An Educational Simulation Tool for Integrated Coastal Tourism Development in Developing Countries

Annick Anctil[a*], David Le Blanc[b]

a: *Environmental Engineering and Earth Sciences, Clemson University, Clemson, United States*

b: United Nations, Division for Sustainable Development, New York, United States

* 342 Computer Ct, Anderson SC, 29625, aanctil@clemson.edu

Annick Anctil is an assistant professor at Clemson University in the department of Environmental Engineering and Earth Sciences. 342 Computer Ct, Anderson SC, 29625, USA. Email: aanctil@clemson.edu

David Le Blanc is at the Division for Sustainable Development at the United Nations, 547 1st avenue, New York 10017, USA. Email: leblanc@un.org.

An Educational Simulation Tool for Integrated Coastal Tourism Development in Developing Countries

This paper presents an educational simulation tool based on a generic model for integrated planning of coastal tourism infrastructure. In spite of the importance of coastal tourism for the economies of many developing countries, tourism infrastructure has often been developed without full consideration of long-term impacts on the environment. The simulation model presented in this paper aims to address critical gaps in awareness and capacity for integrated decision-making and planning in tourism infrastructure development in a developing country context. We build a simple closed-loop model of tourism infrastructure investment, which integrates typical economic, social and ecological dimensions of the problem. The model is calibrated so that within 20 years investment projects in tourist capacity done without concomitant investment in waste treatment result in a collapse of fish stocks and a sharp drop in tourist attendance. The model includes several policy options that allow stakeholders to intervene. The model allows stakeholders to explore how various combinations of policies perform in financial, environmental and social terms over the long period. It can therefore be used as support to an educational tool for training and capacity-building of stakeholders in various contexts

Keywords: tourism; infrastructure development; sustainability; industrial ecology; simulation tool.

1) Introduction

In many countries, coastal tourism development has been characterized by lack of sectorial integration. Tourism infrastructure has often been developed in relative isolation from the other sectors of the economy, and without full consideration of long-term impacts on the environment, resulting in adverse impacts on other sectors of the economy, and in extreme cases eventually causing the decline of the very resource on which tourism is based. In many countries coastal tourism infrastructure was developed in the absence of investments in solid waste treatment capacity and wastewater collection and treatments systems, which has resulted in pollution of water courses, lagoons and coastal seawaters (see e.g. Reopanichkul et al. 2009). In the process, fisheries and freshwater resources have been affected. Ultimately, the degradation in the water quality has caused losses of local marine biodiversity, declines in local fish stocks, and lower seawater quality, which in turn has impacted the attractiveness of local tourism. With local variants, this story has repeated itself in places as diverse as Spain (Fortuny, Soler, Cánovas, & Sánchez, 2008) , Croatia (Logar, 2010), Turkey (Tosun, 2001), Caribbean islands (Maal-Bared, 2006; Yaw, 2005), Zanzibar (Gössling, 2001), the Galapagos Islands (Baine, Howard, Kerr, Edgar, & Toral, 2007), and Mexico (Ortiz-Lozano, Granados-Barba, Solís-Weiss, & García-Salgado, 2005).

Thus, in many places across the world coastal tourism development is conducted in a way that results in investment decisions, which are at odds with long-term sustainability. That is to say, decision-making processes that would give high priority to sustainability considerations and to the long-term health of ecosystems as providers of services would result in different investment decisions. Among the many reasons that have been identified for such disconnect, this paper focuses on three aspects: lack of awareness, knowledge and capacity; conflicting objectives of the different stakeholders; and inadequate institutional framework to address the feedbacks between infrastructure development and ecosystem degradation. These three factors all relate to the political economy of decision-making in tourism infrastructure investment.

First, there is a lack of awareness and ability to understand complex relationships and feedbacks between economic activity, the pollution it generates, and environment quality. The complexity involved in modelling the impacts of pollution on local ecosystems increase significantly when we try to incorporate the feedbacks from ecology to economy, i.e. the relationship between the state of natural resources and the ecosystem services they provide. For example, determining the maximum effluent load that a lagoon can take over a long period without affecting its absorption capacity and preserving its biodiversity necessitates expensive site-specific scientific studies. The last part of the loop, that is, how the decline in ecosystem services such as fish stocks is going to affect the local economy, is almost never studied before investment decisions are made. Even when the information is available, it is not necessarily accessible and understandable by the different stakeholders and it has to be processed in ways that speak to their concerns[1].

Second, generally speaking, stakeholders typically involved in tourism infrastructure development have different and conflicting objectives (Schianetz, Kavanagh, & Lockington, 2007). Governments often see tourism as a source of foreign exchange flows and tax revenues, as well as a source of job creation and induced economic activities. The objective of private investors who develop and exploit tourism infrastructure is to maximize profit for the development considered in isolation, within a time frame that corresponds to internal considerations related to returns on equity invested in those projects. Local residents may see the development of tourism locally as a blessing or a curse depending on the circumstances. However, in many developing countries high unemployment rates and low tax revenues make tourism an attractive proposition, because of the prospect of local direct and indirect job creation. Finally, in some contexts traditional users of the natural resources that tourism development

[1] For example, showing government officials or the manager of a hotel chain how decline in water quality over 20 years is going to make a resort unattractive to international tourists and affect the project bottom line may get their attention. Showing the same numbers to an indigenous group who has no equity stake in the project will probably not. Conversely, for the indigenous group, the main outcome of interest may be how local fish stocks are going to be affected over the years by the presence of the resort. This outcome is less relevant to the hotel manager, as long as local amenities remain at a level sufficient to continue to attract enough tourists to the resort.

intends to exploit (e.g. indigenous communities) often find themselves in a situation where previously free exploitation of local ecosystems services such as fish and shellfish production is negatively affected by the development of tourism in the long run. The latter group, when not having clear land or resource rights, may not be in a position to seek proper compensation for lost sources of livelihoods and income.

These interest groups have often very different levels of political power and influence in decision-making (Schianetz et al., 2007). In many contexts, the characteristics of tourism investment decisions in terms of capacity, financing, and tax-related matters will be the result of an almost exclusive interaction between private investors (foreign or national), and various branches of the government (Bramwell & Sharman, 1999). The reasons why knowledge about the full impacts of infrastructure investment decisions is lacking is critically linked with these conflicting objectives. Because they do not bear all the negative impacts of their investment decisions, private investors have no incentives to engage in elaborate prospective studies of the impacts of their investments on ecosystems. Governments, which see investment as a primary condition for development, are often reluctant to mandate expensive integrated studies and environmental regulation that they feel might deter investors and send them to neighbouring places.[2] Local governments looking for income and employment generation may have little incentive to examine the long-term impacts of investment decisions (Connell, Page, & Bentley, 2009). In fact, the communities using the services provided by the natural resources as a base for livelihoods (and by extension, NGOs and environmental groups representing them or speaking on their behalf) may in some cases be the only ones with advocating for the long-term preservation of those resources as a

[2] This is in spite of international commitments that Governments may have made, for example under multilateral environmental agreements (see Singh & Mee, 2008).

priority and arguing for more complete, integrated studies examining the long-term impacts of investment decisions. However, they often lack a voice in decision-making processes and resources to privately conduct such studies (see e.g. Wang, Yang, Chen, Yang, & Li, 2010). Therefore, it does not come as a surprise that investment in tourism infrastructure, as the result of a politically determined process, may often be biased towards short-term profitability, neglecting long-term sustainability considerations[3].

Thirdly, the institutional framework for the assessment of the environmental impacts of investment projects is often not adapted to the challenge. This is not limited to tourism but has been noted to apply to virtually all sectors. National legislation and investment requirements for donors and multilateral institutions financing investments in developing countries typically require Environmental Impacts Assessment studies, possibly along with Social Impact Assessments, or broader Strategic Environmental Assessments or equivalent (see e.g. Kuo, Hsiao, & Yu, 2005) However, these instruments have long been criticized for being too restrictive in scope, both geographically and in terms of the impacts considered. They typically not include social aspects. When social impact assessment studies are conducted, they too tend to be restricted in scope and not integrated with economic and environmental dimensions. More broadly, such studies are essentially “defensive” in nature, in the sense that they are conceived as safeguards or remedial actions for projects whose broad characteristics have already been decided and upon which they have at best marginal influence. Instead, considering investment projects from a true sustainability perspective would require fully integrated studies, done before any decisions are made, upon which all stakeholders could base negotiations on the characteristics of the project. The work that

[3] For a discussion of related issues on the case of Cyprus, see (Yasarata, Altinay, Burns, & Okumus, 2010).

we present here was done in the spirit of making the case for such integrated studies and promoting them through capacity-building.

The objective of this paper is to present a simple simulation model that illustrates the full loop of feedbacks between tourism infrastructure investment and ecosystems, and in particular the ones from the environmental side to the economic (and social) sides. The model was developed as the basis for an educational tool for training and capacity-building in developing countries. The tool could be used in training sessions gathering participants from different constituencies (investors, hotel managers, government representatives, local residents, indigenous communities, environmental groups) to build a common understanding of the generic implications of tourism development in terms of sustainability at the watershed level, hopefully providing a platform for discussion and a stimulation to undertake “real” integrated, participative studies adapted to their specific circumstances. The training would have participants play role games and negotiate development strategies among themselves, with the objective of coming up to mutually beneficial strategies.

Among a range of possible feedbacks that would be relevant from the policy point of view, we choose to focus on factors that are, to a large extent, manageable by local stakeholders and decision-makers, and specifically we illustrate the necessary interconnectedness of strategies for tourism development, solid waste treatment, and wastewater management. These issues are highly relevant for small islands around the world. The model is built and parameterized in a way that allows one to: (i) show how the different stakeholders are affected by tourism infrastructure decisions; (ii) show the interdependence between the impacts created by tourism development and local sustainability, through solid waste and water quality feedbacks; (iii) show how integrated strategies for solid waste and water quality management affect outcomes of interests for the different stakeholders, thus allowing participants to explore other stakeholders' perspectives and motives; and (iv) highlight the trade-offs between long term and short term decisions, and between individual objectives of stakeholders and integrated sustainability strategies.

The simulation tool was kept deliberately simple, in order to be user-friendly and understandable by non-specialists. It is dynamic, i.e. covering a period of twenty years, in order for participants to see the impacts of their decisions unfold over time; and it lends itself to negotiation role-playing games where participants can see the impacts of their decisions on a range of outcomes of interest. These characteristics make our model similar in spirit to educational simulation tools that have been developed in other areas, for example natural resource management (García-Barrios, Speelman, & Pimm, 2008; Speelman, López-Ridaura, Colomer, Astier, & Masera, 2007) and water management (Williams, Lansey, & Washburne, 2009). Our model is also directly inspired by systems thinking and industrial ecology principles, even though the spatial setting is a lagoon (or a small island) rather than an industrial zone[4].

The idea of using dynamic systems modelling as a basis for collective learning and shared agenda-setting in tourism is not new (Schianetz et al., 2007) explore this concept and review case studies from Bali, China, Austria, the Sporades Islands in Greece, and Australia, where dynamic modelling was used as an assessment tool within broader tourism assessment projects. They mention that system dynamics modelling "*has been used on many different scales in the last three decades to assess sustainability issuers in tourism destination*". However, they also mention that such

[4] One of the first application of systems thinking to tourism simulation model, see (Walker & Walker, 1999) For an application of industrial ecology to tourism, see e.g. (Kuo, Hsiao, & Lan, 2005).

models have usually not been used directly for collective learning purposes, even though case studies show that they have a significant potential to lead to "*significant changes in thinking*" (Schianetz et al., 2007,and references therein). Our paper is a contribution to this strand of literature. We focus on the first, and in our opinion, most difficult, step identified by (Schianetz et al., 2007), i.e. enabling the creation of shared awareness of systemic issues and of a common vision among stakeholders with differing objectives.

The remainder of the paper is constructed as follows. Section 2 presents the setting of the model in relation to its training and educational objectives. Section 3 is devoted to the detailed presentation of the model. Section 4 illustrates the range of outcomes that can be studied by the model, focusing on insights brought by the model on some of the trade-offs that typically arise in coastal tourism infrastructure development in developing countries. Section 5 concludes.

2) The setting

In this section, we describe the main concepts behind the simulation model. A technical description is given in Section 3. The purpose of the model is to provide a support for a one-day training package consisting of an educational electronic simulation tool allowing groups of trainees to get the basic notions of integrated solid waste and water quality management at the watershed level, as applied to the development of tourism infrastructure on a coast, and interact with other stakeholders to explore solid waste and water quality management strategies.

The simulation tool is based on a fictitious case taking place on the scale of a watershed. A group of investors is proposing to invest in a resort on a pristine, undeveloped beach located along a lagoon. There are 4 interest groups:

(1) Investors want to establish a tourism resort;

(2) Local residents (represented by their local government) live in a small town upstream in the watershed, along rivers that discharge in or in the vicinity of the bay where the resort is planned;

(3) A small community of indigenous fishermen live out of the fish caught in the lagoon where the hotel is planned;

(4) The central government, which is negotiating the tourism investment deal with the hotel chain.

The local town has no sewage system or solid waste treatment facilities, so that waste generated by local residents pollutes the lagoon. The sizes of the local town and the dimensions of the lagoon are parameterized in such a way that before the investment takes place, the waste generated by local residents can be absorbed by the lagoon and does not affect fish stocks or seawater quality. The resort generates additional waste coming from both hotel users and additional residents brought by the development to the local town. The size of this additional waste depends on the hotel capacity. The model is parameterized in a way that if the hotel is built without any simultaneous investment in water treatment and solid waste treatment facilities, fish stocks and water quality decline rapidly. For large hotel sizes, after 20 years, which is the time horizon chosen for the simulation model, fish stocks have completely collapsed and water quality is so poor as to cause a severe drop in the hotel occupancy rate. This leads to deficits for the resort, decline in tax revenues, unemployment in the local town and loss of livelihoods for the fishermen community.

The model comprises a few parameters that allow users to consider measures that can mitigate these adverse impacts, such as: investment in solid waste and wastewater treatment facilities and the sharing of the associated expenditures between government and the resort; compensation of indigenous fishermen; and education campaign to promote the use of waste treatment. Given the parameters of the model, there are multiple policy combinations that improve the sustainability of the development, even for large hotel sizes.

All the parameters of the model relating to the functional relationships between pollution and the state of the ecosystem are taken from the published literature, as are the economic parameters such as wages, employment generated by hotels, and income elasticity of waste generation. We choose the remaining parameters (mostly, those relating to the volume of water in the lagoon and the sizes of the local town and fishermen community in relation to the size of the hotel) in order for the model to clearly highlight the following trade-offs and conflicting interests:

(1) Hotel size: small vs. large, with large hotel size causing an influx of new residents in the local town;

(2) Optimal capacity for solid waste treatment;

(3) Optimal sharing of financing of waste treatment facilities and services between the hotel and the government; Short-term versus long-term profiles of cash flows accruing to the hotel, the government and local residents;

(4) Employment of indigenous people at the hotel as a way of insuring them against a drop in local fish stocks.

Baseline – initial situation

Before investment takes place, the water is unpolluted or weakly polluted, endowing the coastal area with abundance of fish, both in terms of quantity and marine biodiversity. Sea resources (fish) are exploited by local fishermen. Those fishermen’s living is mostly based on fish, i.e. they have limited outside opportunities to earn a living (this can represent indigenous people in some countries). Local residents do not have access to waste treatment facilities. They produce a base amount of solid waste, which is simply discarded in the local streams, ultimately bringing solid waste residuals to the beach. They also produce a level of effluents (to simplify, nitrogen and/or pathogen agents) that is carried to the sea by the rivers. In this baseline situation, the quantity of waste coming to the beach is low and water quality is still very good, so the projected resort development can count on and unspoiled beach, pristine water and large fish biodiversity to attract tourists.

Basic Scenario -- development has taken place

The basic scenario reflects a situation in which every actor cares for their private interests, and no environmental regulation is in place. A resort has now been developed on the beach. The resort brings with it:

- Tourists and associated income to the hotel. The number of tourists is affected by the quality of the seawater and marine biodiversity in the bay.
- Solid waste and wastewater, proportional to the number of tourists;
- Workers in the hotel. Those are assumed to live among the local residents (LR). Depending on the size of the hotel, they can be previous residents that have been hired by the hotel or newcomers brought there by the tourism development;
- Local residents earn additional income, directly from the hotel and from induced activities (souvenir shops, traditional handcrafts, etc.). This translates into increased consumption and additional solid waste and effluents.

In the basic scenario, the hotel discharges effluents directly in the lagoon. The hotel also chooses not to build a solid waste treatment plant, and instead dumps its waste in a nearby unorganized landfill. As a consequence of this and of the additional waste generated by the local residents, solid waste increases, the beach gets spoiled by solid waste and sea water gets more polluted, resulting in decreased marine biodiversity, and increasing health hazards for tourists and marine life. This has a negative impact on tourist arrivals, hotel income, and ultimately on the profitability of hotel operation in the area. Decreased marine life also negatively impacts local fishermen's livelihoods. All these changes accelerate over the simulation period, due to threshold effects and feedbacks.

Alternative scenarios -- in search for sustainability

In alternative scenarios, policies and measures are introduced to address the adverse impacts of the hotel development. Those include:

- The hotel installs wastewater treatment for its operations (this can reflect government regulation);
- The development includes a solid waste treatment plant, whose capacity can be varied in the model;
- The hotel and the government agree on a rule for sharing the investment costs and functioning expenses of the solid waste treatment;
- The government can invest in education and awareness campaigns for local residents aiming to limit waste dumping and river pollution;
- The government can also demand that the fishermen community receive a part of the revenues from the hotel, either by being reserved some proportion of the jobs generated by the resort, or through direct payments, as a compensation for degraded water quality and livelihoods.

These measures impact the quality of water and fish stocks over time, thus affecting the hotel's profits, government revenues, and local incomes. In the educational tool based on the model, the combination of investments and policies implemented is the subject of negotiations between the four stakeholder groups (hotel managers, government, fishermen, and local residents). Through the game, stakeholders must be able to visualize the consequence of negotiated strategies in order to come to preferable solutions through a trial and error process.

The spatial setting of the model, the (simplified) physical and financial flows between the various actors, and the way in which some of the policies considered in the model affect these flows are represented in Figure 1.

Figure 1

3) The model

This section describes the model more in detail (a complete description of the model variables, parameters and functional relationships is given in the Appendix. The time horizon for all the simulations is 20 years. Figure 2 presents a simplified diagram flow of the model. For exposition purposes, the model can be divided in two blocks: an economic block and an ecological block. The economic block accounts for hotel income and expenditures; government revenues (taxes) and expenditures (waste treatment); local resident employment and income; and indigenous people income, which is proportional to the stock of fish in the lagoon. The ecological block accounts for water pollution resulting from waste water discharge and leachates from solid waste. From pollution loads (nitrates and phosphorus), the model calculates cyanobacteria, algae, and suspended particulate matter concentrations. Those in turn are converted into water desirability for bathing through a composite index; they also determine fish concentration. There are two main feedbacks from the ecological block to the economic block. Water desirability for bathing affects the occupancy rate of the hotel. Fish concentration determines the income of indigenous fishermen. Physical, biological and economic parameters necessary to calibrate the model were taken from published literature.

Figure 2

Population. The initial population in the local town is 1,000. We suppose that the activity rate is 65%, so that the working population is 650. In the initial situation, the local town suffers from high unemployment, with a 30% unemployment rate. If more jobs are created than the initial population can supply, the difference will be met by in-migration, resulting in an increase in the local population. Total population in the indigenous fishermen community is 400, with 200 fishermen.

Wages and incomes. All wages in the model are based on minimum wages in Latin America in 2008 as reported by the International Labour Organization for 2008 (International Labour Organization (ILO), 2009). The average minimum wage for the sample countries included in that study was US$384 per month, corresponding to US$ 4,607 per year. Annual salaries for different worker categories were determined from this amount. Hotel workers are supposed to earn on average two minimum wages, reflecting a mix of skilled and unskilled workers. Indirect workers are supposed to earn 1.2 times the minimum wage. The income of indigenous fishermen is proportional to the quantity of fish landed. It is calibrated so that initially, fishermen's income is equal to 80% of the minimum wage. The model allows for a certain percentage of hotel staff to be recruited among fishermen as one of the policies that can be explored. In such case fishermen's income is modified accordingly.

Direct jobs created in the hotel. The number of jobs created in the hotel is the sum of a fixed number based on the capacity of the hotel and a variable number which depends on the occupancy rate of the hotel in a given year.[5] In the model, the fixed component is supposed to be equal to 15% of the hotel capacity, whereas the variable component is taken to be 0.25 staff per guest. Therefore a 100% occupancy rate corresponds to a 0.40 employee/guest ratio, which is in the range of statistics reported in India and other developing countries (Market Pulse, 2004). Total hotel workforce is then divided between local residents and fishermen if the government has imposed a minimum percentage of staff to be chosen among fishermen.

Indirect jobs. Tourism is known to have an important impact on direct jobs creation but also creates significant amount of indirect jobs. A study for Latin America over the period 1996-2008 reported ratios of indirect over direct employment created by tourism infrastructure ranging from 1.3 to 1.7 depending on the year considered. We assume that up to 80% of minimum wage workers will become indirect workers with higher wage when the hotel is constructed. If the hotel requires fewer workers after some time, employees will return to their initial jobs, up to the initial amount of employees.

---

[5] Various ratios of employees per room or per bed have been used in the industry. In particular an Indian government study has found that in 2004 4-5 star hotels employed an average of 174 persons per 100 rooms (0.435/guest), while 1-3 stars hotels average employment was 122 persons per 100 rooms (0.305/guest) and unclassified hotels had an average of 0.150/guest (Market Pulse, 2004).In Pakistan, a survey found an average of 0.29/guests for hotels between 30-70 beds without mention to the class of the hotel ((Kakar & Khalil, 2007). Finally statistics from Indonesia show a range of 0.29 to 0.51 which depends on the size of the hotel as well as the occupancy rate (Government of Indonesia Statistical Office, 2008).

Relationship between economic development and water consumption. The construction of a hotel will result in an increase in domestic water consumption, due to the hotel itself as well as increased local residents' income. The relationship between income and domestic water consumption was estimated based on information on water footprint (Hoekstra & Chapagain, n.d.) and GDP/capita (UN Statistics Division, 2009) for 112 countries. In the model, initial GDP/capita is estimated by the average of fishermen's and local residents' income. Every year, water consumption is adjusted as a function of the average incomes for each group. Water consumption by hotel guests is based on developed country averages.

Pollutant generation per capita. The composition of the water will change with lifestyle and economic development. For example, in the pacific island region, where GDP per capita was 1,095 USD person-1 year-1 over the period 1998-2002, the average pollutant discharge of phosphorus was 0.51 g person-1 day-1 while it was 4g person-1 day-1 over the same period in the United States. Phosphorus discharge increases with economic development up to a certain point where it starts decreasing due to wastewater treatment systems development (Tsuzuki, 2009). For the purpose of the model, we assume a linear relationship between income per capita and phosphorus discharge. For the hotel, the content in phosphorus will be constant and equal to 4g/person day and we assume that 50% of the pollutants will reach the sea (IPCC, 2006). The amount of phosphorus discharged to the lagoon water is the sum of the pollutants in water from the various groups as well as the contribution from landfill leachate.

TP biomass consumption. Phosphorus in water is absorbed in proportion to the amount of fish. Phosphorus concentration over time evolves depending on the sum of discharges and absorption. The TP level can be used to calculate TN. Total phosphorus is the most crucial limiting nutrient for primary production. There is an increasing risk of harmful algal blooms (cyanobacteria) when TN/TP is below 15 (see Håkanson, 2009).

Solid waste. The amount of solid waste produced by the hotel is proportional to the number of guests. Per capita solid waste produced by hotel guests is taken from (IPCC, 2006), and corresponds to observed values for the USA in 2000. The amount of solid waste produced by fishermen and local residents depends on per capita income. Values for the model are taken from the literature on municipal solid waste. Initial values were taken from averages for South America (see IPCC, 2006), Municipal solid waste rises with increasing incomes as well as increasing population. The corresponding elasticities were taken to be 0.34 for the income elasticity (i.e. 0.34% increase in solid waste with 1% increase in income per capita), and 1 for population (Beede & Bloom, 1995).

In the model, the amount of waste that is treated depends on the capacity of the treatment plant as well as the waste education of local residents. Solid waste generated by the fishermen is untreated and is added to the portion of untreated waste from the hotel and local residents. Solid waste is supposed to be deposited in landfills. In the base case, there are no organized landfills. Waste produced by residents will be in direct contact with the soil. When solid waste treatment capacity is installed, landfills are more compact and generate less leachate. Solid waste quantities generated in the model are converted to equivalent landfill areas, with the equivalent landfill area for treated waste being 0.05 times the equivalent area for untreated waste (Cointreau-Levine, 1999). The costs of solid waste treatment (fixed and variable costs) are taken from a study done in 2003 for the Ministry in charge of waste management in Morocco. Solid waste generates leachates in groundwater that eventually accumulate in the lagoon. Relations between landfill area and leachates are taken from (Lerner, 2003).

Water pollution. Phosphorus leached to the lagoon is converted into concentrations of algae, suspended particulate matter, and cyanobacteria using the functional relations in (Hakanson & Blenckner, 2008). The concentration of particulate matters is used to calculate the Secchi Depth, a bio-indicator of water clarity that is related to the salinity of water and the amount of suspended particulate matter. The attractiveness of the lagoon for recreational purposes depends on the quality of water. In particular, studies have shown that the amount of algae, clarity of water (Secchi depth) and presence of cyanobacteria are particularly important. Desirability indexes are calculated based on thresholds found in the literature. For algae, the thresholds are taken from (Suplee, Watson, Teply, & McKee, 2009). The thresholds for Secchi Depth are based on values from (Smith, Crocker, & McFarlane, 1995). The thresholds for cyanobacteria are based on the values in (Håkanson, 2009). The overall desirability of water for swimming is calculated as the minimum of these three indicators.

Fish stocks. Fish stocks are affected by water quality and by the intensity of fishing from the fishermen community. The concentration of phosphorus in the lagoon affects fish health in a non-linear way: Under a certain threshold, fish density is unaffected. Above that threshold, it decreases with phosphorus concentration. The fishing effort is a function of the number of fishermen. Before the hotel is built the fish population is in a steady state.

Outcomes of interests for the stakeholders. The model provides graphs illustrating how changes in parameters (including those corresponding to policy measures, see below) affect the outcomes of interest of the various stakeholders in the game. For the government, outcomes of interest can be the aggregated income in the two communities (fishermen, local residents) and profits of the hotel; as well as taxes generated by hotel profits and induced activities in the local town. For the fishermen, the main outcome of interest is the fish stock, as well as any income coming from compensations and subsidies. For local residents, income per capita and the unemployment rate are the main variables to monitor. Lastly, for the hotel profits net of taxes are the primary target.

We now present the policy parameters that can be changed in the simulation model[6]. The choice of policies included in the model was dictated by the need for realistic policies on the one hand, and the need to keep the model simple on the other hand. From a modelling point of view, other policy options could easily be introduced in the game, as long as parameters such as costs and environmental impacts can be found in the literature. However, for training purposes introducing too many policy options in an already complex model would result in a loss of didactic clarity, given that the more options are available, the more difficult it is to try different combinations of them in limited time. This need for simplicity was highlighted for other educational simulation tools (for example García-Barrios, Speelman, & Pimm, 2008). Figure 3 illustrates how these policies impact the model.

Solid waste treatment capacity

The government and the hotel can decide to build a waste treatment plant. The capacity of this plant is one of the policy parameters that can be varied in the model. The corresponding parameter is expressed as a multiple of the capacity necessary to take

---

[6] For simplicity, throughout the article we use the term "policies" to encompass measures that can be taken by the various actors to mitigate adverse economic, social and environmental impacts. The term is thus used in a broader sense than its usual meaning, which is restricted to actions taken by governments.

care of the waste generated by the hotel when it is fully occupied. A value larger than 1 indicates that the plant can also treat some of the additional waste as a result of population increase and by the rise in local incomes.

Sharing of solid waste treatment costs between the government and the hotel

The fixed cost of waste treatment can be shared between the hotel and the government. This parameter can be changed from 0-100% of the total cost of the waste treatment plant, independently from who produces the wastes. The variable cost associated with the actual waste is paid by the one who generates the waste.

Waste education campaigns in local town

Since the local community is new to waste collection, it needs campaigns to promote the use of public disposal systems instead of waste dumping. We model the effect of education campaigns by supposing that they increase the rate of waste that goes to the landfill.

Figure 3

Having the hotel treat its used waters.

This corresponds to a case where the government mandates (and enforces) the treatment of wastewater from hotels. Therefore this parameter takes only two values, 0 and 1. We suppose that the water treatment system will remove 80% of phosphorus in the hotel's wastewater. While the amount of water treated will change each year, the annual cost will remain the same, as it is mainly associated to amortization cost.

Including in the investment agreement a clause of minimal proportion of jobs at the hotel reserved for indigenous fishermen (0 to 30 %)

If the hotel does not employ fishermen, there will be an increase in income inequality between them and local residents, as income from fishing declines due to water pollution. In order to reduce this inequality and provide a safety net to the indigenous community, the government can negotiate with the hotel for a minimum proportion of jobs to be reserved for indigenous fishermen. This can have a negative social impact since it disrupts the traditional activities. On the other hand, such a positive discrimination policy is probably socially less disruptive than cash compensation. Another choice for the government is to compensate the fishermen community for the loss of income from fishing using a subsidy, which would assure fishermen a minimum income[7].

4) Results

In the baseline scenario before the construction of the hotel, the pollution level is low enough to cause no major change in water quality and fish stocks over the 20 years of the simulation. Figure 4 shows what happens to water quality and fish stocks when the hotel is built. The figure considers three sizes for the hotel: 250, 500, and 1,000 beds. In the long run, the construction of the hotel has a serious impact on the quality of the

---

[7] Again, we only provide these two options for the sake of simplicity. In no way do we suggest that these are the only options that should be considered to address the loss of livelihoods of local fishermen. The literature on indigenous people's participation in local development (e.g. in mining, oil and gas extraction, tourism) as well as preliminary role-playing games based on the model suggest that genuinely including the indigenous community in the decision-making process and sharing of the revenues generated by tourism investment would be a critical and difficult issue in real-life situations.

water as well as on the fish stock. The figure illustrates that damage to the environment increase sharply with the size of the hotel.

The absence of sewerage and waste collection systems will not only result in environmental degradation, it will also reduce the hotel profit in the long run. If the hotel management has only a short-term vision, or if they base their cash flow projections on purely financial data, which is likely to be the case in the real world, they may predict that a 1,000 bedroom hotel would be the best choice. However, this fails to recognize that environmental degradation will cause the site to lose its attractiveness and can even lead to a collapse of the tourism sector. Government revenues, which largely come from taxes on hotel profits, also decline sharply over time (Figure 4). In addition, as occupancy in the hotel declines over time, local incomes decrease and the unemployment rate rises. Indigenous fishermen are also seriously affected, their incomes being reduced to a fraction of its initial value due to the decline on fish stocks.

Figure 4

Figure 5

With the introduction of the policy options, it is possible to limit adverse environmental impacts in the long run. We now illustrate some of the trade-offs that the model allows users to explore. We first focus on the impact of solid waste treatment on the long-term sustainability of the project, and in particular on water quality. Figure 6 shows the relationship between hotel size and solid waste treatment capacity (as a multiple of the capacity necessary to treat the waste generated by the hotel) and water desirability for bathing (bathing factor) after 20 years. The latter directly impacts hotel profits. From Figure 6, waste treatment improves water quality on the long run. Beyond 1.3 times the capacity of the hotel, additional waste treatment capacity does very little to improve water quality. In order to retain water quality close to its initial value, the hotel size has to stay below 300 when there is no waste treatment, but can be pushed up to 800 when waste treatment capacity is at 1.3.

Figure 6

We now investigate the relationship between solid waste treatment capacity, hotel size and profits of the hotel over the 20 years of the simulation. We first consider the case when the hotel pays for 100% of the costs of solid waste treatment. The relationship between the two parameters and hotel profits is shown in Figure 7(a). From Figure 7(a) it is clear that there is an optimum for profits as a function of hotel size and solid waste treatment capacity. The optimum is obtained for hotel size slightly above 900 and solid waste capacity at 1.3. That is, it is in the hotel's own interest to pay for more than the waste generated by its residents and also covers some for the waste generated by local workers. It is interesting to note that the optimum obtains even though there are no scale effects in our simplified model of cash flows for the hotel: all incomes and expenditures are strictly proportional to the scale of the hotel. Here, the presence of an optimum is due to the fixed size of the lagoon. Figure 7(b) shows what happens when the government pays for 50 percent of the (investment) costs of solid waste. Whereas hotel profits increase, the optimal size of the hotel hardly changes.

Figure 7

One feature of the model that needs mentioning is that solid waste treatment, while it radically improves the sustainability of the operation, is too expensive to be undertaken by the government alone, in the sense that the costs of treating the additional waste generated by the project is much higher than the revenues collected by the government from the hotel and indirect activities generated by it. In fact, in order for net government revenues from the project to stay positive, the government can only afford to pay for a small share of waste treatment costs. This is illustrated in Figure 8, in a scenario where solid waste capacity is fixed at 100% of hotel waste generation and the hotel treats its used waters. Hotel profits (net income) and government revenues are summed over the 20 years of the simulation. What immediately appears from Figure 8 is that assuming the cost of treating its solid waste does not seriously affect the profitability of the hotel. By contrast, these costs deeply impact government revenues, which are much lower than hotel profits.

Figure 8

This feature of the model depends only on hotel profits, tax rates, and costs of solid waste treatment. Since we took plausible values for these parameters, this reproduces a stylized fact that has been observed in practically all developing countries, where tourism infrastructure has been developed but sewerage and solid waste treatment capacities have never been implemented. In many of these countries, the provision of waste treatment is inscribed in the law as a basic service to be provided by the government; therefore, investors expect the government to foot the bill, even though it is not rich enough to do so.

In our model, it turns out that the hotel has an interest in paying for the treatment of its waste from a pure financial bottom line perspective, at least in the long run. While this feature of the model is due to the choice of parameters (specifically, a lagoon small enough to eliminate pollution externalities, in the sense that water quality directly depends on the pollution generated by the hotel itself), it may be a good representation of situations where the tourism industry as a whole would benefit from financing waste treatment instead of requesting it from the government. In the end, what this suggests is that in coastal regions contemplating tourism infrastructure development, solid waste treatment is one of the few genuine cases for public-private partnerships – because a purely public solution will result in a sub-optimal equilibrium reminiscent of a poverty trap.

Figure 9 illustrates how different combinations of policies and measures will affect fish stocks after 20 years for different hotel sizes. We can see that implementing all the options at hand allows keeping fish stocks at their initial values for sizes of hotel up to 650. By contrast, when no pollution mitigation measure is implemented, for hotel sizes as small as 150 fish stocks decrease within 20 years.

Figure 9

Figure 10 illustrates how the average yearly income of local residents and fishermen over the 20 years of the simulation changes as a function of the percentage of hotel staff being reserved for fishermen. There are two interesting features in Figure 9. First, fishermen's income is much more sensitive than local residents' income to changes in the number of fishermen serving as hotel staff. Imposing a quota of 20 percent of fishermen among hotel staff goes a long way in reducing income inequalities between the two groups. Second, for large hotel sizes increasing the number of fishermen working in the hotel can actually have a positive effect on the average income of both communities (fishermen and local town residents) in the long run, because it reduces immigration and therefore the amount of pollution.

Figure 10

5) Conclusion

In spite of the importance of coastal tourism for the economies of many countries, coastal tourism development has been characterized by lack of sustainability. Tourism infrastructure has often been developed without full consideration of long-term impacts on the environment, resulting initially in adverse impacts on other sectors of the economy, eventually causing the decline of the very resource on which tourism is based. The simulation model presented in this paper tries to address this gap. We build a simple closed-loop model of tourism infrastructure investment, which integrates the economic and ecological sides of the problem. The model is calibrated so that typical hotel projects done without concomitant investment in waste treatment result within 20 years in a collapse of fish stocks and a sharp drop in tourist attendance due to very low water quality. The model includes several policy options that allow stakeholders to intervene at various places in the loop. The model allows users to explore how various combinations of these policies perform in financial, environmental and social terms over the long period.

Our model is designed as the support to an educational tool for training and capacity-building of stakeholders. The tool can be used as the support for role-playing games in which participants explore complex long-term feedbacks between the economic, environmental and social dimensions of investment decisions. We believe such an approach reflects the reality of how investment decisions are taken much better than models with “optimal” solutions.[8] In the area considered here, there is no “optimal solution”. Outcomes of interest and bargaining powers for the different groups involved may be hard to pinpoint and change from place to place and over time; in practice, outcomes will be determined by their relative political clout. Therefore, a first step towards more sustainable decisions is to raise awareness of all involved parties in order to enable them to discuss on a more equal footing.

---

[8] In our case, it would be straightforward to calculate “optimal” solutions to a Nash bargaining program that weighs the interests of the four groups considered here. Rather than the solution, the interesting point would be the selection of weights attached to the different groups.

It is important to underline that a simulation model like ours does not replace site-specific models and involvement of all interested parties. The relations between the state of local ecosystems and the services they provide are governed by non-linear relationships which present highly idiosyncratic components. For example, in our case, the relationship between pollutant concentration in seawater and fish stocks or algae depend on location-specific factors such as temperature, chemical composition of the water, geological and physical configuration of the lagoon, etc. Similarly, the thresholds that trigger rapid declines in fish stock and other ecosystem services are location-specific. Therefore, there is no way a generic model like the one presented here, with parameters borrowed from studies conducted in different places, can faithfully reflect ecosystem interactions in specific contexts.

Instead, the purpose of our simulation model is to raise the awareness of the people and institutions that typically wield the power to commission such integrated studies through participative processes. The model focuses on the generic feedback mechanisms that play a role in determining the long-term sustainability of economic investment in coastal tourism infrastructure. These mechanisms are generic in the sense that they will play a role in all locations, even though the parameters associated with them will change from one place to another. Therefore, there is space for a generic awareness-raising tool that focuses on the mechanisms, rather than on precise estimates of the effects of different policies.

As far as decision-making in the tourism sector is concerned, our main point is that integrated impact studies and simulation models considering long-terms impacts of investment decisions in economic, social and environmental terms should be conducted before investment takes place, and should be designed so as to allow dialogue between all interested parties. This stands in sharp contrast with the current practice for environmental impact assessments, which are segmented and rarely influence the main parameters of investment projects. Given the incentives conflicts mentioned above, such integrated studies should ideally be conducted by third parties. In our opinion, while commissioning such studies should be contemplated by multilateral financing institutions supporting investment in tourism, such as the World Bank, multidisciplinary knowledge institutions such as universities have a key role to play in developing simulation tools that support local capacity development for sustainable tourism development.

References

(IPCC), I. P. on C. C. (n.d.). 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5 Waste. Retrieved from http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf

Baine, M., Howard, M., Kerr, S., Edgar, G., & Toral, V. (2007). Coastal and marine resource management in the Galapagos Islands and the Archipelago of San Andres: Issues, problems and opportunities. *Ocean & Coastal Management*, *50*(3-4), 148–173. doi:10.1016/j.ocecoaman.2006.04.001

Beede, D. N., & Bloom, D. E. (1995). SOLID ECONOMICS WASTE OF MUNICIPAL. *The World Bank Research Observer*, *10*(2), 113–150. Retrieved from http://www.jstor.org/stable/3986579

Bramwell, B., & Sharman, A. (1999). Collaboration in local tourism policymaking. *Annals of Tourism Research*, *26*(2), 392–415. doi:10.1016/S0160-7383(98)00105-4

Cointreau-Levine, S. (1999). Sanitary Landfill Design and Siting Criteria. *Annex A, Terms of Reference for Siting Study for a New Sanitary Landfill, SBMA.*

Connell, J., Page, S. J., & Bentley, T. (2009). Towards sustainable tourism planning in New Zealand: Monitoring local government planning under the Resource Management Act. *Tourism Management*, *30*(6), 867–877. doi:10.1016/j.tourman.2008.12.001

Division, U. N. S. S. T.-N. A. M. A. D. P. C. G. D. P. in U. S. D. 2008. (n.d.). National Accounts Main Aggregates Database Per Capita GDP in US Dollars 2008. Retrieved from http://unstats.un.org/unsd/snaama/downloads/PerCapitaGDP-countries.xls

Fortuny, M., Soler, R., Cánovas, C., & Sánchez, A. (2008). Technical approach for a sustainable tourism development. Case study in the Balearic Islands. *Journal of Cleaner Production*, *16*(7), 860–869. doi:10.1016/j.jclepro.2007.05.003

García-Barrios, L. E., Speelman, E. N., & Pimm, M. S. (2008). An educational simulation tool for negotiating sustainable natural resource management strategies among stakeholders with conflicting interests. *Ecological Modelling*, *210*(1-2), 115–126. doi:10.1016/j.ecolmodel.2007.07.009

Gössling, S. (2001). The consequences of tourism for sustainable water use on a tropical island: Zanzibar, Tanzania. *Journal of environmental management*, *61*(2), 179–91. doi:10.1006/jema.2000.0403

Government of Indonesia Statistical Office. (2008). Number of Accomodations, Average Workers, And Visitors Per Day by Province. Retrieved from http://dds.bps.go.id/eng/tab_sub/view.php?tabel=1&daftar=1&id_subyek=16&notab=1

Håkanson, L. (2009). A general process-based mass-balance model for phosphorus/eutrophication as a tool to estimate historical reference values for key bioindicators, as exemplified using data for the Gulf of Riga. *Ecological Modelling*, *220*(2), 226–244. doi:10.1016/j.ecolmodel.2008.09.012

Hakanson, L., & Blenckner, T. (2008). A review on operational bioindicators for sustainable coastal management - Criteria, motives and relationships. *Ocean and Coastal Management*, *51*, 43–72 ST – A review on operational bioindicators .

Hoekstra, A. Y., & Chapagain, A. K. (n.d.). Globalization of water: Sharing the planet's freshwater resources Appendix XX:Water footprints of nations. Retrieved from http://www.waterfootprint.org/?page=files/NationalStatistics

International Labour Organization (ILO). (2009). Global Wage Report 2008/09: Minimum wages and collective bargaining: Toward policy coherence. Retrieved from http://www.ilo.org/public/english/protection/condtrav/pdf/globalwagereport.pdf

Kakar, M. K., & Khalil, S. (2007). *The Relation between Tourism and Employment in Pakistan*. University of Karachi, Pakistan. Retrieved from http://ictlconference.googlepages.com/42.Mehmood.Kakar.PAR.pdf

Kuo, N.-W., Hsiao, T.-Y., & Lan, C.-F. (2005). Tourism management and industrial ecology: a case study of food service in Taiwan. *Tourism Management*, *26*(4), 503–508. doi:10.1016/j.tourman.2004.02.015

Kuo, N.-W., Hsiao, T.-Y., & Yu, Y.-H. (2005). A Delphi–matrix approach to SEA and its application within the tourism sector in Taiwan. *Environmental Impact Assessment Review*, *25*(3), 259–280. doi:10.1016/j.eiar.2004.09.007

Lerner, D. N. (2003). Estimating Urban Loads of Nitrogen to Groundwater. *Journal of the Chartered Institution of Water and Environmental Management*, *17*(4), 239–244 ST – Estimating Urban Loads of Nitrogen t.

Logar, I. (2010). Sustainable tourism management in Crikvenica, Croatia: An assessment of policy instruments. *Tourism Management*, *31*(1), 125–135. doi:10.1016/j.tourman.2009.02.005

Maal-Bared, R. (2006). Comparing environmental issues in Cuba before and after the Special Period: balancing sustainable development and survival. *Environment international*, *32*(3), 349–58. doi:10.1016/j.envint.2005.08.002

Market Pulse. (2004). Manpower requirement in hotel industry, tour operators and travel sector, report for the Government of India, Ministry of Tourism.

Ortiz-Lozano, L., Granados-Barba, a., Solís-Weiss, V., & García-Salgado, M. a. (2005). Environmental evaluation and development problems of the Mexican Coastal Zone. *Ocean & Coastal Management*, *48*(2), 161–176. doi:10.1016/j.ocecoaman.2005.03.001

Reopanichkul, P., Schlacher, T. A., Carter, R. W., & Worachananant, S. (2009). Sewage impacts coral reefs at multiple levels of ecological organization. *Marine pollution bulletin*, *58*(9), 1356–62. doi:10.1016/j.marpolbul.2009.04.024

Schianetz, K., Kavanagh, L., & Lockington, D. (2007). The Learning Tourism Destination: The potential of a learning organisation approach for improving the sustainability of tourism destinations. *Tourism Management*, *28*(6), 1485–1496. doi:10.1016/j.tourman.2007.01.012

Singh, A., & Mee, L. (2008). Examination of policies and MEAs commitment by SIDS for sustainable management of the Caribbean Sea. *Marine Policy*, *32*(3), 274–282. doi:10.1016/j.marpol.2007.06.004

Smith, D. G., Crocker, G. F., & McFarlane, K. (1995). Human perception of water apperance 1. Clarity and colour for bathing and aesthetics. *New Zealand Journal of Marine and Freshwater Research*, *29*, 29–43 ST – Human perception of water apperance 1.

Speelman, E. N., López-Ridaura, S., Colomer, N. A., Astier, M., & Masera, O. R. (2007). Ten years of sustainability evaluation using the MESMIS framework: Lessons learned from its application in 28 Latin American case studies. *International Journal of Sustainable Development & World Ecology*, *14*(4), 345–361. doi:10.1080/13504500709469735

Suplee, M. W., Watson, V., Teply, M., & McKee, H. (2009). How green is too green? Public opinion of what constitutes undesirable algae levels in streams. *Journal of the American Water Resources Association*, (February 2009), 123–139.

Tosun, C. (2001). Challenges of sustainable tourism development in the developing world: the case of Turkey. *Tourism Management*, *22*(3), 289–303. doi:10.1016/S0261-5177(00)00060-1

Tsuzuki, Y. (2009). Comparison of pollutant discharge per capita (PDC) and its relationships with economic development: An indicator for ambient water quality improvements as well as the Millennium Development Goals (MDGs) sanitation indicator. *Ecological Indicators*, *9*, 971–981.

Walker, P. A., & Walker, P. (1999). The Tourism Futures Simulator : a systems thinking approach, *14*, 59–67.

Wang, H., Yang, Z., Chen, L., Yang, J., & Li, R. (2010). Minority community participation in tourism: A case of Kanas Tuva villages in Xinjiang, China. *Tourism Management*, *31*(6), 759–764. doi:10.1016/j.tourman.2009.08.002

Williams, A., Lansey, K., & Washburne, J. (2009). A dynamic simulation based water resources education tool. *Journal of environmental management*, *90*(1), 471–82. doi:10.1016/j.jenvman.2007.11.005

Yasarata, M., Altinay, L., Burns, P., & Okumus, F. (2010). Politics and sustainable tourism development – Can they co-exist? Voices from North Cyprus. *Tourism Management*, *31*(3), 345–356. doi:10.1016/j.tourman.2009.03.016

Yaw, F. (2005). Cleaner technologies for sustainable tourism: Caribbean case studies. *Journal of Cleaner Production*, *13*(2), 117–134. doi:10.1016/j.jclepro.2003.12.019

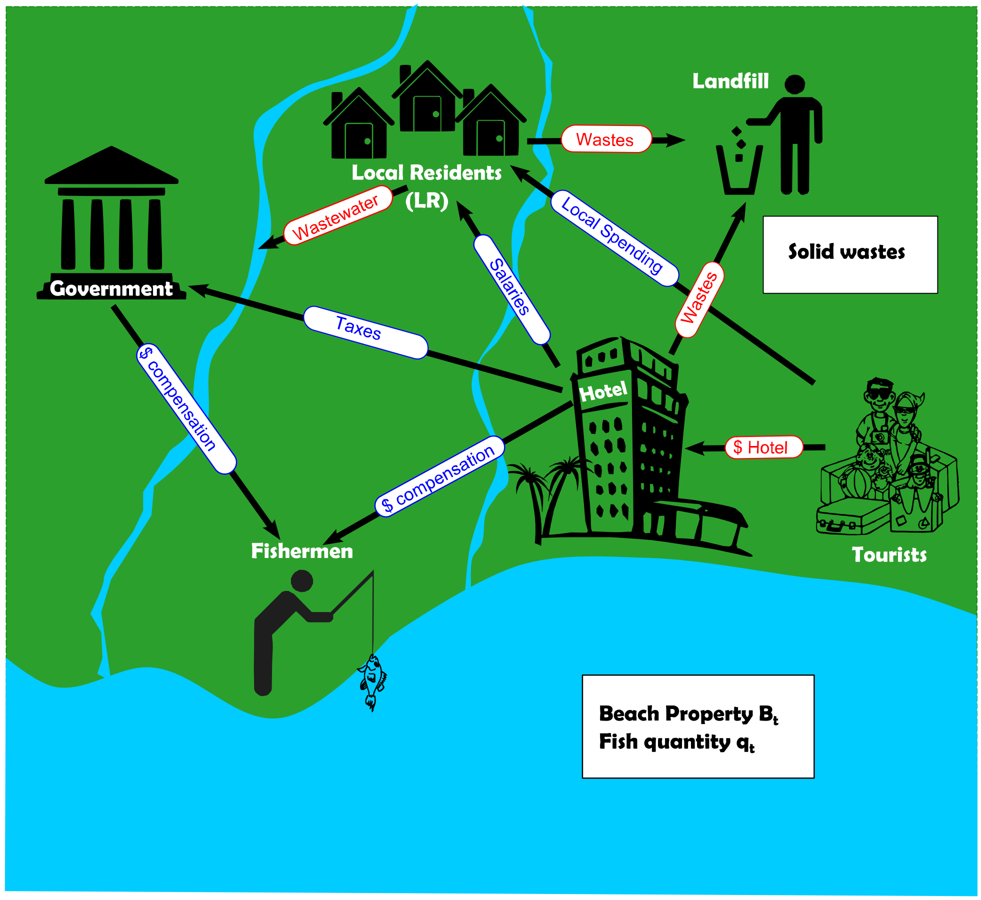

Landfill
Wastes
Local Residents
(LR)
Wastewater
Local Spending
Solid wastes
Salaries
Wastes
Government
Taxes
Hotel
$ compensation
$ Hotel
$ compensation
Fishermen
Tourists
Beach Property B_t
Fish quantity q_t

Fig 1

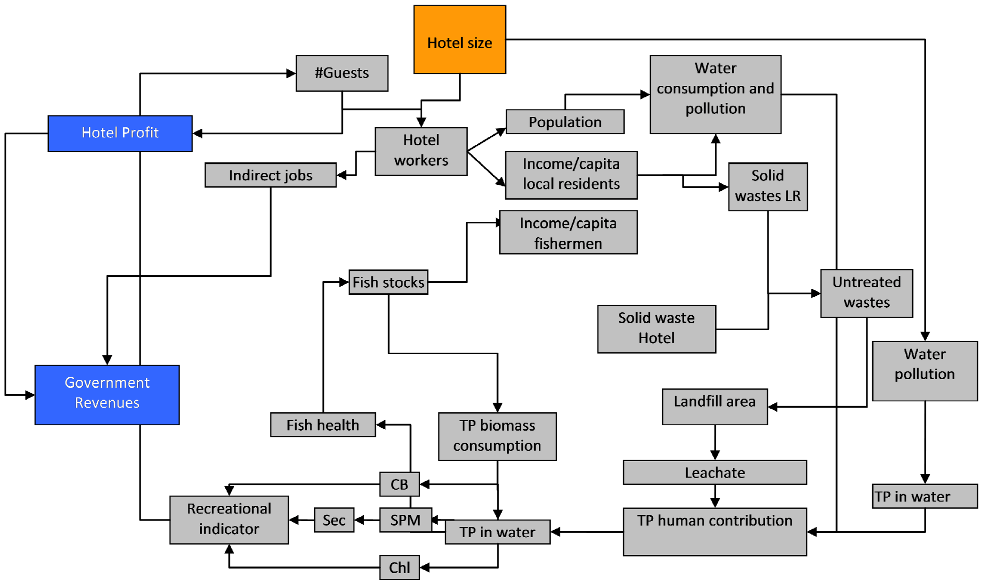

Hotel size
#Guests
Water consumption and pollution
Hotel Profit
Population
Hotel workers
Indirect jobs
Income/capita local residents
Solid wastes LR
Income/capita fishermen
Fish stocks
Untreated wastes
Solid waste Hotel
Water pollution
Government Revenues
Landfill area
Fish health
TP biomass consumption
Leachate
CB
TP in water
Recreational indicator
Sec
SPM
TP in water
TP human contribution
Chl

Fig 2

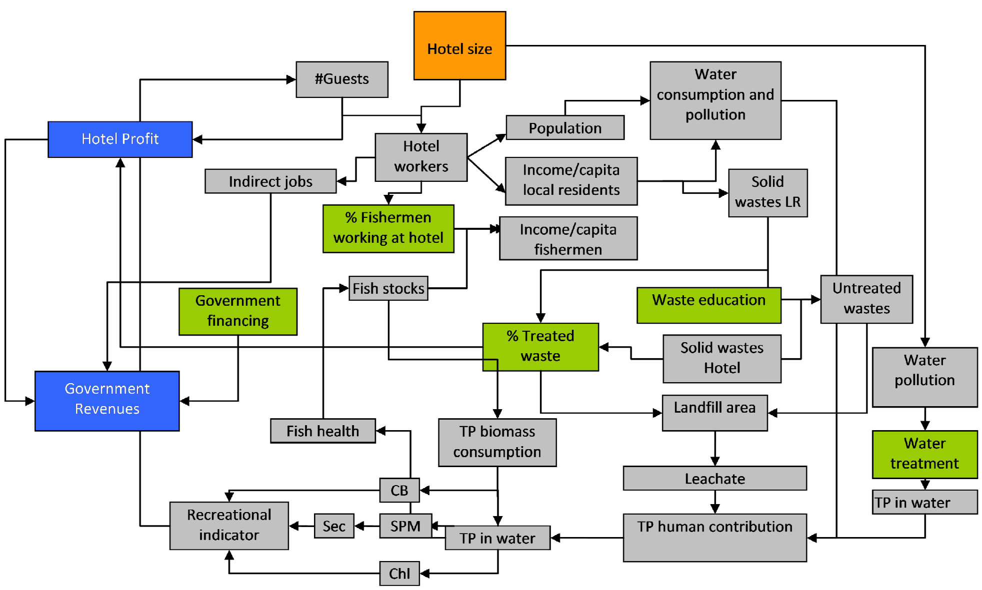
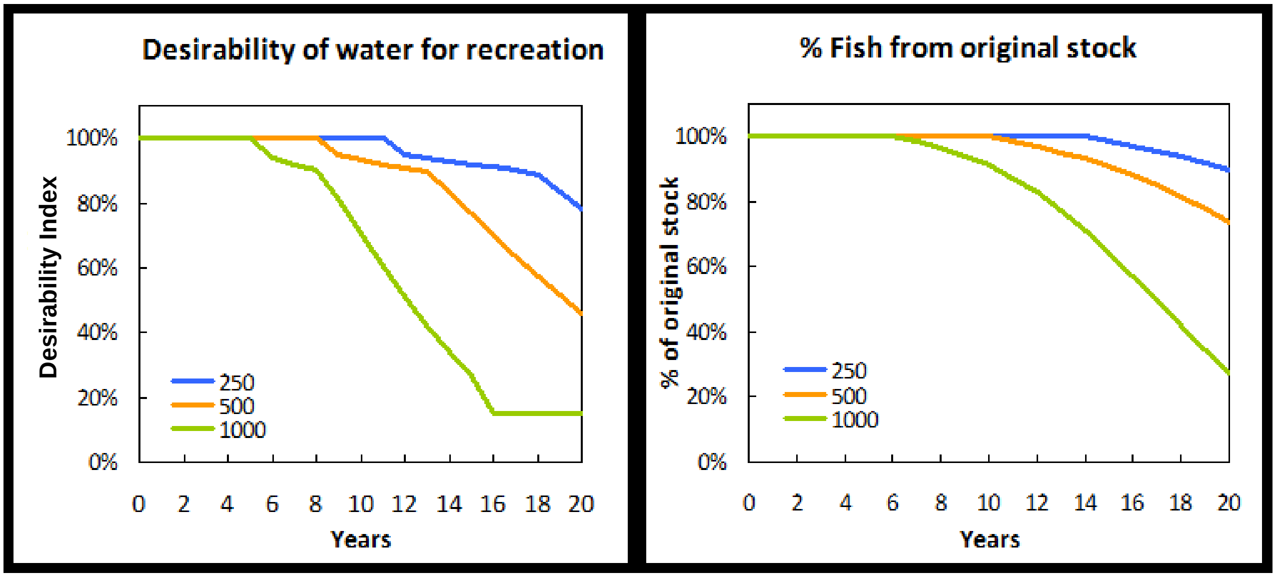
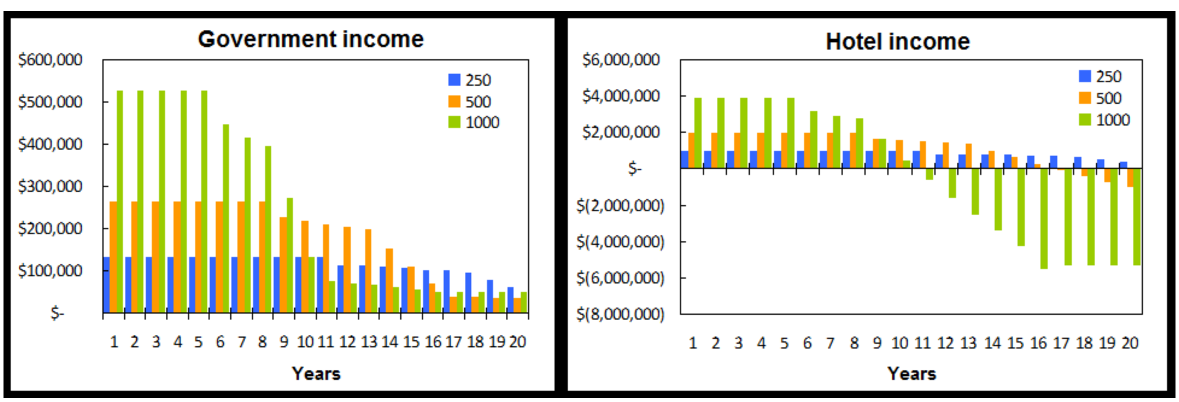

Hotel size
#Guests
Water consumption and pollution
Hotel Profit
Population
Hotel workers
Indirect jobs
Income/capita local residents
Solid wastes LR
% Fishermen working at hotel
Income/capita fishermen
Fish stocks
Government financing
Waste education
Untreated wastes
% Treated waste
Solid wastes Hotel
Water pollution
Government Revenues
Landfill area
Fish health
TP biomass consumption
Water treatment
Leachate
TP in water
CB
Recreational indicator
Sec
SPM
TP in water
TP human contribution
Chl

Fig 3



(a) (b)

Fig 4



Government income	250	500	1000
10 years	$ 1,302,733	$ 2,538,361	$ 4,285,253
20 years	$ 2,297,158	$ 3,619,577	$ 4,852,592

Hotel income	250	500	1000
10 years	$ 9,530,537	$ 18,489,959	$ 30,170,137
20 years	$ 16,413,167	$ 22,224,955	$ (9,188,060)

Fig 5

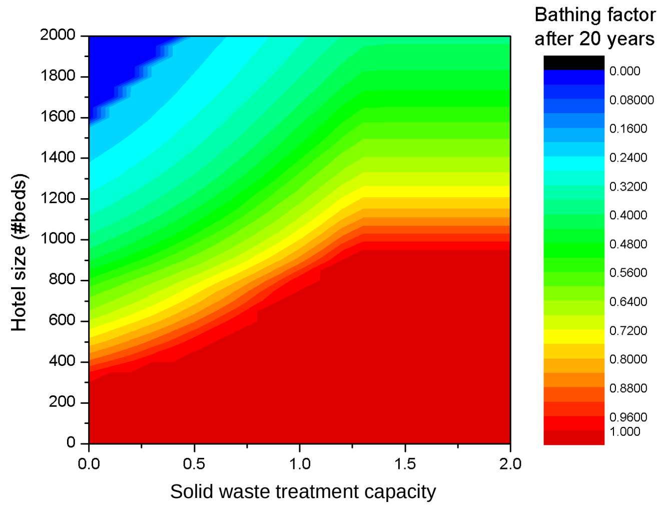

Bathing factor
after 20 years
0.000
0.08000
0.1600
0.2400
0.3200
0.4000
0.4800
0.5600
0.6400
0.7200
0.8000
0.8800
0.9600
1.000
Hotel size (#beds)
Solid waste treatment capacity

Fig 6

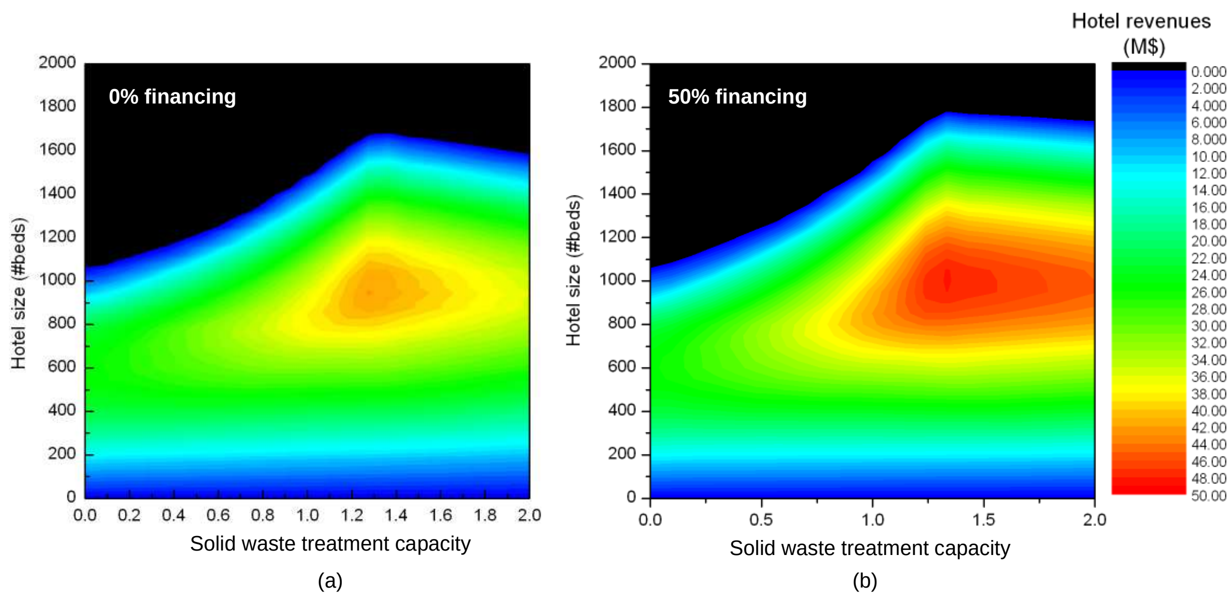
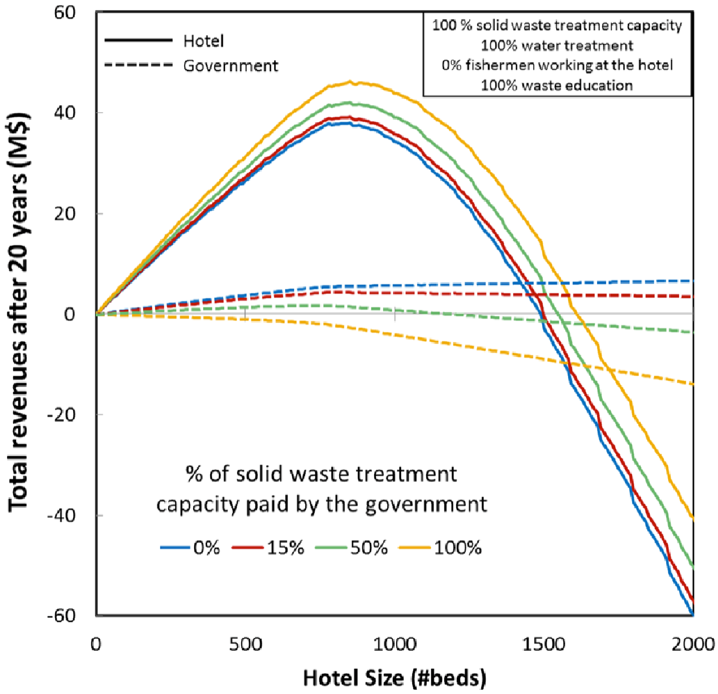
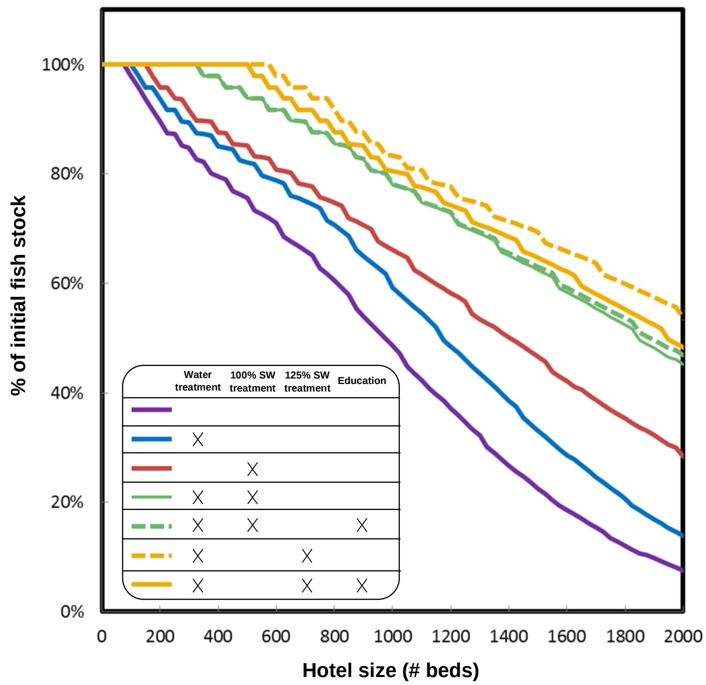

Hotel revenues
(M$)
0% financing
50% financing
Hotel size (#beds)
Solid waste treatment capacity
(a)
(b)

Fig 7



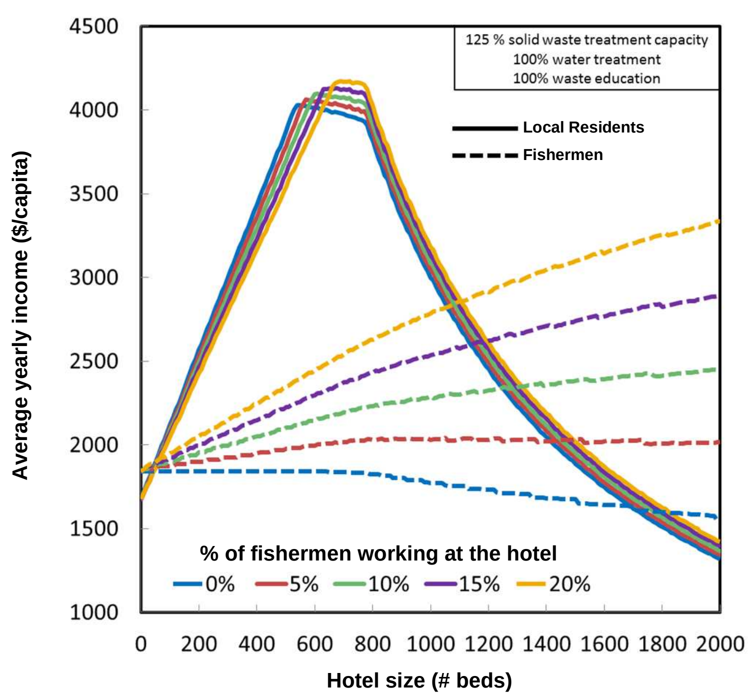
Hotel
Government
100 % solid waste treatment capacity
100% water treatment
0% fishermen working at the hotel
100% waste education
% of solid waste treatment
capacity paid by the government
0%
15%
50%
100%
Total revenues after 20 years (M$)
Hotel Size (#beds)
60
40
20
0
-20
-40
-60
0
500
1000
1500
2000

Fig 8



100%
80%
60%
40%
20%
0%
% of initial fish stock
Water treatment
100% SW treatment
125% SW treatment
Education
X
X
X
X
X
X
X
X
X
X
X
X
X
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Hotel size (# beds)

Fig9



125 % solid waste treatment capacity
100% water treatment
100% waste education
Local Residents
Fishermen
4500
4000
3500
3000
2500
2000
1500
1000
Average yearly income ($/capita)
% of fishermen working at the hotel
0%
5%
10%
15%
20%
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Hotel size (# beds)

Fig 10