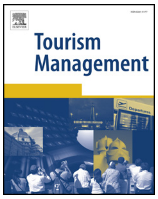
Tourism Management 68 (2018) 336–354

Contents lists available at ScienceDirect

Tourism Management

journal homepage: www.elsevier.com/locate/tourman



Scenario-based planning for tourism development using system dynamic modelling: A case study of Cat Ba Island, Vietnam

Thanh Mai[a,*], Carl Smith[b]

[a] International Centre for Applied Climate Sciences (ICACS), University of Southern Queensland, Toowoomba, Queensland 4350, Australia
[b] School of Business, The University of Queensland, Brisbane, Queensland 4072, Australia

ARTICLE INFO

Keywords:
Scenario planning
System dynamic modelling
Sustainable tourism
Decision making

ABSTRACT

Tourism destinations are dynamically complex systems in which behaviour is controlled by many interacting components and feedback loops. Yet tourism destination planning has traditionally been based on forecasting models that rely on historical data to predict future trends.

We explore system dynamic modelling as an alternative to forecasting models for the scenario-based planning of tourism destinations. We construct a system dynamic model for tourism development on Cat Ba Island, a rapidly developing tourist destination in Vietnam, and use it to model alternative tourism development scenarios.

Our results indicate that the current trajectory of tourism development on Cat Ba Island is not sustainable and limits to growth may be reached as early as 2022 due to water shortages, pollution and overcrowding. Beyond this time the destination risks breaching its limits to growth, which creates a further risk, that of eroding carrying capacity through resource depletion and environmental degradation.

1. Introduction

A tourist destination is a dynamically complex system because it comprises many components (Gunn, 1994; Leiper, 1990; Mill & Morrison, 1998) that interact in a non-linear way (Baggio, 2008; Gunn, 1994). The system also contains a diverse array of stakeholders, each of whom has different management objectives, agendas and interests (Mai & Smith, 2015). Furthermore, the system is influenced by various internal factors (such as policy, government regulation, socio-economic conditions) as well as external shocks from both man-made crises (such as the Global Financial Crisis and Terrorism) and natural disasters (Mai, 2012). The combination of these factors means that the future of any tourist destination is uncertain and managers of tourist destinations have to make decisions in a complex and uncertain environment.

Scenario planning has been put forward by several authors as a systematic approach to creating and testing possible future scenarios in uncertain environments (Maani & Cavana, 2007; Thomas et al., 2005). Unlike forecasting, which extrapolates past and present trends to predict the future, scenario planning is a strategic method expressly developed to allow managers to rehearse the future and be better prepared and able to adapt to possible future outcomes. In tourism, scenario planning has received growing attention since the late 1970s and is now an integral part of destination planning (Gössling & Scott, 2012).

Scenario planning requires the development and use of simulations to anticipate possible futures and to assess the implications of management decisions on those futures. Models have been used to predict the possible futures of tourism destinations in the past, however these models have generally been forecasting models, such as time series models (Burger, Dohnal, Kathrada, & Law, 2001; Lim & McAleer, 2002; Papatheodorou & Song, 2005), econometric models (Algieri, 2006; Croes & Vanegas, 2005; Li, Song, & Witt, 2005), and more recently neural networks (Kon & Turner, 2005; Pai & Hong, 2005; Palmer, Montano, & Sese, 2006). These models rely on historical data to predict future trends with the assumption that tomorrow's world will be much like today's. The consequence is that when conditions are unstable, these models become unreliable because historical trends become poor indicators of future trends.

The past and future behaviour of complex systems is controlled not by the number of components they contain but by the interactions among components. These interactions can be explained using the theories of system dynamics, which essentially relate system behaviour to feedback loops that exist within the system (Sterman, 2000). The complexity we observe in system behaviour is due to shifts in the dominance of these feedback loops over time, as well as material and information delays that exist within the system. This means the future

---

[*] Corresponding author.
E-mail addresses: thanh.mai@usq.edu.au (T. Mai), c.smith2@uq.edu.au (C. Smith).

https://doi.org/10.1016/j.tourman.2018.04.005
Received 2 April 2016; Received in revised form 1 April 2018; Accepted 14 April 2018

behaviour of complex systems can change as latent feedback loops become dominant due to system shocks or as the system approaches limits to growth. Hence, system dynamic models are likely to have advantages when it comes to scenario planning because they do not assume that historical trends will occur into the future and they explicitly model system behaviour as an emergent property of the interaction among system components over time. Precise forecasting or prediction is not the purpose of system dynamic models. Rather, they are used to understand how the interactions and feedback loops among system components influence system behaviour over time, and to understand how scenarios may change system behaviour over time (Kelly et al., 2013).

The objective of this paper is to demonstrate the utility of system dynamics to scenario planning for a tourist destination. We use the case of tourism development on Cat Ba Island, Vietnam (see Mai & Smith, 2015 for a description of the case study area). First, we explain how we constructed and tested a system dynamic model of the tourism system on Cat Ba Island. Second, we develop alternative scenarios for tourism development on Cat Ba Island. Finally, we evaluate the sustainability of each tourism development scenario using our system dynamic model.

2. Research methods

There are five main steps in the system dynamic modelling process. These are problem articulation, formulating a dynamic hypothesis, formulating a simulation model, testing the model, and policy design and evaluation (Sterman, 2000). For this study, the methods used to complete the first two steps are explained in Mai and Smith (2015). Here we explain how we implemented the last three steps to develop, test and use a dynamic model of the tourism system on Cat Ba Island.

2.1. Formulating a simulation model

In Mai and Smith (2015), a causal loop diagram (CLD) was used to describe feedback loops influencing tourism system dynamics on Cat Ba Island. The limitation of CLDs is that they cannot be used to simulate system dynamics over time because they are qualitative descriptions of systems. To quantitatively simulate tourism dynamics on Cat Ba Island we developed a stock and flow model (SFM) based on the CLD described in Mai and Smith (2015).

As the name suggests, a SFM consists of stocks that represent accumulations within a system (population of people, for example) and flows that increase (inflows) or decrease (outflows) stocks (births and deaths, for example). Auxiliary variables and stocks control the flows (population, a stock, and birth rate, an auxiliary variable, control the births flow, for example). Therefore a stock can only change via its flows, and stocks and auxiliary variables control the flows.

All feedback loops contain at least one stock, so the basic steps used to construct a stock and flow model from the feedback loops contained within Mai and Smith's (2015) CLD were: (1) identify the stocks, (2) identify the flows that increase or decrease each stock, and (3) identify the stocks and auxiliary variables that control each flow. An example of the application of these steps is provided in Figs. 1 and 2. Fig. 1 is a single balancing loop taken from Mai and Smith's (2015) CLD. It shows that as tourist numbers grow, investment in infrastructure and facilities increases (such as hotel development). This in turn increases the waste generated, and because waste is currently not treated, pollution increases. After a delay, the increase in pollution acts to decrease the attractiveness of Cat Ba Island to tourists, slowing the growth in tourist numbers. Fig. 2 replicates this balancing loop as a series of stocks, flows and auxiliary variables, in this case focusing on water pollution generated by domestic tourists. The stock is the actual number of domestic tourists, which can change according to the change in the domestic tourists flow. The actual number of domestic tourists, via day night stays, affects the number of non-star hotel rooms required. This affects hotel water use, and combined with the domestic water use of Cat Ba town residents, affects the total water demand for Cat Ba town. A proportion of the water used by Cat Ba town goes to waste, and a proportion of this waste water is untreated, affecting the pollution index for Cat Ba (the pollution index is pollution relative to 2004 pollution levels). The pollution index, in turn, affects tourist growth, which affects the change in domestic tourists flow and the actual number of domestic tourists, hence completing the feedback loop.

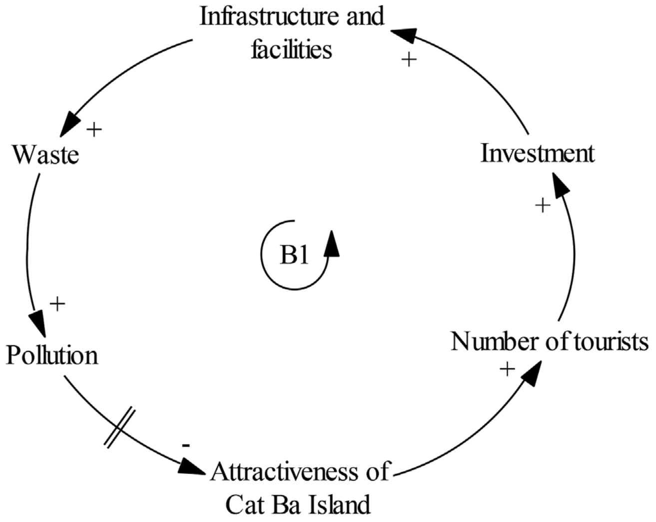


Fig. 1. A balancing loop taken from the CLD for tourism development described by Mai and Smith (2015).

We followed this same process to replicate other feedback loops contained in Mai and Smith's (2015) CLD within our SFM. Not all feedback loops were replicated because we did not have enough information to quantify the stocks, flows and auxiliary variables for all feedback loops. The feedback loops that were replicated in our SFM are highlighted in Fig. 3.

To run simulations a SFM requires parameter values. These parameters include (a) the initial value for stocks at the beginning of the simulation (the initial number of domestic tourists, for example), (b) constants that are stored as auxiliary variables (the average length of stay of domestic tourists, for example), and (c) graphical functions that represent the influence of one variable on another (the effect of pollution on tourist growth, for example). The remainder of the SFM is parametrised using equations (domestic day nights = actual number of domestic tourists × average domestic length of stay, for example). The full list of parameters used in the SFM is contained in Appendix 1. The SFM was parametrised for the year 2004 and used to run simulations on an annual time step until 2050 (a 46 year time period).

Graphical functions were used within the SFM to parameterise variables where empirical data were absent and where equations could not be used. Hence graphical functions were used to capture assumed parameters. These graphical functions are called dimensionless multipliers (Fisher, 2011). Dimensionless multipliers are used to adjust the value of a constant during the course of a simulation based on the value of another variable. They are called dimensionless multipliers because the x-axis of the graphical function is the ratio of two variables with the same units (making the x-axis dimensionless) and the y-axis is a multiplier with no units. For example, Fig. 4 shows the graphical function used for the 'effect of pollution on tourist growth' dimensionless multiplier. The graph represents an extreme end effects curve, meaning that if the pollution index changes a small amount from a central value (in this case 2.5), the y-axis multiplier will not change a great deal from 1. However, as pollution index changes further away from a central value, the y-axis multiplier changes quickly above or below 1. Therefore the curve in Fig. 4 represents the assumption that a pollution index close to 2.5 will not change tourist growth. As the pollution index approaches 5,