APPROACHING TOURISM SUSTAINABILITY USING THE MULTI AGENT BEHAVIOR SIMULATIONS' FRAMEWORK

(DRAFT VERSION)

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SOMMARIO

Il rapido e spesso incontrollato sviluppo turistico di alcune località tende a provocare un preoccupante progressivo depauperamento delle loro risorse naturali, sociali e culturali. Di conseguenza, tali destinazioni divengono meno attrattive, intaccando contemporaneamente la qualità dell'esperienza turistica e il livello di soddisfazione della popolazione. Per questi motivi, negli ultimi decenni si è data crescente importanza all'individuazione di strumenti idonei a gestire la sostenibilità dello sviluppo turistico soprattutto in modo preventivo, nella pianificazione sia di breve sia di lungo periodo. Diversi approcci sono stati suggeriti, quali la Capacità di Carico Turistica o il "*Limits of Acceptable Change*" (LAC) oppure ancora il "*Visitor Impact Management*" (VIM).

Il presente lavoro, partendo da tali approcci, presenta i primi risultati di un progetto di ricerca volto a sviluppare un framework – chiamato MABSiT (*Multi Agent Behavior Simulations in Tourism*)-, capace di simulare i comportamenti degli attori (residenti e turisti), le loro interazioni e il conseguente cambiamento del livello di soddisfazione di un'ipotetica cittadina balneare in diversi momenti temporali.

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1 Introduction

In the last decades the increasing facility in moving and the simultaneous fall of the transportation costs have strongly increased the tourist flows. Tourism has become an important industry for stimulating economic development due to its extensive contribution to gross domestic product, employment, international exchanges and government revenues. In several destinations, mainly in the Mediterranean area, tourism quickly developed in a unplanned and casual manner, transforming or even destroying natural, cultural and social resources (Saveriades, 2000). An uncontrolled tourism development can cause a reduction of the satisfaction levels of both tourists and residents. From one hand, the deterioration of the resources makes less attractive the destination, causing a progressive decrease of tourism, till a complete decline of the tourist destination with negative effects on its economy. From the other hand, a massive presence of tourists reduces the level of tolerance of the host population, worsening the life quality of residents. Thus, one of the core issue of tourism sustainability is the necessity to avoid that excessive tourist flows cause both a decline in the quality of the tourist experience (as a result of the environmental and social resources' deterioration) and a decrease of life quality of host population.

In order to avoid these problems, policy makers should be able to promote a sustainable development of tourism, planning and implementing effective and pro-reactive protection policies. Nevertheless, the literature on tourism sustainability and on Tourist Carrying Capacity (Washburne, 1982; Stankey and McCool, 1984) has highlighted that this task is not easy, a cause of the tight difficulties in measuring the different dimensions of sustainability and, as concerns the social carrying capacity, the variation of the level of satisfaction.

The aim of the paper is to present an innovative framework, called MABSiT, Multi Agent Behaviour Simulation in Tourism, able to study by a dynamic way the behaviours, the interactions and the variation of satisfaction level of the different actors of a generic tourist destination. This framework is based on the economic theory, as concerns the study of satisfaction, and on Agent Based Modelling Simulation (ABMS) approach, as concerns the behaviour simulation. ABMS is applied in the social sciences in order to understand and describe the dynamics of the social, economic and spatial systems (Gilbert and Conte, 1995; Sanders, 2007). The framework presents a modular structure, composed by four main elements, corresponding to input data, ontology, simulation model and output data, represented by Web-GIS (Web-Geographical Information System) maps. This paper, in particular, presents the basic idea and the first results of the framework MABSiT. Further developments are still on-going in order to refine the work.

The paper is structured as follows. In the next section a brief literature review on tourism sustainability approaches is presented. In the third section the framework MABSiT is

explained. A description of the assumptions and the characteristics of the simulation model follows: utility function, local environment and attractors, agents and attributes, behaviours, interactions and impacts influencing the perceived level satisfaction of the agents. Finally, some conclusions and recommendations are drawn.

2   Tourism Carrying Capacity and alternative approaches to tourism sustainability

The relevance of the negative effects caused by a uncontrolled tourism development and the simultaneous spreading of the sustainable development concept have pushed towards the identification of new tools and approaches to sustainable tourism. These approaches aim to sustain an effective process of planning, development and management of sustainable tourist activities. In particular, one of the more widespread approach, Tourism Carrying Capacity (TCC), which has been developed even in the 1930s (McCool and Lime, 2000), emerged as an important concept in the 1970s and 1980s. In literature several definitions are available (for a review see, among the others, European Commission, 2002; Coccossis and Mexa, 2004; Maggi and Fredella, 2010). Nevertheless, the most cited definition has been developed by the World Tourism Organisation (UNWTO, 1981) and adopted by the UNEP MAP's Priority Actions Programme – PAP (1997). According to this definition, the TCC is: "the maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic and socio-cultural environment and an unacceptable decrease in the quality of visitors' satisfaction". It appears evident that the problem of tourist satisfaction level is a core issue of TCC. In particular, the behavioural element, reflecting the quality of the recreation experience, is a central aspect, together with the physical and ecological component, of the TCC assessment (Wall, 1982; Saveriades, 2000). Some researchers, extending the definition of TCC given by UNWTO, underline that the social carrying capacity refers to the levels of tolerance of the host community to the presence of tourists as well as to the quality of visitors' experience (Saveriades, 2000).

For example, in the TCC definition given by Chamberlain (1997) - "..the level of human activity an area can accommodate without the area deteriorating, the resident community being adversely affected, or the quality of visitors experience declining" – also the population tolerance level is highlighted.

Therefore, the majority of definitions contains two aspects: "a capacity issue", e.g. "how many tourists can be accommodated without causing irreversible negative impacts on the destination", and a "perception of capacity" issue, e.g. "how much tourism is acceptable before a decline in visitor and resident satisfaction occurs" (adapted by Coccossis and Mexa, 2004). As a consequence, the TCC should simultaneously focuses attention, on one hand, on the host destination impacts and population attitudes (Martin and Uysal, 1990) and on the

other hand, on tourist satisfaction, two issues interfaced one with the other. In fact, the greater the intensity of tourist use and the level of saturation of the tourist assets are, the more limited becomes the appeal of the tourist attraction and the more intolerant become the residents. This happens mainly in the case of overcrowding, in mass tourist sites (Marzetti and Mosetti, 2008).

Thus, carrying capacity is composed by three different subsystems (O'Reilly, 1986):

- the physical carrying capacity: "the maximum number of people who can use a site without an unacceptable alteration in the physical environment and without an unacceptable decline in the quality of experience gained by visitors" (Mathieson and Wall, 1982; Simón et al., 2004);

- the social carrying capacity: the level of tolerance of the host population for the presence and behaviour of tourists in the destination area (on which this paper focuses);

- the economic carrying capacity: the ability to absorb tourist functions without squeezing out desirable local activities and avoiding the decline of the tourist destination caused by the disruption of the local attractions.

However, it soon became clear that the concepts of TCC are difficult to apply; in particular, there is the impossibility of assigning an objective scientific value to TCC and to apply a rigorous analysis in calculating capacity in terms of threshold or limit (among the others, Washburne, 1982; Stankey and McCool, 1984). For this reason, in several recent works the interest on carrying capacity has shifted from an objective measure to a planning process tool for sustainable tourism development (among the others, Linderberg, 1997; Coccossis and Mexa, 2004; Miller, 2001; Abernethy, 2001; European Commission, 2002).

Moreover, alternative or, in some case, complementary approaches to tourism sustainability have been also suggested, such as Limits of Acceptable Change (LAC) (Stankey et al., 1985) or Visitor Impact Management (VIM) (Graefe et al., 1990). The LAC approach has been developed in the early 1980's in order to deal with questions of recreation management in protected areas than the carrying capacity paradigm (McCoole and Cole, 1998). It "strives to define those conditions which are deemed desirable in an area and sets up management strategies to achieve specified goals." (Glasson et al., 1995). It shifts the focus from "How much use is too much?" to "How much change is acceptable" (Dai Xue-jun et al., 2002, cited by Zhang, 2005), aiming at evaluating the costs and benefits from alternative management tourism actions.

Visitor Impact Management, which has been elaborated by some researchers in conjunction with the U.S. National Parks and Conservation Association, aims at identifying the unacceptable visitor impacts and their cause and at defining effective actions to address the problems. According to LAC approach, VIM doesn't seek a numeric value, but it identifies a set of standards which can be used to compare with existing conditions (Glasson et al., 1995).

Recently, some preliminary efforts have been developed by the literature on the use of simulation models and tools as analytical methods in assessing tourism sustainability. Wang

et al. (1999) built a dynamic model of visitor travel on the carriage roads of Acadia national park of Maine in the U.S.A. The model simulates the recreation days on the carriage roads, using as input data travel routes and travel speeds. Zhang (2005) elaborated a multi-agent and GIS model to assess the carrying capacity of tourist resorts, simulating the actions of individual visitors and using travel patterns data (location, cost, state, etc.).

3   The MABSiT framework

The aim of the Multi Agent Behaviour Simulation in Tourism (MABSiT) framework is to propose a tool that could facilitate planners and decision-makers in their efforts to develop and implement strategic policies for sustainable tourism development. It can be used in order to better understand the behaviour of the agents, their interactions and the variables influencing their level of satisfaction. The agents are residents and visitors (tourists and excursionists); they have specific attributes that will be explained in the next section.

The framework has mainly three functions: data collection and analysis, simulation of the present situation and prediction of different future scenarios and, finally, data representation by web-GIS. It can help the policy-makers, giving them information on the probable impacts of different policies (e.g.: traffic policy) or actions (e.g.: the openness of a new attractor, such as a thematic park or shop centre).

It is a very flexible instrument, able to manage the different components, changing only one of them in a independent way with respect to the others; it is also cheaper than other instruments because it uses free licence software and open source applications.

The architecture of MABSiT is described by figure 1. The main components are the layers, which are of three types: input, management and output layers. The function of the first one is to collect the input data and to set up the simulation. The input layer defines the number of runs and agents that are involved in the simulation process. Moreover, it identifies the characteristics of the artificial environment, in terms of number and type of attractors and geographical position.

The management layer manages the information in a Data Base Management System (DBMS) and run the simulation. The DBMS includes four categories of data: input, raw, output and spatial data. The input data come from the set-up of the input layer, while the raw data are accessory data (e.g. on transport modes and means, length of way, and so on), which assure the correct functioning of the system. The output data are the disaggregated results of the simulation. Finally, the spatial data are the needed information for the Web-GIS representation, which is one of the function of the third type of layer. In fact, the output layer aggregates the simulation results and produce maps or other forms of representation, such as graphs, diagrams, etc.
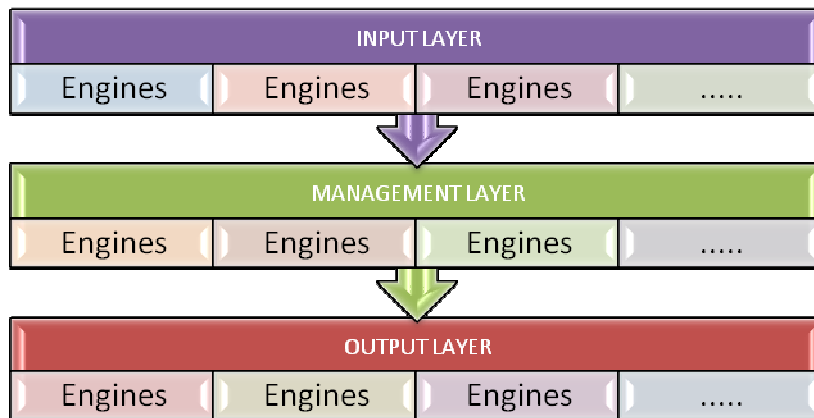
The layers are composed by different engines (Figure 2), which implement one or more activities required by the layers, such as data acquisition, elaboration and storage. Each layer may be composed by a variable number of engines, that are individually independent. Thus, the single engine might be easily changed without altering the whole system.

Finally, another important element of the MABSiT framework is the regulator, which manages and controls all the layers and engines and their interactions.

Figure 1 - The scheme of MABSiT frame work
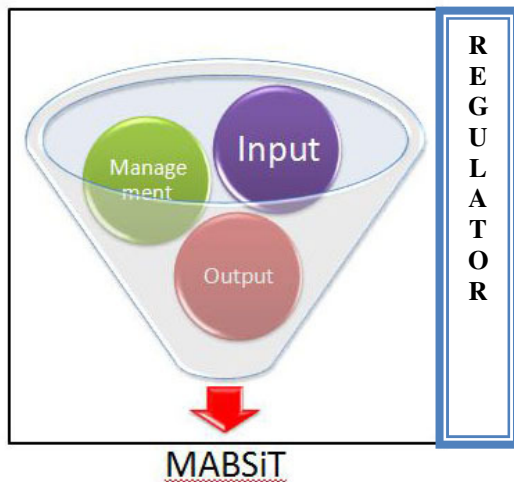
Figure 2 - Representation of the main MABSiT components

4   The MABSiT simulation model: assumptions, actors and environment

4.1   Agent-Based Modelling

The simulation model belongs to the category of Agent-Based Models (ABM). More and more frequently this type of models is applied in the social sciences. In particular, one of the first application of ABM within these sciences has been dated in the 1970's. Schelling (1971; 1978) demonstrated, without the use of a computerized model, that the micro-effects produced by single agents' behaviour might make macro-impacts, on the whole or a part of a community. The agent-based models, also called individual-based models (Hiebeler, 1994) or bottom-up models, are now considered one of the best way of modelling complex and dynamic social system, where there are inter-connected agents (Robertson, 2005). Even if the agent-based model relies, such as other methods, on certain assumptions, the very flexible structure of this model allows to study a wide range of systems composed by autonomous, interacting agents in a variety of fields.

The agent presents the following characteristics (Macal and North, 2005; Wooldridge and Jennings, 1995):

− it is a discrete individual, with social ability: it is identifiable by a set of characteristics and rules governing its behaviours and decision-making capability;

− it is located in an environment where it interacts with other agents; the agent has also the capability to respond to the environment and to identify the features of other agents;

− an agent is pro-active, i.e. its behaviours aim to achieve goals (not necessarily of maximization);

− it is autonomous with respect to the environment and the other agents and it controls its actions;

− an agent is flexible and has memory, i.e. the ability to learn and adapt its behaviours over time based on experience.

4.2   The characteristics of the MABSiT simulation model

In MABSiT, the simulation model measures the variation of the level of satisfaction (U) of the agents, with respect to their starting level (calculated by the Central Limit Theorem), in performing different actions during the day in the artificial environment. If the value of U

varies between 0 and 1, the agent is more or less satisfied; if it equals one or is more than one, the agent is unsatisfied.

The level of satisfaction of the model agents can be expressed by the following utility functions.

(1) $U_{V\,(i)} = f\,(c, pa, o, ws, wt, po)$

(2) $U_{R\,(j)} = f\,(c, pa, o, ws, wt, po, i)$

where:

$U_{V(i)}$: level of utility of a generic visitor i (i = 1, ..., n), which should be a tourist or even an excursionist;

$U_{R(j)}$: level of utility of a generic resident j (i = 1, ..., m) of the tourist destination;

c: level of congestion on the road, measured in terms of transit time along the urban roads; an increase of the time makes the agent unsatisfied. We assume that the decrease of satisfaction is higher in the peak hours than in the other hours (e.g.: the impact of the time increase of 5% in the peak hours is more important than the impact related to an increase of 15% in non-peak hours);

pa: availability of parking near the place where the agent is going (e.g.: restaurant, beach, hotel, shop, school, job place, etc.); it is positively related to the level of its satisfaction;

o: rate of occupancy of the structures (restaurant, accommodation structures, i.e. hotels and similar establishments, etc.), that are chosen by the agents. The unavailability of a structure makes the agent unsatisfied;

ws: waste; especially during peak season, the local municipality might have some problems in the waste disposal, altering the level of satisfaction of both visitor and resident;

wt: water; during the high season water supply is exacerbated by tourist flows for use in hotels, swimming pools and other tourist structures. This high demand increase might lead to water shortages, making residents and tourists unsatisfied;

po: pollution; the level of air pollution is negative related to the level of satisfaction;

i: income; we suppose that the residents which have a direct or indirect income from tourism are more tolerant towards the tourists (pro-tourism residents). The above mentioned impacts make a smaller decrease of level of satisfaction of pro-tourism residents than not pro-tourism inhabitants. The variable is of binary type, i.e. we assume that its value equals 1 in the case of pro-tourism resident and 0 in the opposite case.

The utility functions of visitor and resident are very similar and differ only for the income variable. As it will be explained below, they are employed in order to study the effect of different impacts, when the agents make different daily actions, interacting one with the others.

In our model there are three kinds of agents: residents, tourists and excursionists. The community residents can be aggregated in groups of families; every family is composed by a random number of residents. Tourists and excursionists are part of groups that are randomly

composed by one up to six persons. The excursionist is a daily-visitor, while the tourist spends minimum one night in a accommodation structure.

Each agent is autonomous and presents specific attributes, which may be of two types: fixed attributes (f-attributes) or variable attributes (v-attributes). The difference is that during the simulation the first ones don't vary (e.g.: age, gender), while the second ones can change (satisfaction level). The following two tables show the main attributes of visitors (Table 1) and residents (Table 2).

Table 1 - Main attributes of visitors

Attribute	Description
Number of group elements	components of each visitor group
Transport modes and means	type of transport mode and mean used by the visitor (e.g.: car, train, bicycle, motorbike, etc.)
Willingness to pay	expenditure capacity per day
Ecosystem impact	the environmental impact produced by the agent on the ecosystem, in terms of pollution, congestion, waste and water consumption (ISTAT and ARPA data)
Satisfaction	individual function utility
Number of overnight stays	number of nights spent by the visitor (it equals zero in the case of excursionist)
Geographical position	area of the artificial environment in which the agent is located

Table 2 - Main attributes of residents

Attribute	Description
Age	personal age of the agent
Transport mode	the variable indicates if the agent uses a car (value = 1) or not (value = 0)
Social position	worker, student, retired, housewife
Satisfaction	individual function utility
Pro-tourist or not	a resident is defined pro-tourist when it earns a direct or indirect income from tourism (value = 1)
Geographical position	area of the artificial environment in which the agent is located

The following table (3), extracted by the MABSiT model database, show an example of different type of residents.

Each agent, in the case of resident or each group of agents, in the case of visitor, performs different actions in an artificial environment in different days and hours, which will be described below. The agent level of satisfaction is positively related to the level of quality of the agent experience during its action and negative related to the perceived negative impacts which it does tolerate.

*Table 3 - Example of residents of the MABSiT model*

Resident_id	Age	Social Pos	Satisfaction	Car	Geog. Position	Pro Turist
1	35	2	0.448012	1	1	1
2	52	1	0.448012	0	1	0
3	40	1	0.448012	0	1	1
4	52	2	0.492225	1	2	1
5	27	1	0.492225	0	2	1
6	58	2	0.49795	1	3	0
7	79	1	0.49795	1	3	1
8	59	2	0.380051	1	4	1
9	54	1	0.380051	0	4	0
10	50	2	0.441651	1	5	0
11	55	4	0.441651	0	5	1

As concerns the spatial aspects, the artificial environment has the characteristics of a medium-small coastal destination. It is composed by eleven areas: one central zone, four mid-central zones and four sub-urban zones and finally two important areas in which high-flows' attractors are located (in one zone beaches and in the other a shopping centre). In the whole artificial tourism destination the visitor and resident attractors are 143 and they concern, for example, hotels or other accommodation structures, restaurants, cafeterias, museums or other expositions, monuments, shops, schools, offices, civil houses, etc. Each attractor has a predetermined physical maximum capacity in terms of number of persons and of parking places. The accommodation structures are of different types of quality/price (e.g. stars for the hotels); thus, each tourist choices the structure in relation to its willingness to pay.

Referring to the temporal issues, the model considers the seasonality and distinguishes the working days from holidays. Thus, the tourist arrivals are higher in peak-months and in holiday days than in the other periods. As a consequence, the number of visitors per day is variable, while the number of residents is stable.

Moreover, each day is divided in six different stages, corresponding to different predictable agents' actions: morning, lunch, afternoon, dinner and evening and one administrative stage (Figure 3).

Figure 3 - Scheme of a day turn
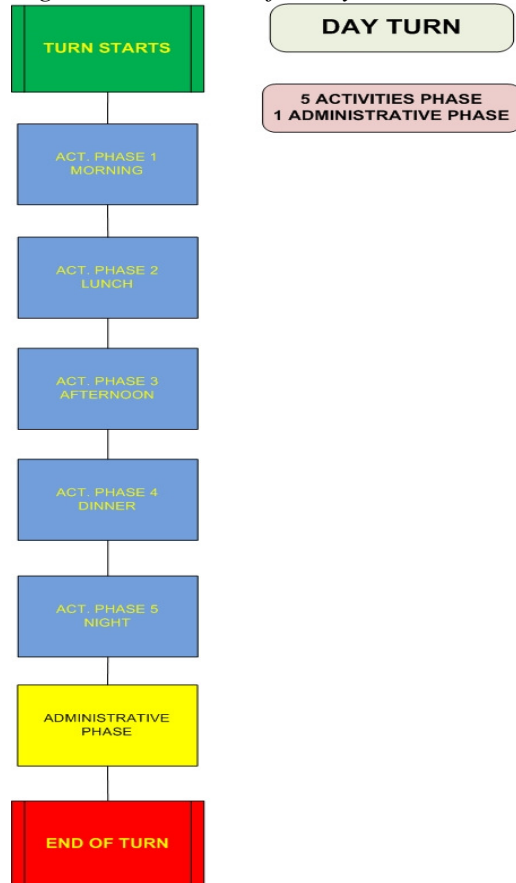
At each stage, the model describes the behaviour of the individual agent on the basis of its attributes which establish a set of rules. The agent can carry out different activities: for example, as it is shown in Appendix 1, in the morning stage a resident wakes up and goes to the school if he is a student or to the office or other job places (during the working days) if he is a worker or to other places (e.g.: shops, postal offices, etc.) if he is a housewife or a retired person. In order to reach the destination place, the agent can use its own car, if he has one, or the public transport. These activities contribute to create pollution, congestion, parking difficulties, etc.; the higher is the number of the people moving in the same time and in the same space the higher are the values of these externalities and the lower is the level of satisfaction of the agent.

Similarly, a visitor in the morning stage (Appendix 2) can perform different activities: in a coastal destination, typically he goes to the beaches or, alternately, to do shopping. The group of tourists with a car, from one hand, makes and, from the other hand, does support specific negative impacts, such as pollution and congestion.

In the case of overcrowding, the demand for basic service, such as water or waste disposal, is higher than the supply capacity of the water depurator or waste disposal site; during the day, the water shortages and the waste piles make a decrease of the level of satisfaction of both the resident and visitor.

The strength of the simulation model is its flexibility and ability to describe in a realistic way the behaviours and the interactions of the agents, moving them in relation to their attributes and the rules that are predetermined by the system ontology.

A process of validation of the model is on-going: the output data will be compared with real data coming from empirical investigations. More precisely, the validation is organised in the following steps:

- components' test: control of the correct functionality of the model components and sub-components;
- functional validation: control of the congruity between the assumptions of the model and the output results;
- qualitative check: comparison between the simulated behaviours and the expected ones;
- quantitative tests: comparison between the simulated behaviours and the empirical evidences, using time series analysis or blind prediction techniques.

5   Conclusions

The aim of the research presented in this paper is to provide a model able to study and describe touristic flows, the behaviours, the interactions and the level of satisfaction of the tourism destination actors. The information given by the MABSiT framework can help planners and policy makers in identifying the best strategies and interventions in order to make tourism sustainable in the long term.

The adoption of an approach based on computer agents and the economic theory allows to take advantage of the flexibility offered by computer simulations, simultaneously guaranteeing scientific rigour. In particular, the model makes possible to easily manage a high number of variables and constraints, allowing to conduct investigations based on realistic scenarios.

ABM simulations, which are explanatory rather than predictive, provide tools aiming to support the researchers' intuition on the modelled phenomenon.

Currently, the development of MABSiT is on-going and in the test phase, but it is yet possible to identify the strengths of the system. First of all its structure is modular, i.e. composed by independent and autonomous elements; thus, each simulation is independent from the others. Secondly, it is scalability: new components and parameters, such as number of agents, attractors, attributes, may easily joined to the system. Thirdly, the model allows to replicate

the phenomenon in a unlimited number of times without cost. Finally, it has been conceived in order to be used in a very easy way by public and private tourism actors, without any experience on this model.

On the other side, at the present the framework presents a weakness: the high number of parameters and the mass of output data for each parameter makes the simulation results "weak"; in other words, by now it is not easy to understand if the simulation results are simply an artefact of the configuration parameters or real remarkable results. The theoretical definition of the model can help in identifying which parameter interval is more critical to test, in order to reduce the total parameter space. Also a strict and accurate validation process should transform the weakness in a strength point.

As a consequence, the next step of the work is to complete the model validation. Once this task will be performed, the MABSiT will be applied to one or more case studies and will be used in order to predict future scenarios of the tourism development of a destination, studying the impact of the evolution on visitor and resident satisfaction.

Further developments will concern the evaluation of the effectiveness of one o more policies, predicting ex-ante by the simulation their positive and negative effects on the satisfaction levels of tourists and residents and the future stages of tourism development (included the possible decline of the destination). Thus, the policy makers may be aided in the choice of the best policy before its real application with a remarkable cost saving.
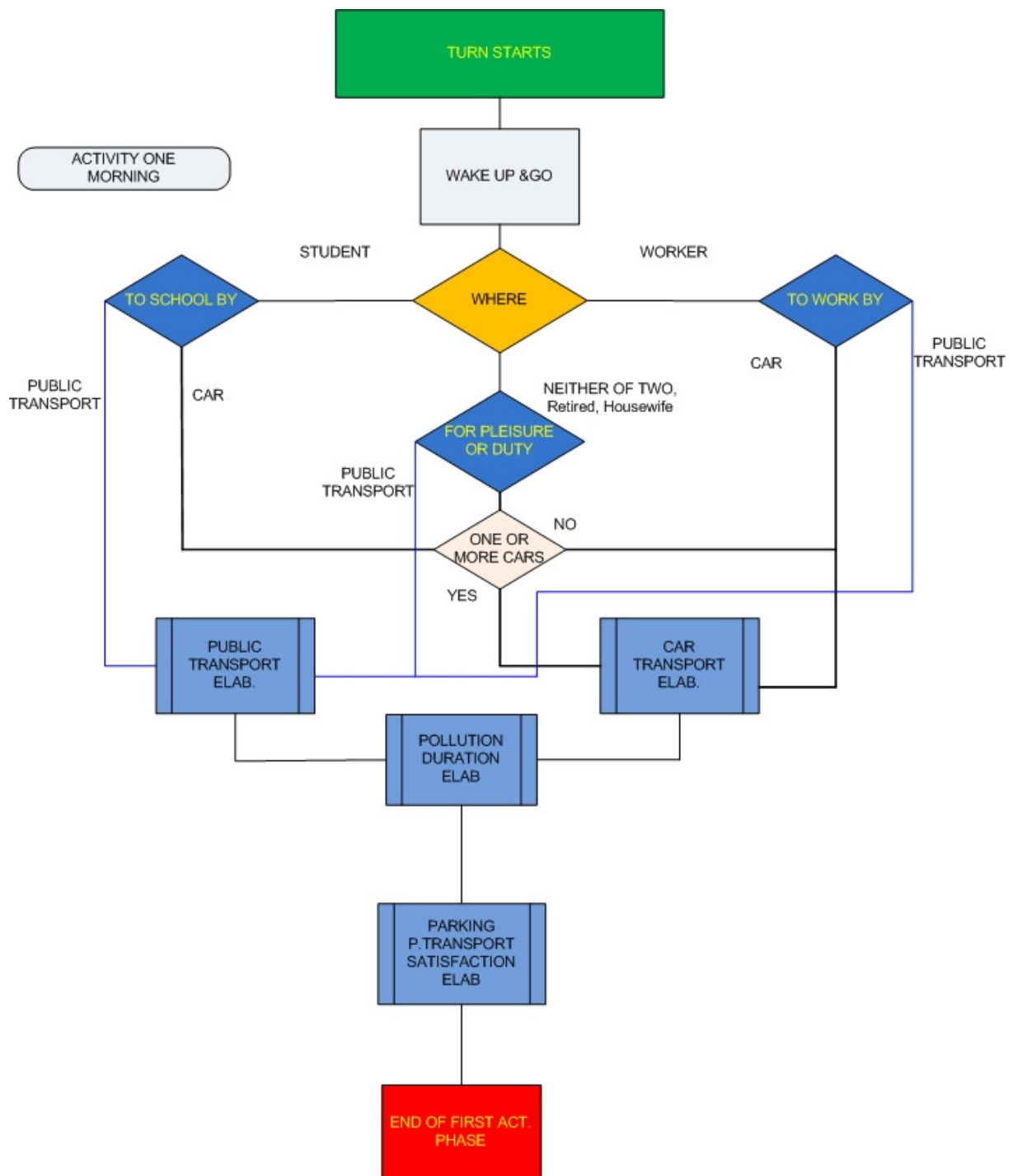
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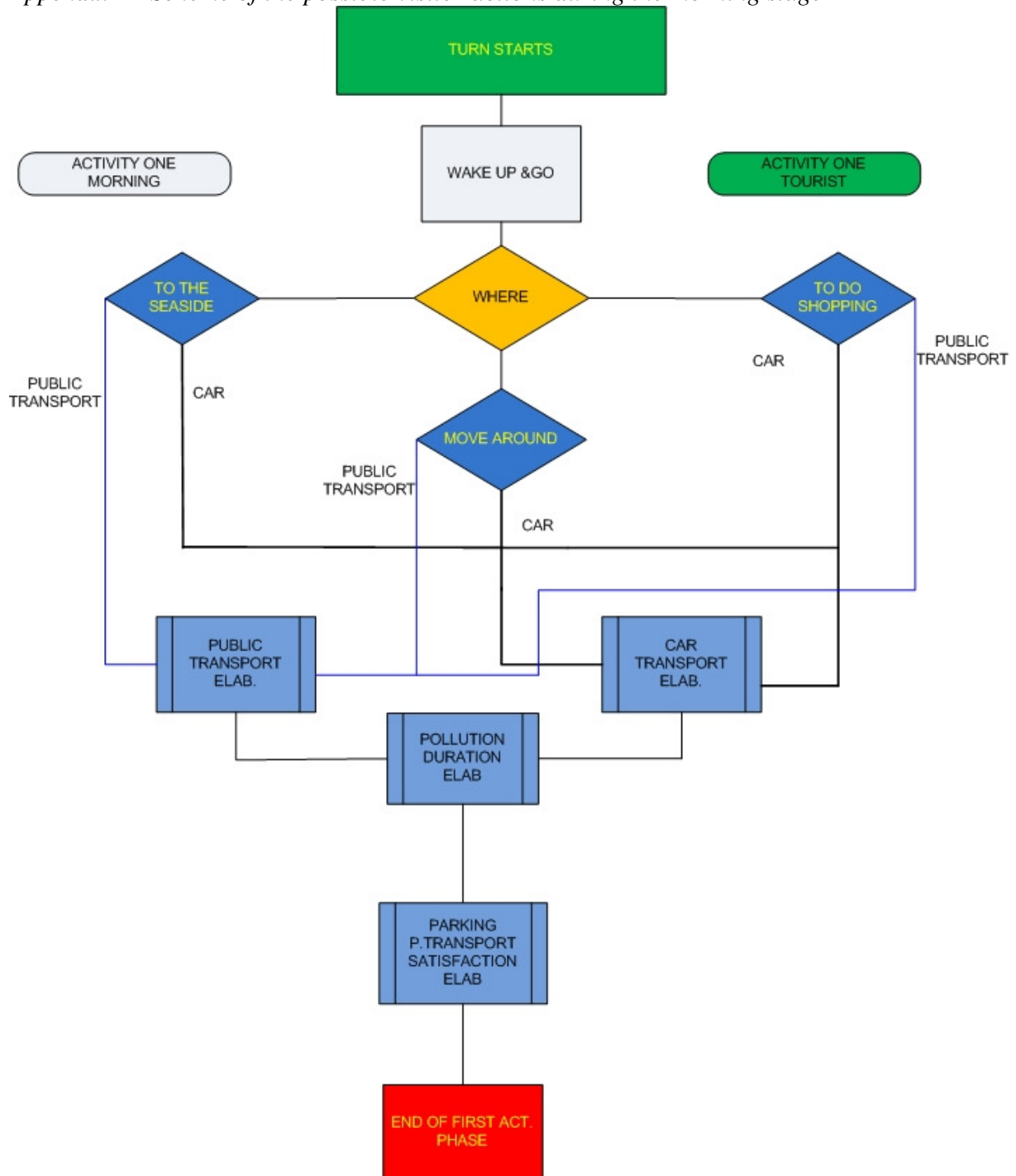
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Appendix 1 - Scheme of the possible resident actions during the morning stage in a working day

ACTIVITY ONE MORNING

TURN STARTS

WAKE UP &GO

STUDENT — WHERE — WORKER

TO SCHOOL BY

TO WORK BY

PUBLIC TRANSPORT

CAR

PUBLIC TRANSPORT

FOR PLEISURE OR DUTY

NEITHER OF TWO, Retired, Housewife

CAR

PUBLIC TRANSPORT

ONE OR MORE CARS

NO

YES

PUBLIC TRANSPORT ELAB.

CAR TRANSPORT ELAB.

POLLUTION DURATION ELAB

PARKING P.TRANSPORT SATISFACTION ELAB

END OF FIRST ACT. PHASE

Appendix 2 - Scheme of the possible visitor actions during the morning stage

ABSTRACT

The rapid and often uncontrolled tourist development of several destinations might cause a progressive and worrying deterioration of their natural, social and cultural resources. As a consequence, these destinations become low attractive and the quality of tourist experience, as well as the satisfaction level of the population, decreases. Thus, in the last decades several efforts have been devoted in order to individuate instruments and methods able to support the short and long term planning of the tourist development in a sustainable way. Different approaches have been developed, such as the Tourism Carrying Capacity (TCC) or the Limits of Acceptable Change (LAC) or the Visitor Impact Management (VIM).
According to these approaches, the present paper describes the preliminary results of a research project aiming at developing a framework for tourism sustainability. This framework, called MABSiT (Multi Agent Behavior Simulations in Tourism), is able to simulate in a hypothetic coastal destination the behaviors and the interactions of the actors (residents and tourists), as well as the change of their satisfaction level in different moments and seasons.