables that are related to tourist preferences. Table 3 presents a summary of parameters used in the calibration of the model: simulation, provinces, and agents. These parameters come from four databases (Figure 5), and Table 3 specifically shows which database is used for each parameter.

- Provinces: Provinces with a high flow of tourists and that can be accessed by land transport (peninsular Spain) are considered. The selected provinces belong to the six autonomous communities of peninsular Spain that had the highest flows of tourists (90% of all tourists) in 2018 (National Statistics Institute of Spain, 2019). The activities in these provinces are characterised according to a database that contains the number of activities relating to gastronomy, culture, and nightlife available on the TripAdvisor website (www.tripadvisor.com).
- Tourists: Only groups of international tourists who travel for "leisure, recreation, or vacation" for a period equal to or less than 21 days (holiday period), stay in hotels or similar, and are composed of six people or fewer. The different travel parties are typified according to their preferences.

Table 3. Model calibration.

	Parameters	Values	Source
1 Simulation	Number of provinces	23	Most visited provinces in peninsular Spain
	Number of agents	18,000	Number of monthly visitors to the selected provinces during the simulation period (Turespaña, 2014b).
	Number of periods (MAX_P)	10 stays	Maximum number of provinces to visit, with a stay of two days per province, during a holiday period.
	Number of simulations (MAX_S)	800	Ten times the number suggested by Goldenberg et al. (2001) to eliminate the stochastic effect.
1.1 Province	Activities	Gastronomy Culture Nightlife	Activities per 100,000 inhabitants of province according to data extracted from TripAdvisor (2018).
	Distances	Between 65 and 1,348 kilometres	Table "Distancias kilométricas entre ciudades españolas (Spanish)" (Ministry of Industry, Tourism and Commerce, Turespaña & European Community, 2009).
1.2 Travel Party	Preferences	Gastronomy Culture Nightlife	Seven combinations of the three preferences (Turespaña, 2014a).

3.4. ABM RoutePlanner architecture

ABM RoutePlanner was implemented in Java (SE 8) using the IntelliJ IDEA (JetBrains, 2001) editor. To run simulations, we used a MacBook Pro with Mojave operating system, Intel Core i7 Hexa-core of 2.6 GHz with 16GB of RAM. Running each simulation took 4.4 minutes and processing of results took 5 hours in the data management software STATA (StataCorp LLC, 1996).

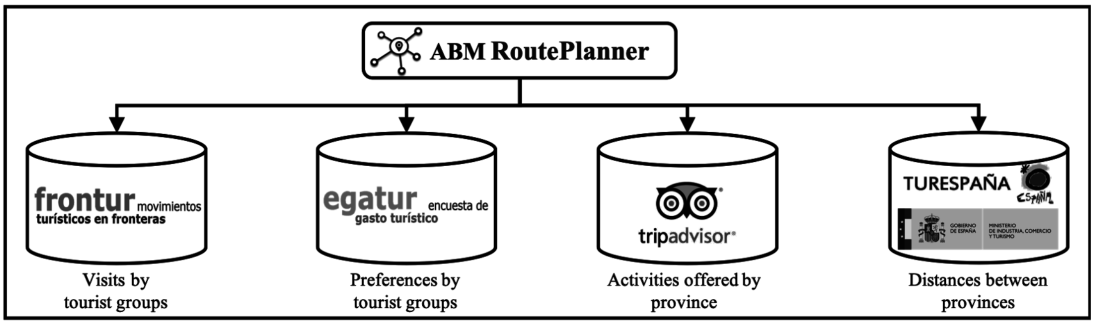


Figure 5. Dataset employed for the calibration of ABM RoutePlanner.

The class diagram extract, presented in Figure 6, contains the main components of the ABM RoutePlanner simulation. The Simulation class contains two instance variables, one of which is Environment and the other is TravelParty. The Environment class contains Province as the instance variable and is associated with the Travel party class. As the types of travel parties differ according to their preferences, we use a factory class to create these groups; from them, the actions are stored in travel logs.

4. Results, validation, and discussion

Using simulation results, this section shows the suggested routes for each combination of preferences of the seven types of travel parties. Additionally, some interfaces of the Java and Web application are shown and explained. The Web application has been created so that Internet users can view the routes recommended by ABM RoutePlanner.

4.1. ABM RoutePlanner results

Using ABM RoutePlanner, we ran 800 simulations to obtain the statistical mode of the routes generated for each type of agent according to their preferences. There were seven combinations of preferences (weighted equally):

(1) Gastronomy – Culture – Nightlife
(2) Culture – Nightlife
(3) Gastronomy – Culture
(4) Gastronomy – Nightlife
(5) Nightlife
(6) Gastronomy
(7) Culture

Using simulation results, we can draw personalised routes for each combination of preferences; these are presented in Table 4, which shows the recommended

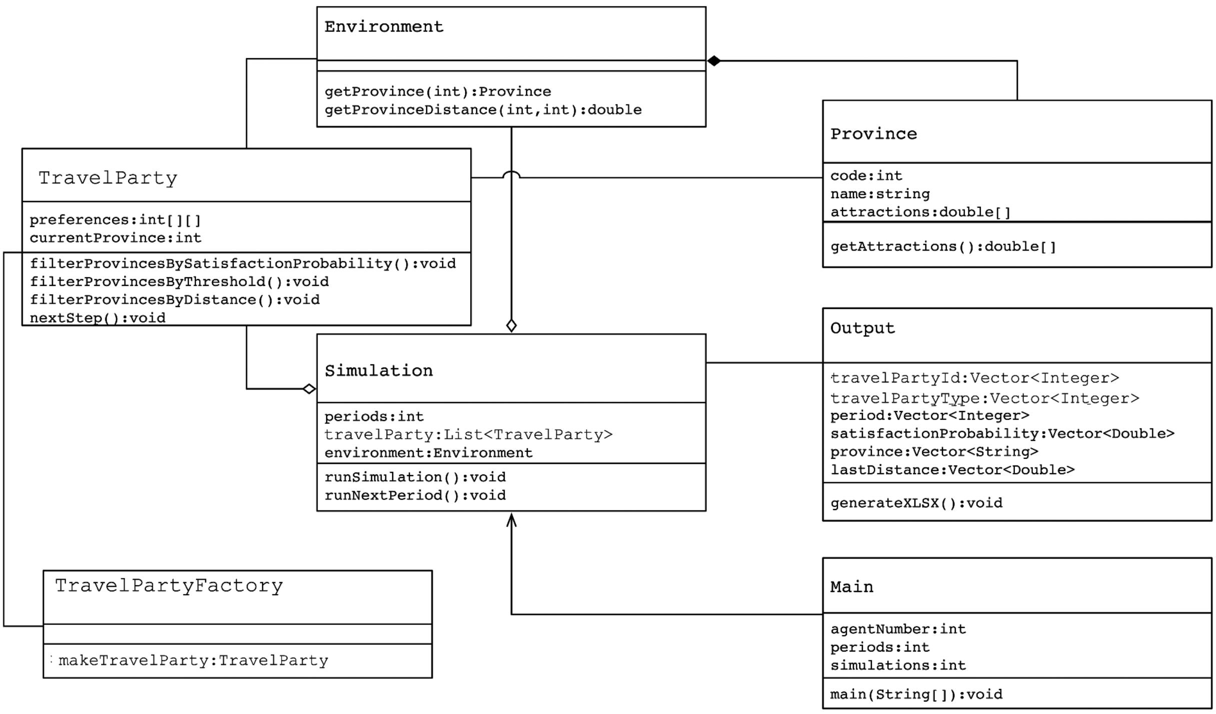


Figure 6. ABM RoutePlanner class diagram.

Table 4. Suggested routes with average days per province for each preference combination.

Stays\Routes by preferences	GastronomyCultureNightlife	CultureNightlife	GastronomyCulture	GastronomyNightlife	Nightlife	Gastronomy	Culture
Stay 1	Girona (6)	Girona (6)	Girona (6)	Girona (6)	Málaga (5)	Girona (6)	Lleida (7)
Stay 2	Tarragona (6)	Tarragona (6)	Tarragona (6)	Tarragona (6)	Alicante (5)	Tarragona (6)	Tarragona (6)
Stay 3	Lleida (7)	Lleida (7)	Lleida (7)	Alicante (5)	Madrid (4)	Álava (2)	Girona (6)
Stay 4	Málaga (5)	Málaga (5)	Álava (2)	Madrid (4)	Girona (6)	Málaga (5)	Málaga (5)
Stay 5	Granada (3)	Granada (3)	Málaga (5)	Álava (2)	Barcelona (4)	Granada (3)	Granada (3)
Stay 6	Jaén (2)	Jaén (2)	Granada (3)	Málaga (5)	Tarragona (6)	Alicante (5)	Jaén (2)
Stay 7	Sevilla (3)	Córdoba (2)	Jaén (2)	Granada (3)	Lleida (7)	Madrid (4)	Córdoba (2)
Stay 8	Madrid (4)	Sevilla (3)	Córdoba (2)	Castellón (5)	Castellón (5)	Biscay (3)	Sevilla (3)
Stay 9	Álava (2)	Huelva (5)	Huelva (5)	Lleida (7)	Gipúzkoa (3)	Gipúzkoa (3)	Huelva (5)
Stay 10	Gipúzkoa (3)	Madrid (4)	Madrid (4)	Barcelona (4)	Álava (2)	Lleida (7)	Castellón (5)

Table 5. Mean length of stay in the 23 provinces, by alphabetical order, according to EGATUR data.

$Average_{stays}$	Province	$Average_{stays}$	Province	$Average_{stays}$	Province	$Average_{stays}$	Province
7	A Coruña	3	Cádiz	5	Huelva	4	Ourense
2	Álava	5	Castellón	2	Jaén	4	Pontevedra
5	Alicante	2	Córdoba	7	Lleida	3	Sevilla
4	Almería	3	Gipúzkoa	2	Lugo	6	Tarragona
4	Barcelona	6	Girona	4	Madrid	4	Valencia
3	Biscay	3	Granada	5	Málaga		

number of days to stay in each province. To determine the number of recommended days, we processed the EGATUR database to create a data set containing the average length of stay of travel parties for each province (Table 5).

4.2. Validation of results and discussion

This section presents the validation and analyses of the simulation results generated by ABM RoutePlanner.

Table 6 presents the validation of the results of our proposal. We undertook two comparisons between the results of the simulation and the real data contained in the EGATUR database (Turespaña, 2014). The first comparison, which considered only visits to the 23 provinces used in ABM RoutePlanner, indicates that 71% of the suggested routes had a match greater than or equal to 50% with the most visited provinces by the corresponding travel party. The second comparison, which considered visits to all of peninsular Spain, shows that the same percentage of coincidence, equal to or greater than 50%, was maintained. Therefore, both comparisons indicate an acceptable validation that the provinces contained in the suggested routes were in fact visited by tourists who possessed each combination of preferences.

The validation results show that the highest degree of coincidence was obtained in the nightlife travel party, with Alicante province being one of the first options in the simulation results and the analysis of the EGATUR database (Turespaña, 2014). Additionally, the differences in the validation results mainly appear in relation to culture, which can be explained by the number of visits to some of the provinces with the highest satisfaction being low. In fact, Lleida and Tarragona provinces stand out in the culture offer compared to other provinces; however, the number of visits to these provinces was not very high according to the EGATUR database. Therefore, although advice is beyond the scope of this paper, we would recommend that tourists visit Lleida and Tarragona provinces because they have fewer than one million inhabitants each and offer a wide range of activities.

We informally discussed these results with Spanish marketing researchers. We can say that the nightlife route highlights the coastal provinces

Table 6. ABM RoutePlanner validation according to generated routes vs frequency of real visits.

	Percentage of matches of the provinces contained in the suggested routes with the provinces most visited in the database, limited to the destinations used in RoutePlanner.	Percentage of matches of the provinces contained in the suggested routes with the provinces most visited in the database, limited to peninsular Spain.
Gastronomy – Culture – Nightlife	60	50
Culture – Nightlife	50	50
Gastronomy – Culture	40	30
Gastronomy – Nightlife	50	50
Nightlife	80	80
Gastronomy	70	50
Culture	40	40
Percentages of at least 50%	71	71

and Madrid (Spain's capital), which Spanish people associate with the best provinces for nightlife. According to Spanish people, empirical knowledge of a gastronomy route must include provinces with many kinds of foods, such as kebabs (Biscay, Gipuzkoa, and Álava) and tapas (Granada and Málaga); our gastronomy route contains these provinces. To get to know the culture of Spain, people must visit the major cities and historic sites. The culture route suggested by ABM RoutePlanner contains, on the one hand, the provinces of the region of Andalusia, presenting Jewish and Muslim Spain to tourists; on the other hand, this route also includes Catalonia's provinces, giving tourists a vision of architectural modernism.

4.3. The ABM RoutePlanner platform and its Web application

The ABM RoutePlanner platform consists of two software applications that together allow tourists and tour operators to access the route recommendations generated by our ABM. The applications that make up the platform are:

- ABM RoutePlanner: A Java Graphical User Interface (GUI) application that takes the execution parameters and performs the simulation using ABM RoutePlanner. Figure 7 shows the user interface for the execution of the ABM RoutePlanner, where we can set up parameters and the base name of the output file.
- MyRoutePlannerAgent: A Web application that allows tourists to enter their preferences and the number of stays (provinces) to obtain route recommendations; these recommendations are displayed on an interactive map of Spain and its provinces.

Figure 8 shows the processing chain of the ABM RoutePlanner platform. First, the ABM RoutePlanner executes the simulation according to the entered parameters, which results in the creation of Microsoft Excel files with routes of all simulations (raw data). Then, using a STATA script file, all the simulations are processed to generate suggested routes in another Microsoft Excel file. Once the file is generated, it is used as an entry for the MyRoutePlannerAgent Web application.

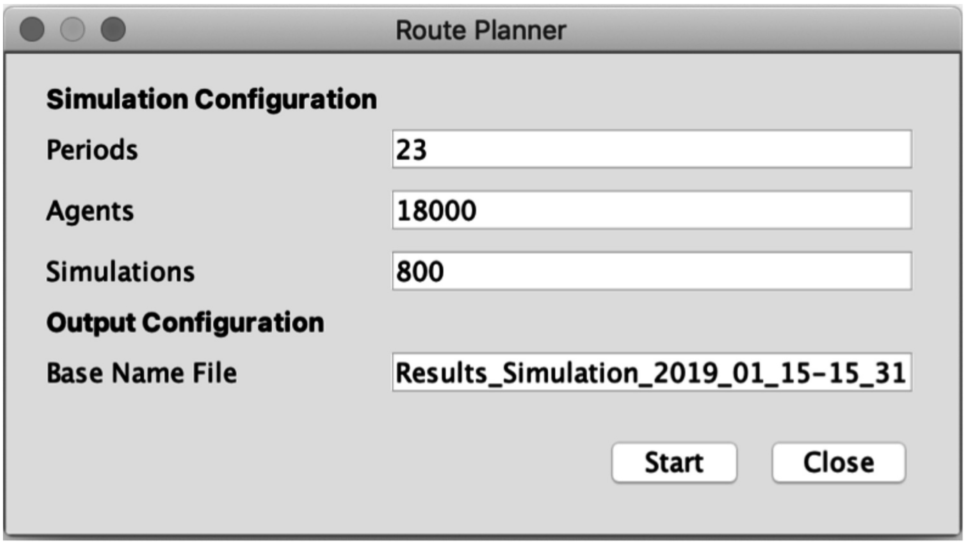


Figure 7. A screenshot of the main UI for ABM RoutePlanner.

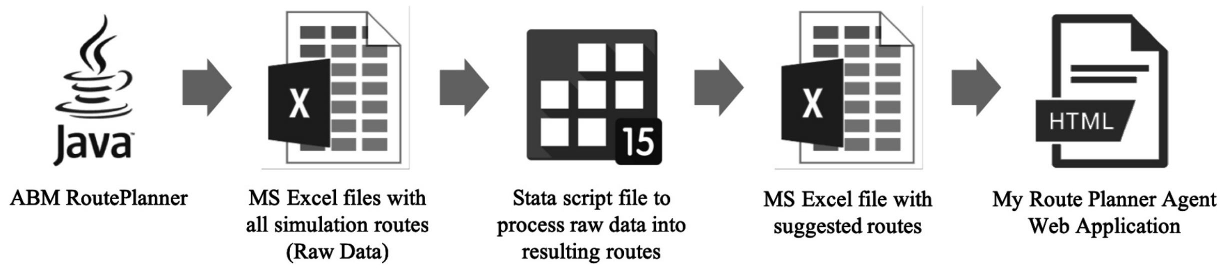


Figure 8. Process to disseminate ABM RoutePlanner results on the Internet.

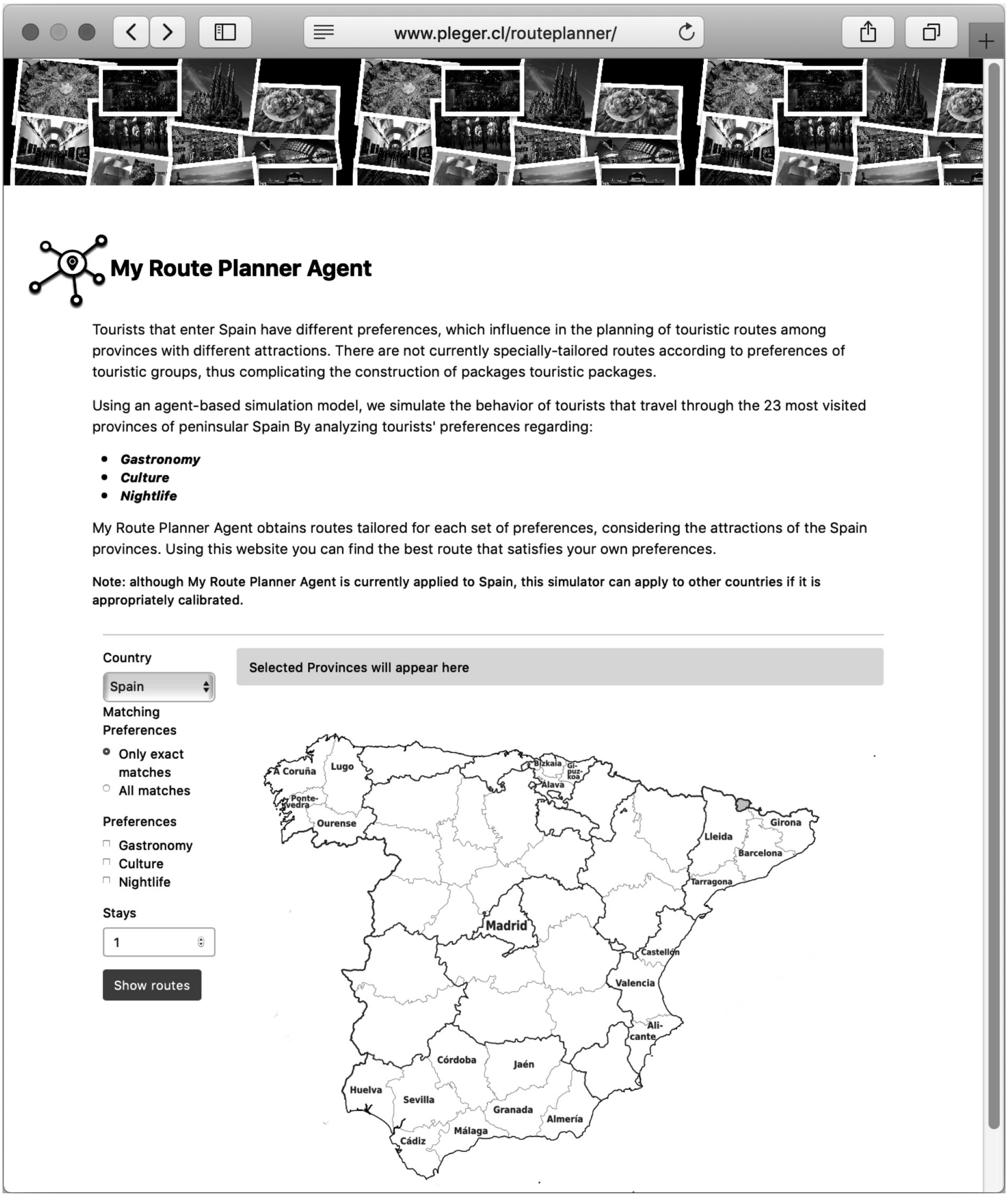


Figure 9. Screenshot of the MyRoutePlannerAgent Web application.

Figure 9 shows a screenshot of the MyRoutePlannerAgent Web application, which, following modern Web development practices, consists of a backend and a frontend. We decided to maintain a minimalist design that allows users to quickly access the routes suggested by ABM RoutePlanner. Figure 10 shows a result of the MyRoutePlannerAgent Web application. First, a country must be selected (for now, only Spain is available). Then, the potential tourist must select one or more preferences, and either an exact or an approximate search selection. An exact search returns exactly one route that fits all the indicated preferences. The ABM RoutePlanner ensures that there will always be a route for a combination of preferences. An approximate search offers a set of possible routes, each of which is associated, at the very least, with the preferences indicated by the tourist.

Once the preferences and the type of search (exact or approximate) have been selected, the tourist has to enter the number of stays (provinces) for a vacation plan. This number can be between 1 and 10. Finally, the tourist must press the “Show Routes” button.

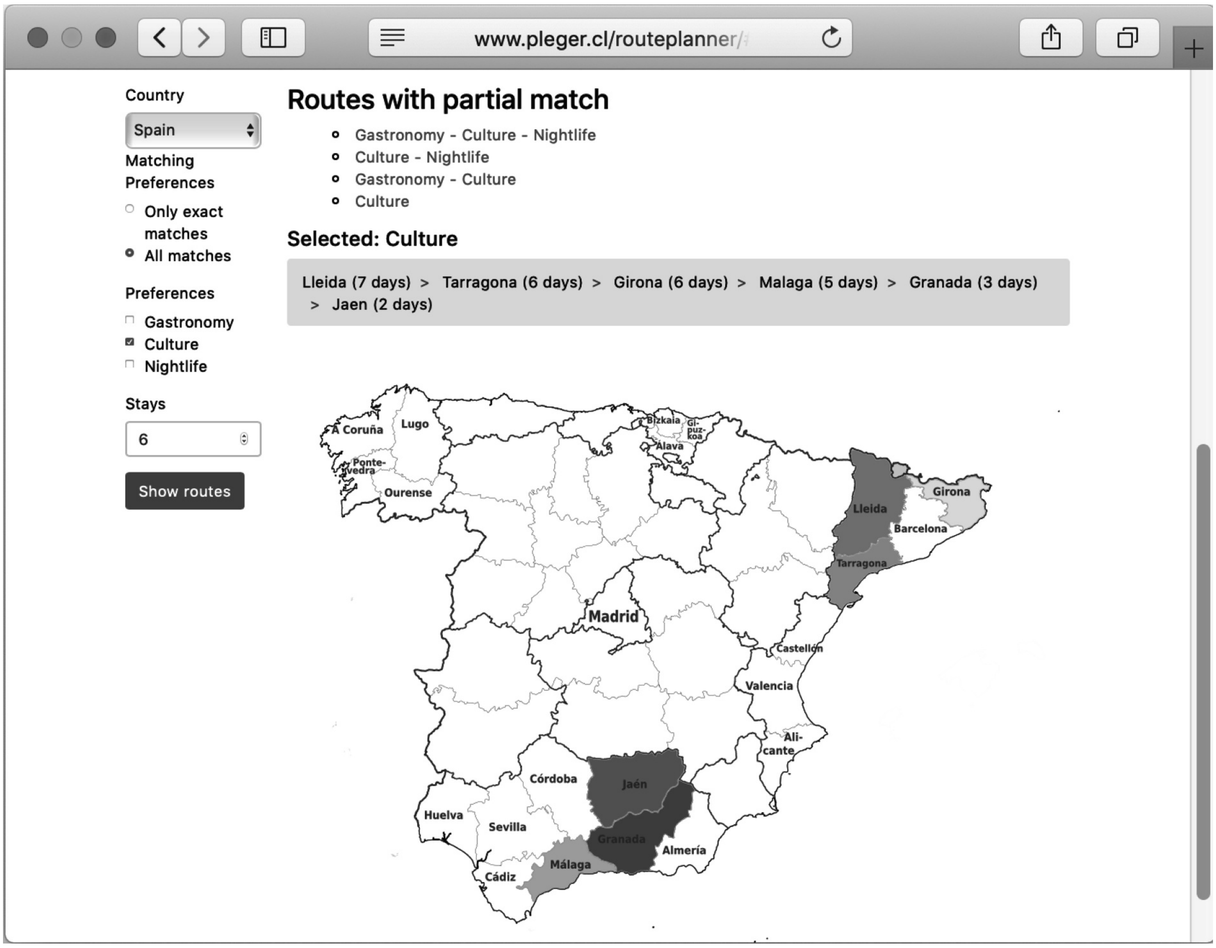


Figure 10. Configuration and results of routes of the MyRoutePlannerAgent Web application.

Once the tourist request has been processed and the route defined, the Web application shows a route that is composed of a sequence of provinces. Each province appears with a suggested number of days of stay. In addition, the provinces belonging to the route are highlighted on a map. If the user adjusts the number of days of stay, MyRoutePlannerAgent automatically adjusts the route offered.

5. Conclusions

An agent-based simulation model applied to tourism increases understanding of tourism processes and tourists' travel patterns. The possibility of representing tourists as interacting agents is one of the benefits of using an ABM, because, using a reduced amount of real data and in a shorter period of time, results can be obtained that can reflect the decisions of tourists (Johnson & Sieber, 2011).

Therefore, ABMs have much to offer tourism, and indeed the tourism research community has been quite forward looking in its historical investigation and adoption of new techniques, particularly in exploring complexity and systems approaches from a theoretical perspective. The degree of complexity and uncertainty inherent in ABM can challenge the communication of simulation processes and results. In response, protocols have been suggested as one way of standardising the communication of model development; Grimm et al. (2006), Grimm et al. (2010) proposed the ODD protocol, which incorporates seven critical elements of how and why an ABM is designed. Similarly, Kornhauser et al. (2009) provided visualisation design guidelines aimed at improving the communication of ABM results. Continuing refinements like these can further illuminate the utility of ABM for tourism researchers and practitioners.

In the field of tourism, there are two contributions of this article. The first contribution is the application of the ODD protocol to a new domain: creation/suggestions of tourist routes based on matching users' preferences and places' attractions. Although we can find studies about applications of ODD in tourism in the literature, these studies largely ignore, to the best of our knowledge, the creation/suggestion of tourist routes considering these aspects. In addition, the software architecture of the model is presented. This model has been validated by comparing statistical models obtained from the outputs of simulations with information obtained from the databases of tourist surveys in Spain. Additionally, given that it is possible to adapt the model to hypothetical scenarios and new environments, its application can be extended by evaluating its operation after incorporating new destinations or applying the model in other countries, as long as those countries can provide detailed information about tourists.

In addition, ABM RoutePlanner has a business application informing tour operators of the activities that tourists prefer in the different provinces of Spain. This is because provinces are classified according to the degree of satisfaction that they provide to travel parties according to the tourists' preferences. The suggested routes, based on a characterisation of the travel parties, are useful for tour operators to offer routes that fit their target audience and promote the activities of each province. For this reason, we created a Web application for travel parties and tour operators that shows the suggested routes generated by the model. In addition, ABM RoutePlanner gives guidelines about defining strategic proposals that improve the supply of services and increase visits to the different provinces. While it is true that international tourist trips with package tours have worked well for a long time, this is no longer the case. The majority of international tourists who visited Spain in 2020 travelled independently (Statista, 2020). This is not something caused by COVID-19, as 70% of the 57.6 million international tourists who visited Spain between January and November 2014 did so independently (FRONTUR, 2014). Thus, this methodology can also be used by regional and national destination management organisations to suggest routes to independent visitors planning their country/region tour online.

5.1. Limitations and future outlook

Despite the strengths of using an ABM to represent tourism, there are several limitations and simplifications in the development and use of ABMs. Some of these issues may be addressed in future studies.

In the first versions of our proposal, we considered variables like budget, cost of transport, and cost of accommodation, but these variables were discarded. The principal reason was that ABM RoutePlanner's results did not vary if these variables (which were calibrated with the EGATUR database) were used. It is important to recognise that budget and costs – which were not considered – are closely interwoven with and often heavily impact on preferences. So whilst not incorporated explicitly, they can provide an implicit influence.

In order to simplify the model and prevent results that are not based on preferences, this study selected only one distribution centre and assumed that all tourists start their journey from this central location (Madrid). Using multiple entry points potentially improves the comparison of simulation results and reality. Moreover, the validation of the model's results is a central challenge in the modelling process. We used real data from the EGATUR database to validate RoutePlanner. For future studies, it may be more appropriate to gather primary validation data rather than trust secondary data sets.

There are several challenges in developing and implementing tourism applied ABMs; for example, a lack of available micro data sets, the model validation process, and the lack of a standardised documentation procedure to enhance transparency and facilitate model replication by other researchers. Furthermore, the gap between academic research and tourism practitioners makes the communication and acceptance of ABM results more difficult.

Notwithstanding, ABM can be a useful tool for tourism researchers and stakeholders in producing new insights in tourism about system dynamics, and providing a social laboratory to experiment with "what-if" scenarios or more empirical models that can replicate real-life problems. Moreover, ABM adds value to tourism, especially as the modelling, simulation, planning, and building recommendations of routes can speed up decision-making and save time and costs, both for tour operators and independent visitors.

Notes

1. In Spain, the institution behind the EGATUR survey provides annual and complete information only up to 2014. From 2015, another institution, INE, has been in charge of distributing this information; however, this information is no longer completely public and accessible. For this reason, we often resort to EGATUR survey data.
2. The use of "per 100,000 habitants" to define the impact of human behaviour or conditions in a population within a territory: https://www.paho.org/spanish/sha/be_v23n3-estandariz.htm.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Availability of the software and web application

The ABM RoutePlanner software and its associated Web application are available at: http://github.com/vapg/routeplanner - http://pleger.cl/routeplanner

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