# Chapter 11
# Agent-Based Modelling: A Dynamic Scenario Planning Approach to Tourism PSS

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## 11.1 Introduction

Creating simplified models of a system to better understand its workings has long been an effective method of solving complex problems (Bradley and Schaefer 1998; Gilbert and Troitzsch 2005). Models help to formalize theories and can be used to test hypotheses before committing to implementation (Holling 1978). Agent-based Modelling (ABM) is one branch of computerized simulation modelling that shows particular promise as a tool for planning support. Recent work has explored the application of ABM to study volatile gasoline market dynamics (Heppenstall *et al.* 2006), urban sprawl (Benenson and Torrens 2004), the conversion of Amazonian forest into farmland (Deadman *et al.* 2004) and economic development in response to climate change in the remote Canadian north (Berman *et al.* 2004). These research examples push the use of ABM from simplified theoretical models towards more detailed representations that incorporate real-world data (Alessa *et al.* 2006). These next generation examples of ABM have the potential to fill a role as a planning support system (PSS) within variety of planning and policy development areas.

Tourism is one area that could benefit from the integration of ABM and PSS. Planning for tourism development is a complex undertaking, as it affects processes involving multiple individuals interacting over time and space. Traditional approaches to tourism planning have focused on *ad hoc* decision making, and past performance evaluation of individual impacts, rather than examining system changes and effects. If tourism planners incorporated a system-wide perspective into their planning activities, it is argued that better decisions could result (Hall 2000; Jamal *et al.* 2004). The visioning of future scenarios and evaluation of a range of actions, all aimed to increase the benefits derived from tourism development,

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are the main functions of tourism planning (Yeoman *et al.* 2005). These types of goal-directed plans are often developed in a community consultative environment, where a set of agreed future states are broken down into functional steps required for their achievement (Hall 2000). Scenarios can be used to anticipate these various 'what if?' questions and are often used as a tool to generate discussion amongst stakeholders (An *et al.* 2005), for example, on whether to focus on supply (e.g. creating tax incentive for bed and breakfast establishments) or demand (e.g. increasing marketing efforts to attract a specific type of tourist). It is this iterative experimentation to which the ABM method shows particular promise to address specific planning challenges, integrating various stakeholder viewpoints, evaluating a course of action and creating impetus to effect change (Walker *et al.* 1999; Zellner 2007).

This chapter presents research on the design and application of an ABM-based PSS to study tourism in Nova Scotia. Nova Scotia is Canada's easternmost mainland province, with a formerly resource-based economy that is becoming increasingly invested in tourism development. We begin by reviewing select literature on ABM and tourism planning. The reader is then introduced to *TourSim*, an ABM-based PSS that we developed for tourism planning. We demonstrate the use of *TourSim* to generate a planning scenario set in Nova Scotia that examines the effect of port of entry on tourist visitation levels. Reflections on the development and application of *TourSim*, drawn from interviews with tourism planning practitioners, inform a broader discussion of the use and adoption of an ABM-based tourism PSS.

## 11.2 Using Agent-Based Modelling to Provide Planning Support

ABM is a computer-based simulation approach that uses heterogeneous 'agents' to represent real-world decision makers, possessing characteristics of autonomy, communication, reactivity and proactivity (Wooldridge and Jennings 1995). These agents tend to be represented as graphic points that move and interact within a 2D world that represents reality. Here we choose to run our agents (i.e. simulated tourists) against a geo-referenced base, although agents can interact in social and other networks. Using an ABM, one can set initial parameters and grow that system forwards in time, comparing the results of separate model runs (Bonabeau 2002; Grimm and Railsback 2005). Agents are assigned behavioural rules that model socio-economic characteristics and simulate preferences and needs. Agents act out these rules on a varied and competitive landscape, generating system-level outcomes from individual-level interactions. These behaviours are often based on heuristic pathways or bounded rationality, rather than an optimizing equation (Manson 2006).

ABM is used in a variety of capacities, from simple models focused on theoretical exploration, to empirically-based representations of real-world systems. Creating a model that represents a real-world system is an approach that has potential for conducting policy-relevant research (Parker *et al.* 2003). Recent studies have focused on the application of ABM to planning problems. Bolte *et al.* (2006) advocate the use of ABM in developing alternate futures of landscape change in

Oregon. They point to ABM as an integrative tool that acknowledges the coupled nature of human/natural systems and the variety of spatial and temporal scales that characterize their systems of study.

A tourism-specific example of ABM implementation comes from Berman *et al.* (2004) who use ABM as a visioning tool, showing economic outcomes in a remote community in the Canadian north, specifically the impacts of road construction, re-training and climate change. This type of policy application is evaluated by Ligmann-Zielinska and Jankowski (2007), who use ABM to generate alternate scenarios of urbanization effects in a small community in Washington State. The authors point to several advantages of an ABM-based PSS, as opposed to traditional equation-based models. Key amongst these benefits include a better representation of individual decision making through the use of heterogeneous agents, making ABM a more intuitive construct for community consultation. Additionally, the creation of multiple futures, with an emphasis on iterative experimentation, underlines the role that an ABM can play in a collaborative planning environment, particularly one marked by uncertainty and multiple viewpoints (Lempert 2002; Ligmann-Zielinska and Jankowski 2007). It is these tasks of future visioning, scenario development, community consultation and integrating multiple sources of input that provide the strongest application areas for ABM within planning.

Despite these entry points, integrating ABM within PSS presents several barriers. At the development stage, when deciding how to represent a complex real-world system as an ABM, tension frequently exists between the desire for simplicity and a level of detail required to accomplish planning goals. A model will never perfectly reflect reality, and decisions to increase both the realism and complexity of the model often inhibit analysis (Bankes *et al.* 2002). This friction between simplicity and realism is manifested in concerns of model validation (Parker *et al.* 2003) and the use of rich data sources to parameterize models (Robinson *et al.* 2007). Historically, simplicity in model creation was promoted, using theoretical landscapes and simplified assumptions to create models that developed theory rather than policy (Bonabeau 2002). When considering the use of ABM in planning, a model that represents reality is essential. Validating an ABM, or ensuring that it adequately represents the system under study, is a process that can require large data sets for statistical or pattern-oriented comparison of model output to real-world data (Grimm and Railsback 2005). As ABM moves into the planning arena, model builders must aim for a higher level of validity, yet ensure that models do not become so complex as to preclude analysis by non-modellers (Bolte *et al.* 2006). The use of realistic landscapes (especially those informed by geospatial data) and validation with robust datasets mediates these needs of realism and simplicity that are required for the use of ABM within planning.

## 11.3 *TourSim:* An ABM-Based Approach to Tourism PSS

*TourSim* is an ABM-based PSS whose purpose is to simulate the interactions between tourists and destinations. It is designed to help policy makers visualize and evaluate impacts of external processes as well as proposed planning decisions. Building the *TourSim* model followed an iterative process, aiming to create the simplest model that still provided a realistic view of tourism dynamics (Gilbert and Troitzsch 2005; Grimm and Railsback 2005). It is conceived to be an open system, so that complexity and user-specific detail can later be added.

### *11.3.1 TourSim Model Structure*

Creating a tourism PSS such as *TourSim* requires the developer to follow several steps. Grimm and Railsback (2005) present a six stage model development cycle: formulate the purpose; assemble hypotheses; choose model structure; implement the model; analyse the model; and communicate the model results. We rely on tourism literature to hypothesize that a supply-demand relationship characterizes much of the tourism system. Tourists provide a demand according to their preferences, and destinations contain a supply of product to satisfy this demand. At model structure stage, agent behaviours are characterized by preferences for accommodation and activities. Accommodation choices include types of hotels, campgrounds and resorts. Activities include visits to national parks, historic sites and a variety of outdoor pursuits. Each tourist is heterogeneous, possessing multiple preferences, potentially selecting any location that meets at least one accommodation and activity preference. The landscape on which these agents interact consists of the supply of accommodation and activity at each destination.

Implementation comprises the choice of software development environment and data and the actual programming of the model. For *TourSim,* the implementation environment of choice is *AnyLogic* (http://www.xjtek.com). Compared to other environments, *AnyLogic* was chosen due to a user-friendly interface, visualization options and ability to develop web-based versions for further communication of model results, all factors that are important for use in planning. Tourist agents are based on data from the Canadian Travel Survey (CTS), collected from 2000 to 2004, and the International Travel Survey (ITS), collected from 2001 to 2004. These are both products of Statistics Canada. Tourist agent preferences were parameterized using a method developed by Berger and Schreinmachers (2006), where survey data are randomly assigned to agents according a sample distribution. This method results in the larger group of agents replicating the sample distribution. Using the thousands of records of unique preference data from the CTS and ITS allowed us to represent agent heterogeneity. The use of large, multi-year surveys, such as the CTS and ITS, gives us a high level of confidence that the sample is representative (Robinson *et al.* 2007). Destination (supply) data was sourced from the Nova Scotia Department of Tourism, Culture, and Heritage tourism portal (www.novascotia.com), which contains a database of accommodation and activities. From this database, 35 destinations were selected for use in *TourSim.* These destinations were plotted on a base map of Nova Scotia, drawn from the Digital Atlas of Canada (www.atlas.gov.ca). This map is used for visualization purposes, placing *TourSim* components in the appropriate geo-referenced context. In addition to the main supply-demand dynamics, *TourSim* includes a daily straight line travelling distance and length of stay preference, each informed by the CTS and ITS distributions. This selection of variables and interactions is considered the base version of *TourSim*, to which specific planning scenarios and further dynamics can be added.

Validation ensures that the model sufficiently resembles the real system and provides confidence in the results. For *TourSim,* this involves matching the modelled tourist visitation data to the total provincial visitation numbers published by the Nova Scotia Government. Whereas these numbers are suitably close, this is only a preliminary measure of model validity. A more robust method is under development that will validate the model against tourist visitation in each destination, attempting to replicate monthly variations in tourist distribution. The final step in the model development cycle is communicating model results. *TourSim* allows users to run the model themselves through a web-based user interface. This feature can be used to create an ongoing dialogue of collaborative development with the user, allowing the developer to quickly add features, and distribute new versions of *TourSim* in response to feedback on the utility and validity of the model, as well as incorporate feature and scenario requests.

Rather than focus on 'launching' a finished product for site-specific users to then either accept or reject, we have distributed the current version of *TourSim* as the first step in an ongoing model development process. This prototype is available at http://toursim.wordpress.com. *TourSim* was introduced to the Canadian tourism research community at the Travel and Tourism Research Association of Canada (TTRA-Canada) annual conference in October 2007. A web-based version of *TourSim* was then distributed to a select group of tourism planning experts to gather feedback on the usability and applicability of the model. These experts work throughout Canada in tourism planning at both the provincial and local scale. Experts were contacted with a follow-up telephone interview after viewing a presentation that introduced the *TourSim* scenario detailed in this chapter. This type of development cycle blurs the distinction between 'user' and 'developer', as feedback from users is constantly incorporated into the model. An iterative, collaborative model development precludes the production of a finished product, as indeed all versions of *TourSim* are experiments that aim to continually improve on the state of the tool. Reflections from this panel of experts are used to inform the discussion in Section 11.4.

### *11.3.2 TourSim Model Use*

Figures 11.1 and 11.2 show the user interface of *TourSim*. In the first pane (Fig. 11.1), users are introduced to the model and can set initial system conditions. The user then runs *TourSim* through a Java-based map loaded into a web browser (Fig. 11.2). A tool bar at the top of the browser window allows control of the model execution. A date counter is visible in the lower left corner. The user views agent routes from location to location on a map of Nova Scotia, as well as a bar chart of total tourist arrivals in the selected destination areas. The simulation unfolds as tourist agents access Nova Scotia at one of seven ports of entry. Agents then randomly evaluate destinations to satisfy their accommodation and activity preferences. If the first destination does not match, then an agent evaluates another destination until a successful match on both accommodation and activity is found. Next the tourist agent checks whether the destination is within a particular straight-line distance threshold, and if so, moves to that location, causing a route to symbolically widen, as more trips take place along it. If the destination is outside of the tourist agent's distance threshold, the agent returns to the start of the decision-making loop. In the default setting, *TourSim* runs for one calendar year, which is compressed into a few minutes of actual run time. The time setting can be modified to suit the time scale of the particular scenario. When the model finishes its run, parameter settings and bar graph results are available for import to spreadsheet software for further analysis.

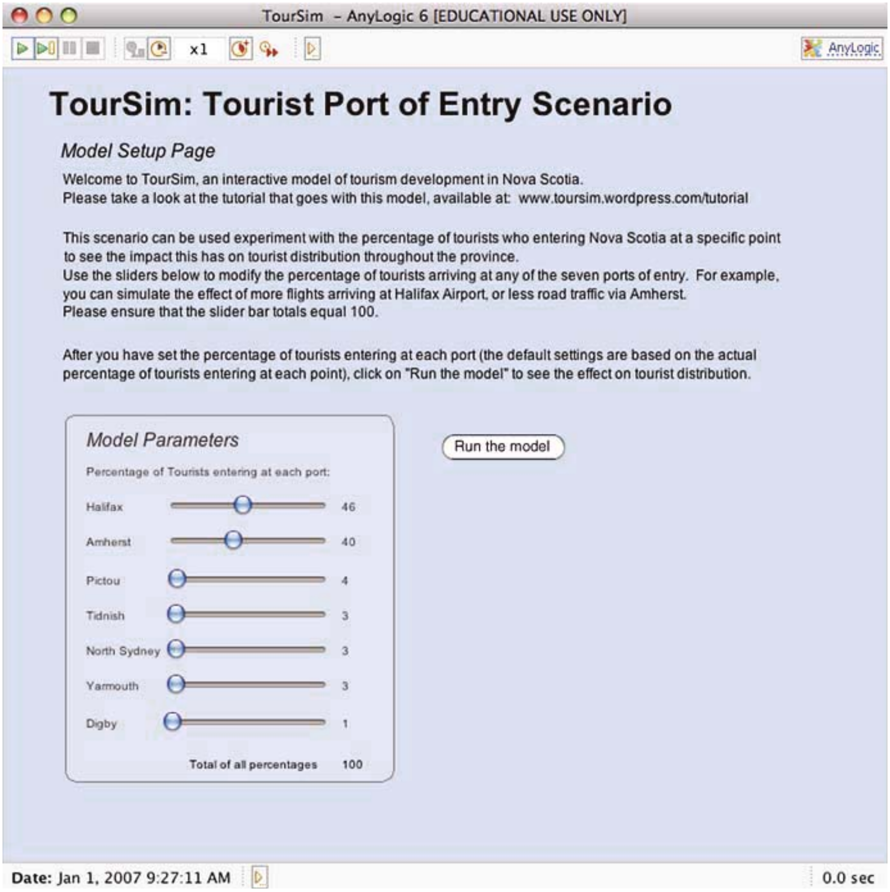


**Fig. 11.1** *TourSim* model setup page showing slider bars used to manipulate model parameters

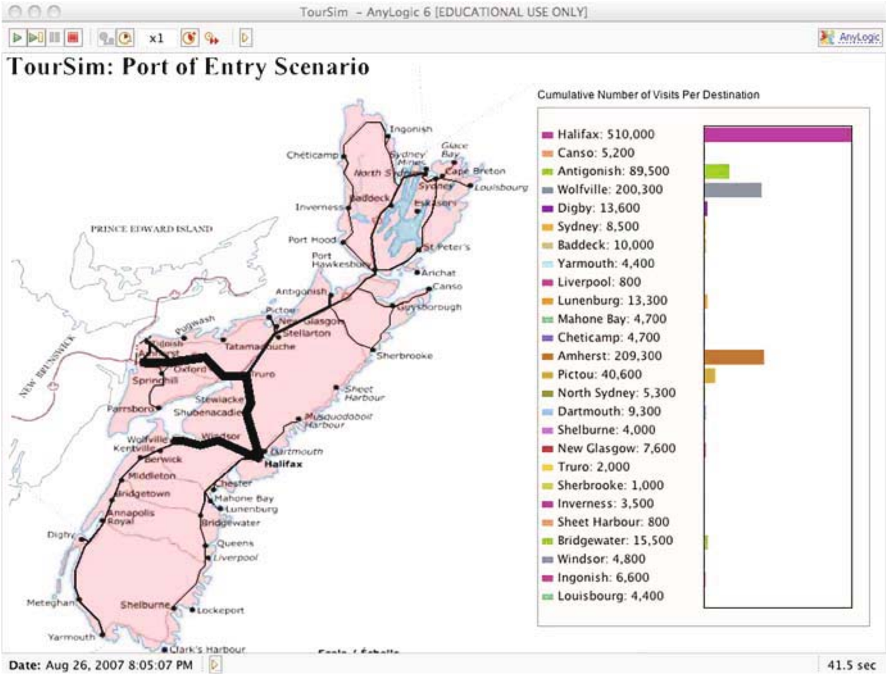


**Fig. 11.2** Main *TourSim* model page, including map of Nova Scotia; the width of each route represents the number of tourist trips with bar chart showing cumulative visitation (See also Plate 23 in the Colour Plate Section)

### *11.3.3 Using TourSim to Experiment with Tourism Planning Scenarios*

We designed *TourSim* to allow experimentation with a host of tourism-related scenarios, such as the effects of developing new tourism infrastructure on tourist distribution (e.g. establishing a local music festival), 'what if' questions concerning global tourism trends (e.g. an upturn in the value of the Canadian dollar relative to the American dollar) and changes to tourism demand as a result of geopolitical or economic events (e.g. a greater focus on travelling domestically).

We illustrate *TourSim* with a scenario that examines changes to the tourist port of entry on total tourism distribution. These entry points include four ferry (Caribou, North Sydney, Yarmouth, and Digby), two road (Amherst, Tidnish) and one airport access point (Halifax International Airport). Ferry linkages to Nova Scotia have received increased attention, as financial difficulties of ferry operators have caused service disruptions and threatened the closing of two ferry ports. Varying the percentage of the total tourist pool that enters at different ports of entry can be used to develop scenarios, such as quantifying the benefits of adding extra flights at Halifax Airport or marketing approaches to attract more driving tourists from adjacent provinces. We looked at three alternatives: (i) a 'business as usual' or base scenario,

**Table 11.1** Share of tourists entering at each port, under three scenarios, and resulting change in visitation levels

| Port of entry | 1 Base scenario | 2 Increase ferry scenario | | 3 Decrease ferry scenario | |
|---|---|---|---|---|---|
| | Share of tourists (%) | Share of tourists (%) | Tourist visitation change (%) | Share of tourists (%) | Tourist visitation change (%) |
| Amherst | 40 | 38 | 26 | 41 | 7 |
| Halifax Airport | 46 | 44 | 2 | 47 | 0 |
| Yarmouth | 3 | 6 | 74 | 1.5 | 7 |
| Digby | 1 | 2 | 6 | 0.5 | –5 |
| North Sydney | 3 | 3 | 58 | 3 | 0 |
| Tidnish | 3 | 3 | 1 | 3 | –13 |
| Pictou | 4 | 4 | –38 | 4 | 15 |

where the shares of tourists entering at each port of entry match observed averages collected by the provincial government; (ii) increased emphasis on ferry connections, introducing a larger share of tourists at Yarmouth and Digby, compared to the base scenario; and (iii) a reduced emphasis on ferry connections, with a smaller share of tourists entering through the above ports of entry. The adjustments for each scenario are made on the model setup page (Fig. 11.1). This allows users to modify the share of tourists entering at each port. Note that when these parameters are adjusted, the total of all share percentages must still equal 100 per cent. Table 11.1 lists each port of entry, the percentage share of tourists arriving under each scenario, and model results in the form of the percentage change in total tourist visitation levels compared to the visitation levels observed under the base share scenario. Common parameters throughout each scenario include tourist preferences, destination supply and number of tourists entering the model per simulated day.

Table 11.1 shows that by varying the share of tourists entering at selected ports of entry, system level effects are generated. Under scenarios 2 and 3 (the increased ferry, and decreased ferry emphasis, respectively), not only do the destinations show changes in total visitation, but often other ports of entry show changes in total visitation as well. Whereas some of the relationships between port of entry and a rise or fall in visitation seem intuitive, such as a rise in entry at Yarmouth and Digby resulting in a positive increase in total tourist visits (although at very different degrees of effect), not all destinations where port of entry was altered show a similar degree of response. This type of non-intuitive finding can be used as a step towards better understanding the effects of change at one location on an entire system. For example, even though the initial share of tourists entering at Caribou, Tidnish and North Sydney was held constant, they experienced large fluctuations in visitation as a result of changes at other entry points. These results suggest that changes to ports should be discussed at a provincial scale, instead of remaining the problem of the impacted community. *TourSim* benefits local and regional tourism planners by allowing them to see how local initiatives could fare as a response to system conditions, and in turn, what system effects they themselves contribute to.

### *11.3.4 TourSim Areas of Application*

The port of entry scenario indicates how *TourSim* can be used to study tourism system dynamics. These results show that changes in tourist port of entry can lead to a wide variety of changes in tourist dispersion. For tourism planners, this tool can be used within a community consultation process to focus discussions and development of new ideas, or decide between competing options. *TourSim* can be expanded to address many other tourism planning concerns such as evaluating the effects of competition between destinations, economic impact of tourist visitation, effects of targeted marketing on specific tourist generating areas, and diversifying the mix of accommodation and activity choices within Nova Scotia. Additionally, our development and use of *TourSim* shows that tourism dynamics can be formalized in an ABM, creating an environment with which to explore theories of tourism development and change.

## 11.4 Discussion

Notwithstanding these initial findings, further development of *TourSim* into a tool for planning support requires consideration of a number of factors, including how well *TourSim* represents the tourism system, how easy both the development and user environments are to use, and how *TourSim* can be applied within real world planning situations. These factors mirror the study of constraints, or ‘bottlenecks’ that have challenged the widespread adoption of PSS as well as the adoption trajectory followed by GIS (Budic 1994; Nedovic-Budic 1998). Vonk *et al.* (2005) outline a number of adoption constraints, including: (i) awareness of and experience with PSS; (ii) technical issues such as software user interface and data availability; and (iii) the overall applicability of a PSS towards planning tasks. We consider each in turn as a way to evaluate and refine *TourSim*.

### *11.4.1 Awareness of and Experience With an ABM-Based PSS*

ABM and similar approaches have found application in business logistics, manufacturing, and telecom infrastructure planning, yet this has not translated into general use of ABM. Applications of ABM-based PSS are few, either in municipal planning more generally or tourism planning more specifically. This low level of penetration within municipal planning departments contrasts with the more rapid uptake of GIS in 1990s (Budic 1994). The early commercialization of GIS software provided a professional-level product, with consistent resources for its development, and correspondingly raised awareness of GIS, further driving the development of the technology within a base of users. Comparably, there is no dominant commercially available ABM software program and there is a lack of consensus on a common approach to ABM development.

Current applications of ABM within planning practice use a variety of software programs, ranging from in-house custom development (Bolte *et al.* 2006; Deadman and Gimblett 1994) to those based on open-source platforms (Berman *et al.* 2004; Brown 2001), as well as proprietary, closed-source platforms developed as commercial products, with copyright protection to inhibit alternate uses and user customization (Ligmann-Zielinska and Jankowski 2007). We continue this latter tradition in our choice of *AnyLogic*, a commercial, copyright-protected development environment that finds most of its application within manufacturing and business logistics. Selected due to its relatively advanced graphic development interface (Fig. 11.3), *AnyLogic* does not yet possess the critical mass of users who can share experiences and push development. The lack of a common, accessible and user-friendly environment on which to build successful ABM implementations continues to retard adoption in planning practice. Until a clearly dominant ABM environment emerges that can provide both a user-friendly interface and attract a community of users, ABM development will continue to split ABM-related resources and expertise into diffuse nodes.

Awareness of and experience with ABM was highlighted by the panel of tourism experts as an important consideration in the adoption of *TourSim*. Comments highlighted the importance of who was promoting and developing *TourSim*, and the credibility (or lack thereof) that this would engender. It was noted that consultant or private enterprise driven development and 'release' of a product like *TourSim* would be met with a large amount of scepticism by tourism planning practitioners. The panel instead proposed targeted development of *TourSim* in collaboration with a specific jurisdiction, who would then act as 'champions' for the model. These comments underline the conflict between the need for both a common ABM development environment and the simultaneous requirement to develop specific models and applications in a site-specific, collaborative manner.

### *11.4.2 Technical Issues*

Expert interviews with tourism planners reinforced the idea of *TourSim* as a user-friendly way to manipulate large datasets (in this case, the CTS and ITS), generating better value from those products. Additionally, feedback from planners has pointed to the use of such dynamic representations of tourism as an effective way to advocate specific tourism issues to decision makers. Figures 11.1 and 11.2 show how end users interact with *TourSim*. Graphic sliders and activation buttons should facilitate use by those with a general level of computer skill. We feel that, with the help of a tutorial and documentation, the *TourSim* scenarios could be used by non-technical users with some previous experience using web-based applications. This simplified user front-end is built using the *AnyLogic* development environment (Fig. 11.3). *AnyLogic* provides graphic tools to assist users with basic structure but for more complex functions, programming is required. From a developer perspective, a programming requirement is not unusual for this type of customized ABM. However, from a planners' perspective, the level of programming knowledge required to expand or alter the structure of the model, add new data sources or change visualization options is high and may slow adoption of *TourSim*. Due to these greater technical requirements, using *TourSim* within planning practice would be likely to require in-house or contracted expertise to build simulations for less technical users to then operate. This mirrors some of the early GIS analyses in planning but contrasts with current GIS, where insights from human-computer interaction

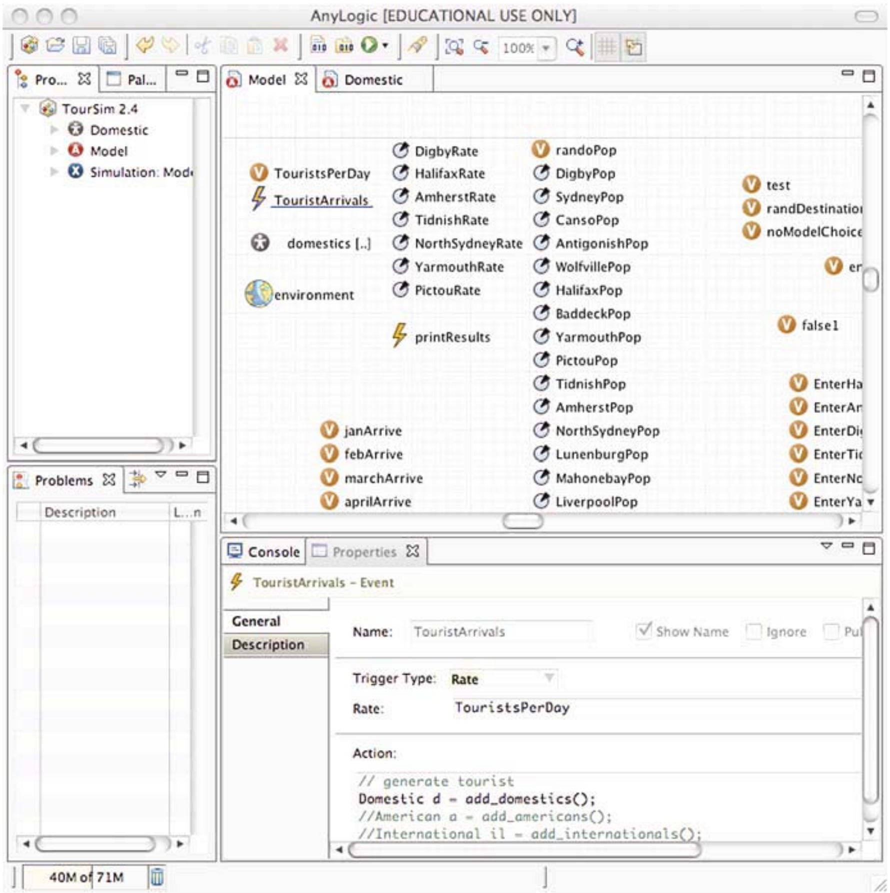


**Fig. 11.3** *AnyLogic* developer environment. Based on Eclipse IDE, this interface provides for organization of model variables, Java programming and debugging

research have made GIS more broadly accessible and responsive to the needs of non-technical users (Haklay and Tobon 2003; Talen 2000). Much research on ABM involves models built, tested, used and evaluated largely by those individuals who developed them, rather than being developed and evaluated by potential end users of the product (McIntosh *et al.* 2007). Recent advancements in computer interface design has increased the accessibility of many types of command line based software. By replacing current environments that require pure computer programming code with clickable menus, reusable graphic components, and a 'what you see is what you get' style interface, ABM development will require less specialized knowledge, opening it up to a wider range of users. In the near term, it is still likely that end users will rely on a model developer, or 'chauffeur', to carry much of the technical programming weight when implement revisions to the model.

### *11.4.3 Overall Application to Tourism Planning Tasks*

Essential to the development and promotion of any PSS is an assessment of how that technology integrates with planning tasks and how it adds value to existing methods. Advocates of the use of ABM within planning point to it as a method that integrates a variety of data, allows for evaluation of comparable options, and visualizes complex interactions and future outcomes (Bonabeau 2002; Zellner 2007). Consultations with tourism planning experts have identified several planning situations where the *TourSim* model would be useful. These include its use as a method to develop thinking and expectations on investment opportunities, such as marketing, the development of regional attractions, or expanding transportation infrastructure. Other identified improvements of the *TourSim* model include the ability to model the economic value of each tourist trip, and to observe the spatial characteristics of this expenditure. In order to better tie *TourSim* to tourism planner needs, the panel of experts recommended that the model move away from showing simple tourist numbers, and towards showing dollars spent, particularly how it differs depending on where the tourist trip originated. This addition was seen to be beneficial as an aid to determining where advertising dollars might be best spent in order to attract the highest yield type of tourist.

Tourism planning in Nova Scotia has evolved into a consultative procedure, with government agencies working with local groups and industry to guide the development of tourism in a manner that is sensitive to the needs and desires of the host communities. To support this process, *TourSim* could provide an environment to capture the ideas of a tourism working group. Ideally, a joint community-industry-government consultation process using *TourSim* would allow participants to identify areas of concern or interest, outlining scenarios to be programmed into a simulation, tested and evaluated by the group. Accordingly, these simulations would run through a number of iterations. As *TourSim* becomes a tool to focus discussion and ideas, it can allow group members to test and visualize various options, particularly risky ones, without investing actual resources.

## 11.5 Conclusions and Future Directions

Tourism planning is a process marked by complexity, multiple stakeholders and outcome uncertainty. Compared to urban or municipal planning which aims to provide services to taxpayers, tourism planning has the additional difficulty of developing a product that must compete effectively within a global marketplace. In a location such as Nova Scotia, where tourism represents a vital part of the economy, the desire to develop new attractions and increase tourism benefits must be tempered by the risk inherent in these plans. Tools that can visualize and evaluate scenarios serve as a starting point for community consultation on developing and evaluating a range of tourism policies. This is a strength of *TourSim*, as it can be used to experiment with possible outcomes.

In its current state, *TourSim* simplifies tourism processes in Nova Scotia. Various data and interactions have been excluded and, while this makes *TourSim* easier to operate and analyse, results may miss a sense of validity. To increase the validity of *TourSim*, incorporating aspects of destination popularity, accommodation capacity, and event and seasonal-driven inputs of tourists, such as for summer festivals could help. Adding these dynamics will enable a wider range of scenarios and analysis options, providing a more compelling tool for tourism planning. As *TourSim* is further introduced into tourism planning in Nova Scotia, we will be soliciting ongoing feedback from numerous planners about the possible integration of *TourSim* into their site-specific tasks. Additional steps include a user needs analysis of planners operating at various scales, to provide an indication of where and how *TourSim* could be modified to better provide value to tourism planners. This type of collaborative PSS development will continue to help identify bottlenecks to adoption, build awareness of ABM-based PSS, and provide for a test bed for future implementations of *TourSim*.

As an emerging technology, the use of ABM as a PSS in tourism planning holds potential, but is accompanied by significant hurdles. Adoption constraints include a lack of awareness and a lack of experience using ABM, technical issues, and the fit of ABM with planning tasks. *TourSim* is affected by all of these restrictions, particularly when compared to more conventional GIS-based PSS. The development of *TourSim* is one step in translating the benefits of an ABM approach into applied planning practice, building on the notable work of others (Berman *et al.* 2004; Heppenstall *et al.* 2006; Ligmann-Zielinska and Jankowski 2007) to promote this technology. Clearly there is still much work to be done, particularly in raising awareness of the technology, and mitigating a host of constraints to adoption.

The use of empirical datasets to inform model parameters, and the integration of ABM functionality into desktop GIS are important areas of research that will shape the further development of ABM-based PSS. Recent advances in techniques to translate large datasets into model parameters (Berger and Schreinemachers 2006; Robinson *et al.* 2007) represents a significant step towards improving the quality and realism of agents represented in an ABM. This movement of ABM towards more realistic models increases the potential for ABM application as a PSS. The integration of ABM functionality within commercial desktop GIS is another area of future development that could also improve adoption and awareness aspects of ABM-based planning tools (Brown *et al.* 2005). By coupling ABM with an established base of users and computer skills, ABM-based PSS can be implemented as an additional tool within the GIS tool box. Integrating ABM with GIS may provide the tools for creating dynamic models but it will not necessarily increase awareness of the ABM's potential. Continued academic research and applied projects are needed to evaluate the use and impacts of ABM-based PSS in specific planning situations, building a wider base of knowledge.

## References

Alessa, L.N., Laituri, M. and Barton, M. (2006) An "all hands" call to the social science community: establishing a community framework for complexity modeling using agent based models and cyberinfrastructure, *Journal of Artificial Societies and Social Simulation*, 9(4): 6. http://jasss.soc.surrey.ac.uk/9/4/6.html.

An, L., Linderman, M., Qi, J., Shortridge, A. and Liu, J. (2005) Exploring complexity in a human-environment system: an agent-based spatial model for multidisciplinary and multiscale integration, *Annals of the Association of American Geographers*, 95(1): 54–79.

Bankes, S., Lempert, R. and Popper, S. (2002) Making computational social science effective: epistemology, methodology and technology, *Social Science Computer Review*, 20(4): 377–388.

Batty, M. (2004) Dissecting the streams of planning history: technology versus policy through models, *Environment and Planning B*, 31: 326–330.

Benenson, I. and Torrens, P.M. (2004) Geosimulation: object-based modeling of urban phenomena. *Computers, Environment and Urban Systems*, 28(1): 1–8.

Berger, T. and Schreinemachers, P. (2006) Creating agents and landscapes for multiagent systems from random samples. *Ecology and Society*, 11(2): 19. http://www.ecologyandsociety.org/vol11/iss2/art19/.

Berman, M., Nicholson, C., Kofinas, G., Tetlichi, J. and Martin, S. (2004) Adaptation and sustainability in a small Arctic community: results of an agent-based simulation model, *Arctic*, 57(4): 401–414.

Bolte, J.P., Hulse, D.W., Gregory, S.V. and Smith, C. (2006) Modeling biocomplexity – actors, landscapes and alternative futures, *Environmental Modelling and Software*, 22: 570–579.

Bonabeau, E. (2002) Agent-based modeling: methods and techniques for simulating human systems, *Proceedings of the National Academy of Sciences USA*, 99(3): 7280–7287.

Bradley, W.J. and Schaefer, K.C. (1998) *The Uses and Misuses of Data and Models: The Mathematizations of the Human Sciences*, SAGE Publications, Thousand Oaks, California.

Brown, D.G. (2001) Project SLUCE, http://www.cscs.umich.edu/research/projects/sluce/.

Brown, D.G., Riolo, R., Robinson, D.T., North, M. and Rand, W. (2005) Spatial process and data models: toward integration of agent-based models and GIS, *Journal of Geographical Systems,* 7: 25–45.

Budic, Z.D. (1994) Effectiveness of geographic information systems in local planning, *Journal of the American Planning Association*, 60(2): 244–263.

Deadman, P. and Gimblett, H.R. (1994) The role of goal-oriented autonomous agents in modeling people-environment interactions in forest recreation, *Mathematical and Computer Modelling*, 20(8): 121–133.

Deadman, P., Robinson, D., Moran, E. and Brondizio, E. (2004) Colonist household decisionmaking and land-use change in the Amazon rainforest: an agent-based simulation, *Environment and Planning B*, 31: 693–709.

Gilbert, N. and Troitzsch, K.G. (2005) *Simulation for the Social Scientist* (Second edition), Open University Press, Maidenhead.

Grimm, V. and Railsback, S.F. (2005) *Individual-based Modeling and Ecology,* Princeton University Press, Princeton, New Jersey.

Haklay, M. and Tobon, C. (2003) Usability evaluation and PPGIS: towards a user-centered design approach, *International Journal of Geographical Information Science*, 17(6): 577–592.

Hall, C.M. (2000) *Tourism Planning: Policies, Processes and Relationships,* Prentice Hall, Harlow.

Heppenstall, A., Evans, A. and Birkin, M. (2006) Using hybrid agent-based systems to model spatially-influenced retail markets, *Journal of Artificial Societies and Social Simulation*, 9(3): 2. http://jasss.soc.surrey.ac.uk/9/3/2.html.

Holling, C.S. (1978) *Adaptive Environmental Assessment and Management*, John Wiley and Sons, New York.

Jamal, T., Borges, M. and Figueiredo, R. (2004) Systems-based modeling for participatory tourism planning and destination management, *Tourism Analysis*, 9(1–2): 77–89.

Lempert, R. (2002) Agent-based modeling as organizational and public policy simulators, *Proceedings of the National Academy of Sciences USA*, 99(3): 7195–7196.

Ligmann-Zielinska, A. and Jankowski, P. (2007) Agent-based models as laboratories for spatially explicit planning policies, *Environment and Planning B*, 34: 316–335.

Manson, S.M. (2006) Bounded rationality in agent-based models: experiments with evolutionary programs, *International Journal of Geographical Information Science*, 20(9): 991–1012.

McIntosh, B., Seaton, R.A F. and Jeffrey, P. (2007) Tools to think with? Towards understanding the use of computer-based support tools in policy relevant research, *Environmental Modelling and Software*, 22: 640–648.

Nedovic-Budic, Z. (1998) The impact of GIS technology, *Environment and Planning B*, 25(5): 681–692.

Parker, D.C., Manson, S.M., Janssen, M.A., Hoffmann, M.J. and Deadman, P. (2003) Multi-agent systems for the simulation of land-use and land-cover change: a review, *Annals of the Association of American Geographers*, 93(2): 314–337.

Robinson, D.T., Brown, D.G., Parker, D.C., Schreinemachers, P., Janssen, M.A., Huigen, M. *et al.* (2007) Comparison of empirical methods for building agent-based models in land use science, *Journal of Land Use Science,* 2(1): 31–55.

Talen, E. (2000) Bottom-up GIS: a new tool for individual and group expression in participatory planning, *Journal of the American Planning Association*, 66(3): 279–285.

Vonk, G., Geertman, S. and Schot, P. (2005) Bottlenecks blocking widespread usage of planning support systems, *Environment and Planning A*, 37: 909–924.

Walker, P.A., Greiner, R., McDonald, D. and Lyne, V. (1999) The tourism futures simulator: a systems thinking approach, *Environmental Modelling and Software*, 14: 59–67.

Wooldridge, M. and Jennings, N.R. (1995) Intelligent agents: theory and practice, *The Knowledge Engineering Review*, 10(2): 115–152.

Yeoman, I., Galt, M. and McMahon-Beattie, U. (2005) A case study of how VisitScotland prepared for war, *Journal of Travel Research*, 44(1): 6–20.

Zellner, M.L. (2007) Generating policies for sustainable water use in complex scenarios: an integrated land-use and water-use model of Monroe County, Michigan, *Environment and Planning B*, 34: 664–686.

## Additional Reading

Axelrod, R. and Tesfatsion, L. (2006) On-line guide for newcomers to agent-based modeling in the social science. http://www.econ.iastate.edu/tesfatsi/abmread.htm.

Bankes, S. (2002). Agent-based modeling: a revolution? *Proceedings of the National Academy of Sciences USA*, 99(3): 7199–7200.

Epstein, J.M. and Axtell, R. (1996) *Growing Artificial Societies: Social Science from the Bottom Up,* The Brookings Institution, Washington, D.C.

Gimblett, H.R. (2002) *Integrating Geographic Information Systems and Agent-Based Modeling Techniques for Simulating Social and Ecological Processes,* Oxford University Press, New York.

Milne, S. and Ateljevic, I. (2001) Tourism, economic development and the global-local nexus: theory embracing complexity, *Tourism Geographies*, 3(4): 369–393.

Reed, M.G. (1999). Collaborative tourism planning as adaptive experiments in emergent tourism settings, *Journal of Sustainable Tourism*, 7(3–4): 331–356.