Energy Equipment Diffusion & Touristic Competitiveness: Building of an SD Model for the Greek Islands

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ABSTRACT

The real-world problem the research aims to address is the continuing highly seasonal, exponential electricity demand growth in the Greek islands that are unconnected to the national electricity grid over the past decades. This paper presents only part of the on-going research. It specifically tests an early draft of the sub-model concerned with the interplay of an island's tourism volume & attractiveness, local technological learning-by-using effects and the dynamics of demand-side equipment diffusion. The general assumption is that a tourist chooses a basket of services received at the place visited, one of which is cooling comfort. Cooling-comfort eventually translates to installed cooling capacity and in effect electricity consumption. This paper examines the sub-model which, based on a figure of cooling comfort per person, constructs an indicator of competitiveness to similar destinations and relates the flow of tourists to it. Similarly, a cost comparison incorporating a learning curve between a conventional and an efficient variant of cooling equipment drives the installation stocks at any time and effectively alters the efficiency of the overall service across the island. The sub-model is run for a number of structural and behavioural tests and also assessed for its potential use in policy making.

Keywords: islands, diffusion, substitution, learning, system dynamics, tourism, Greece, niche markets

1 INTRODUCTION

1.1 THE BROAD RESEARCH QUESTION & BACKGROUND

The Greek grid-unconnected, or autonomous, islands are almost entirely dependent on stacks of small to medium size thermal power units. The exponentially growing consumption trend and great demand variation between the extended off-peak winter season and the energy-intense but short peak summer season means these already inefficient engines are running either below the recommended load, if at all, or at peak emergency rating. These factors drive the unit price of electricity in the islands to costs up to tenfold the cost in the mainland where the generation is based on cheap local lignite. The tariffs across the country are uniform thus electricity in the islands is heavily subsidised leaving the Public Power Corporation (PPC) and its Islands Directorate with a burgeoning debt. Despite numerous studies on the great potential of renewable energy technologies on autonomous islands, these have never significantly picked up due to lack of a consistent support policy, various land use conflicts, a liberalized but unclear and stagnating energy market and the intertwined interests of the influential refinery & shipping lobbies.

The intervention envisaged is on the contrary looking on the demand-side of the problem in a structured cross-disciplinary fashion. How could energy policy makers foster the great entrepreneurial potential on the islands in order to initiate a self-propagating demand for energy efficient equipment? How would such a market, on one hand reduce the costs of power generation in the islands and, on the other hand, not hinder the local economy heavily dependent on providing a competitive touristic product? The key aim of the broader research is to assess whether the diffusion of energy efficient demand-side equipment can significantly reduce the rate of capacity expansion in the Greek islands beyond a BAU future, look into the right levels of financial support and comment on paybacks for the policy-makers and adopters. To date, there has been no concerted and sustained action for DSM in the country or the islands in particular.

1.2 OBJECTIVES & SCOPE OF THIS PAPER

The intervention is studied by means of a dynamic non-linear simulation model. This paper is focussing on the working draft of the sub-model relating tourism growth to technology diffusion, equipment substitution, destination competitiveness and technology learning. In the hope of constructive feedback by the readers, what is presented here are the formulating assumptions of the diffusion sub-model, its operating principles and analyses of test runs of its behaviour under a number of situations including the effects of sample policy interventions. This paper is not conclusive to the broader research question as described previously. Rather, its objective is to produce a meaningful and island-specific diffusion simulation model that can stand on its own. It shall be later linked with a bottom-up demand profile generator, a utility costing sub-model, an intervention scenario selector and an appraisal tool to provide an insight to the pressing energy problem of the Greek islands as set in the introduction.

The causal loop diagram (CLD) in Figure 1 summarises the approach to the design of the diffusion sub-model, demonstrating the feedback loops simulated.

There are two dominant loops in the CLD of Figure 1:

LOCAL SERVICE COVERAGE > COMPETITION GAP >…ADOPTIONS…> LOCAL SERVICE COVERAGE

The size of the total adoption of the service provided by the equipment in combination with tourist arrivals provides a figure of the coverage, i.e. percentage of visitors receiving the service. This figure compared to an international average determines the urgency to adopt either of the two variants of the equipment and feeds again back to number of units installed.

COST DIFFERENCE > EFFICIENT EQUIPMENT ADOPTION > LEARNING > EFF EQUIPMENT COST > COST DIFFERENCE

The older equipment is a mature technology and has a stable cost and price. On the other hand, the more the installations of the efficient equipment, the more the learning effects. The cost is steadily declining, reducing the cost difference thus making the efficient technology increasingly competitive. A promotional scheme as can be seen in the diagram could aim at increasing the learning effect.

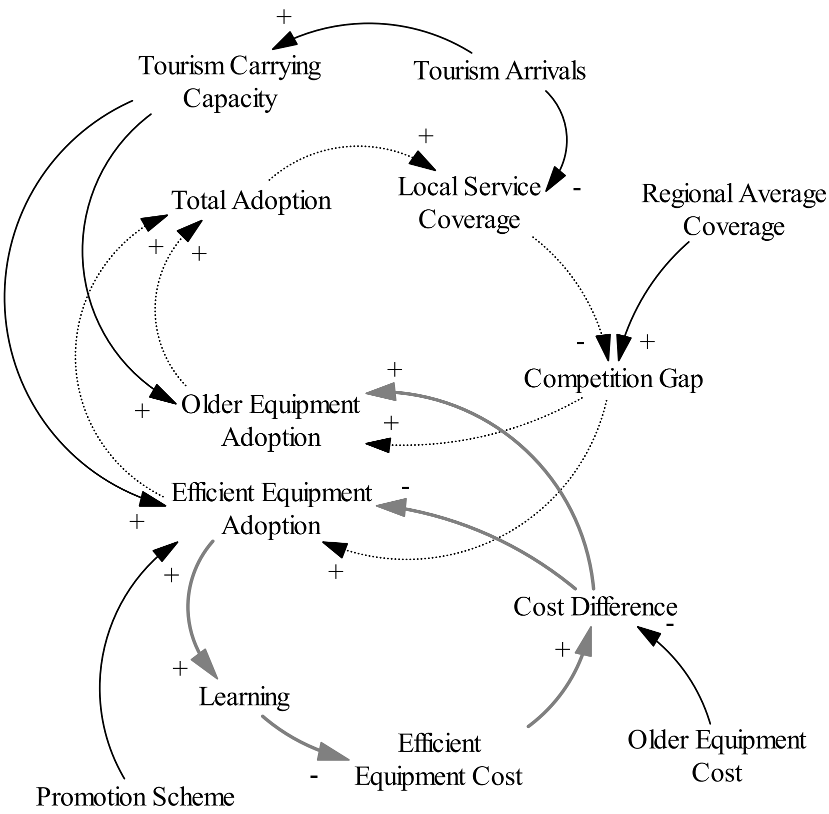

Figure 1: The approach to diffusion modelling in CLD notation

The next section (2) briefly introduces considerations on tourism, its relevance to the research question and influence on model design. Section 3 is reviewing the major parameters used in the model, followed by section 3.5 that illustrates the model's mechanics through a simplified model run. Section 4 is testing the structural validity and robustness of the model's responses under various test situations. Finally, section 5 is summing up the task undertaken in this paper, draws conclusions on the sub-model and reveals future steps.

2 TOURISM, ENERGY USE & COMPETITION

2.1 TOURISM IN GREECE

According to a 2004 Financial Times article, tourism is identified as a major income source of Greece, accounting for about 18% of the national GDP and employing over 15% of the workforce (Hope 2004). The FT reporter finds out in a series of interviews that apart from better touristic promotion, the country needs to provide better services to its visitors, as it cannot afford to put that sector in peril. The Greek National Tourist Authority has drawn up plans for the sustainable growth of the sector (Box 1).

Box 1: GNTO's tourism development plan

A strategic plan for tourism development has been elaborated by GNTO, in the framework of the "National Plan for Regional Development 2000-2006". This plan (Operational Program for Tourism) takes into account all relevant environmental concerns and it enhances specific actions towards a sustainable tourism development. The main objectives of this plan are:

- Upgrading the quality of tourist services;
- Elaborating environmental protection projects;
- Encouraging the wise use of water and energy;
- Modernizing equipment and installations of tourist establishments; and
- Promoting cultural tourism as well as eco-tourism, mountain tourism and other forms of alternative tourism.

This plan is elaborated through cooperation with regional authorities, local stakeholders and the private sector.

Source: United Nations Conference on Environment and Development 2002 Country Profiles

2.2 COMFORT, SPACE COOLING & ENERGY DEMAND

The World Trade Organisation (WTO) states that "a key element in leisure travel demand is the degree of comfort (or discomfort) to be experienced at the traveller's destination" (WTO and Todd 2003). It is mentioned that comfort is harder to maintain at air temperature exceeding 31°C that is the norm in the Greek islands during the peak summer season. This paper assumes that the 'comfort factor' constitutes a major attractiveness of a Mediterranean destination assuming that they compete on similar levels of scenery, cultural heritage, bathing facilities and cuisine.

Air-conditioning has also been recognised as a main culprit contributing to extreme demand peaks in Greece (Daskalaki and Balaras 2004:1091-1105). It does also connect conceptually and practically to the comfort factor requirement to assess competitiveness of an island as air-conditioning is the technology of preference providing that service.

2.3 THE COMPETITION HABITAT OF THE ISLANDS

In the simulation, a regional competition indicator on cooling comfort coverage affects the rate of adoption between the two A/C equipment variants. Among other things the success of technology diffusion includes keeping as close as possible to a regional average of cooling service coverage. Is the assumption of a regional competition average valid? Can one assume all other factors affecting destination attractiveness constant? What are the geographical boundaries for the aims of the research?

The WTO has reported that there is a mass movement of people with the intrinsic purpose for travel to visit a sunny seaside destination (WTO and Todd 2003). For 2002, a total of 133 million arrivals have been registered to the northern coast of the Mediterranean and the Caribbean. This is clearly the market the Greek islands are competing in: population flows where the weather is evidently of paramount importance in much of the leisure travel as opposed to the destinations' cultural heritage.

Out of the figure quoted above, 116 million arrivals are concerning flows from Northern Europe to the Mediterranean's South European coast and islands alone. This refines the competition environment even further. The activity exhibits a 3% growth rate per annum and its market worth was US$70 in 2000, projected US$300 by 2050 (WTO and Todd 2003). Thus, the Mediterranean basin's boundaries can be adopted as those of the simulation, which being also an area of homogeneous climatic characteristics enhances the validity of a regional competition indicator. That is to say:

a) The similar temperature profile and seasonality of the tourism wave indicate an equally similar visitor expectation and cooling comfort demand in the region.
b) Attractiveness of Mediterranean destinations balance along complementary elements of hospitality, climate, culture, gastronomy and natural beauty, thus one can safely assume all other factors constant across that economic habitat when comparing performance on cooling comfort.

3 ELABORATING ON THE MODEL'S PARAMETERS

3.1 SERVICE BENCHMARKING & COOLING CAPACITY

A standard reporting framework for air-conditioning consumption in tourism does not seem to exist in international bibliography yet (WTO 2002;WTO 2003;WTO and Todd 2003). Specific statistics on consumption of electricity for air-conditioning on the Greek islands do not seem to exist either. As a matter of fact, there has been an effort in the 1980s to measure up energy consumption and use patterns in the islands. The programme reached only the residential sector and was abandoned as early as 1988 with limited output available. To overcome the lack of statistics on A/C consumption, the demand profile is build from scratch. Each visiting tourist is 'credited' with a peak demand made up of typical electricity consuming activities for the duration of a visitor's stay.

The air-conditioning load of a person comprises of two parts: a) the sensible heat load, i.e. removing heat to reduce temperature, and b) the latent load that has to do with the dehumidification necessary when hot air is removed from an enclosed space. Each person generates 75W of sensible heat and 60W of latent load in sedentary occupation (Stephenson 1968, CBD-105). In order to confirm that figure as the per person cooling load suitable for the Mediterranean, papers from France (Cron, Inard, and Belarbi 2003:41-52), Italy (Gugliermetti, Santarpia, and Bisegna 2001) and Turkey (Gürbüz 2001) were consulted. The warmer climate suggests that the latent load is higher thus an aggregate of 200W/person is adopted. Based on that, the necessary share of size of equipment for that load is about 700BTU/person. Assuming each tourist has $10m^2$ to move in, a 4,000 BTU unit is suggested making broad assumptions on the number of windows, orientation of the building and insulation among other parameters[1]. The Energy Efficiency Rating (EER) of an A/C unit is its BTU rating over its wattage and is widely used in the USA. The higher that number is the more efficient the unit. Assuming an EER of 8, the equipment capacity necessary is 500W/person. A higher

[1] http://www.purityplanet.com/air-conditioner-sizing.aspx & http://personal.cityu.edu.hk/~bsapplec/cooling.htm [15/08/2004]

efficiency unit will have a higher EER, i.e. a EER 10 unit will require 400W/person – 20% decrease in required installed capacity per person. On the contrary, an EER 6 unit requires 670W/person for the same load.

To evaluate a regional average, the coverage of service should also be considered. It shall be assumed that in the average case there is 40% coverage based on touristically developed destinations in the Mediterranean where large proportion of visitors reside in hotel complexes offered through package holidays.

*BTU/person ÷ average_EER_of_equipment_installed * (coverage%/100)*
*In this example: 4,000BTU/p ÷ EER8 * 0.4*

Therefore, the average installed capacity of air-conditioning per tourist for the given cooling load comes to 200W/person. The figure shall be the regional competition average towards which the island needs to keep as close to as possible in order to be comparable, in terms of cooling comfort, to other destinations in the region.

In a study of room air-conditioners in Europe by the European Council for an Energy Efficient Economy (ECEEE), the cooling hours where found to be 1.5 to 2 times more in Mediterranean countries than the average. All sectors were found to require cooling above 500 hours/year in all sectors (commercial, domestic, office, hotels). For the study, the average of the weighted averages of all sectors in Spain, Greece, Portugal and Italy will be adopted – i.e. 1,023 cooling hours per year.

3.2 THE SIMULATION MODEL & ITS MECHANICS

The methodological approach to capturing the interrelation among tourism arrivals, cooling service coverage, equipment substitution, and destination competitiveness is based on two major assumptions[2]:

a) There is an expected regional, i.e. Mediterranean, cooling comfort average to visitors (measured in BTU) based on cooling wattage capacity per visitor per area occupied. The model assumes that all competing destinations must be as close to that average as possible to attract visitors.
b) The air-conditioning load can be met by two variants of cooling equipment averaging at distinct values of rating and efficiency. These are assumed to be a conventional electric A/C unit opposed to a hybrid solar absorption chiller; the former being more power consuming than the latter albeit cheaper to buy. The latter has overall more desirable characteristics and the purchase/installation price is the only deterrent to potential adopters of the technology.

Figure 2 presents a simplified *stock-and-flow diagram*[3] of the diffusion model. What is not shown in the diagram is the technology-learning loop. This is a separate module that

[2] The assumptions as well as the simulation model later are built with a single visitor (tourist) as the base unit of the model metrics. That has been decided to keep in line with WTO practices that defines a visitor "as a particular type of individual consumption unit, who is distinguished from other individuals by the fact that he/she is outside his/her usual environment and travels or visits a place for a purpose other than the 'exercise of an activity remunerated from within the place visited'" (WTO 2004).

is not shown here for space economy: the module receives data from the two-adopter pools, runs a learning algorithm based on the number of installations of each equipment variant, and then returns this to the cost ratio.

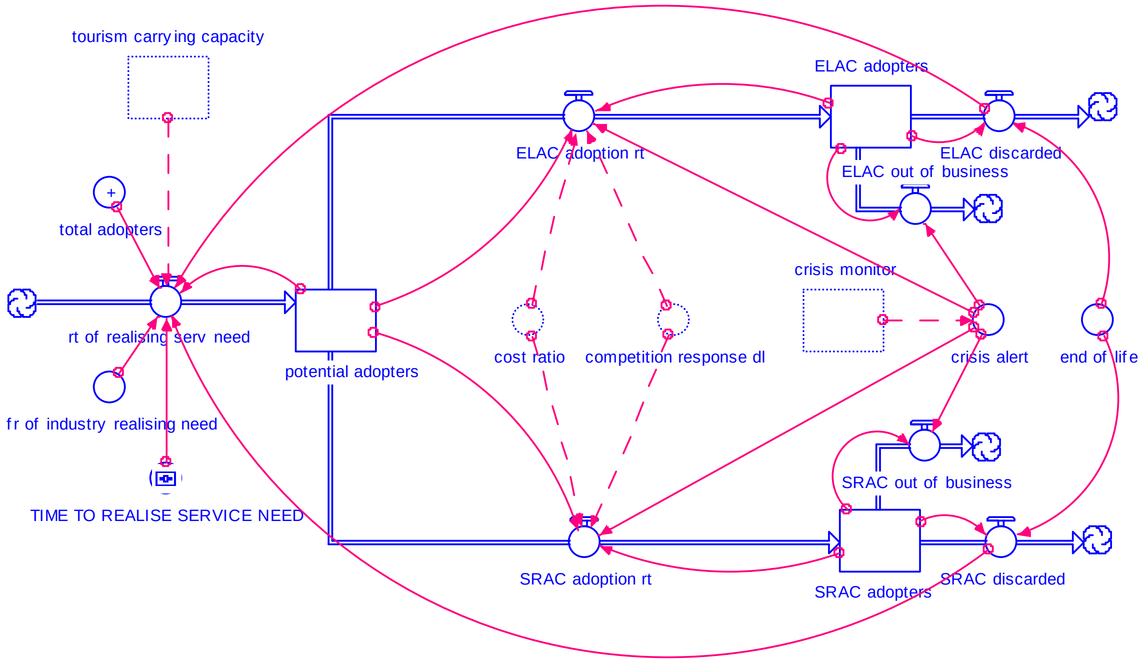

Figure 2: Diffusion with seasonal tourism and two adopter stocks

A seasonal tourist population appears that has a ramp and random function combined to generate a fluctuating, seasonal and growing tourist wave. The outcome is shown in Figure 3 where Line 1 (in red) are the tourists arriving at any time given the seasonal pattern while Line 2 (blue) is effectively the hosting carrying capacity of the island. Line 2 represents the stock at the top-left in Figure 2 and logs successive peaks of visitors during the simulation when there is a net increase. If this year's visitors are less than last year's then the blue line remains straight. If however, there are more visitors this year there is a step increase to accommodate for that demand.

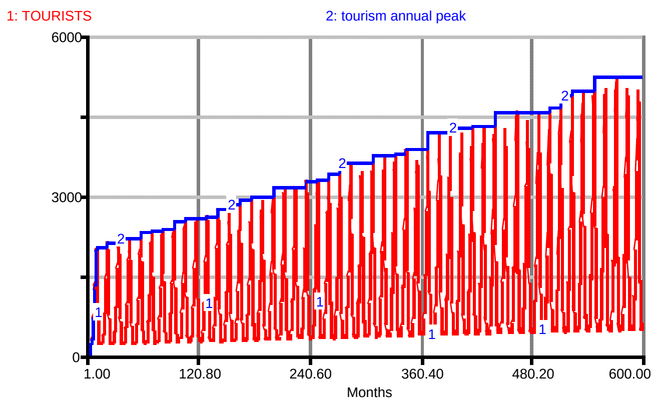

Figure 3: The seasonal tourism wave

[3] In the stock-and-flow notation, the square boxes represent the quantities that accumulate and perform an integrating function, the valve and double line combination represent flows and rates of change while the remaining circles are auxiliary functions containing variables and constant parameters. The single line arrows show where this auxiliaries are used. Valves, auxiliaries and less commonly stocks, include formulas.

The two variants in the adopter stocks of Figure 2 are ELAC (ELectric Air-Conditioning) and SRAC (SolaR Assisted Air-Conditioning) whose efficiencies are relatively related as $SRAC_{eff}=\alpha*ELAC_{eff}$ where $0<\alpha<1$, i.e. the former technology is more efficient than the latter by a factor of α which can be a constant or a variable.

There are three evident and one concealed stocks on the diagram that share the carrying capacity at any moment. Referring back to Figure 2 these are the stocks of the "potential adopters", the "ELAC adopters" and the "SRAC adopters". The resulting figure when subtracting the sum of the three stocks from the hosting carrying capacity of the island is the concealed stock of visitors that will not experience any space-cooling service during their stay. The mechanism by which the carrying capacity expands is not explicitly modelled here as it is of no immediate effect to the modelling exercise and the research question. It can be assumed to be a forecasting of some sort that allows the commercial sector to absorb any hosting demands and then maintain that level.

3.3 THE COST COMPARISON

The cost ratio (C_{OLD}/C_{NEW}) consists of the price paid for the installation per unit of marginal installation and the running cost aggregated for five years; i.e. a safe payback period for the Greek islands (Betzios 2003). The ratio does appear and parametrically affects the flows of population to the adopter pools of the model (Figure 2). A fraction of the commercial agents servicing the carrying capacity of the island are aware of the proposed, or improved variant, and are willing to install it if conditions are right ("fraction of industry realising need" in Figure 2). These agents consequently control a share of the carrying capacity that ends up in the "potential adopters" pool.

3.4 THE COMPETITION INDICATOR

But do all potential adopters eventually install one of the two variants based just on relative costs? That exactly is the purpose of the loop that compares the quality of service to a supposed regional average. A commercial accommodation owner might wish to upgrade his services to customers but will not do so if the standard is acceptable for the type of destination and clientele the island appeals to. Furthermore, the model has that "fraction of industry realising need" variable that is meant to leave out smaller family-run accommodation owners who only provide basic services, bed and bathroom, and marginal shops.

When the local cooling capacity per tourist is above the regional average, it is suggested that it makes the basket of services provided by the island marginally costlier than competing destinations. Whereas when it is below that figure then the quality is not up to standard. The competition indicator is based on the amount of service required, i.e. cooling capacity installed in BTU per person per area quota. There could be a reduction in power consumption simply by degrading service quality but that is not deemed a desirable policy or sensible commercial practice. On the contrary, the success would be to maintain the service standard by reducing the power input required for it. For each tourist to receive that service there is an installed capacity to generate the cooling load required. Introducing a new power-saving technology, it would allow the energy expenditure to drop while maintaining or even increasing service coverage.

3.5 DEMONSTRATION OF THE MODEL’S OUTPUT

This paragraph aims to familiarise the reader with the model’s output and parameters through a simple run. Each year a number of visitors arrive on the island while facilities expand to accommodate that demand. However, for illustration purposes the following assumptions are held for the model in Figure 2:

- “Tourists” have a steady flow of 2,000 throughout the year without any seasonal peaks.
- The “fraction of industry realising need”, set to 1 signifying all commercial premises are to be space-cooled if the competition & prices permit.
- The cost ratio C_{OLD}/C_{NEW} is set at 0.20 defining the relevant flow from potential adopters to either of the variant stocks in a constant manner.
- The consumption of SRAC is half that of ELAC, i.e. α=0.5.
- The learning rate in the background is not affecting the system since the cost ratio is stable. The system thus adjusts on competitiveness performance alone.

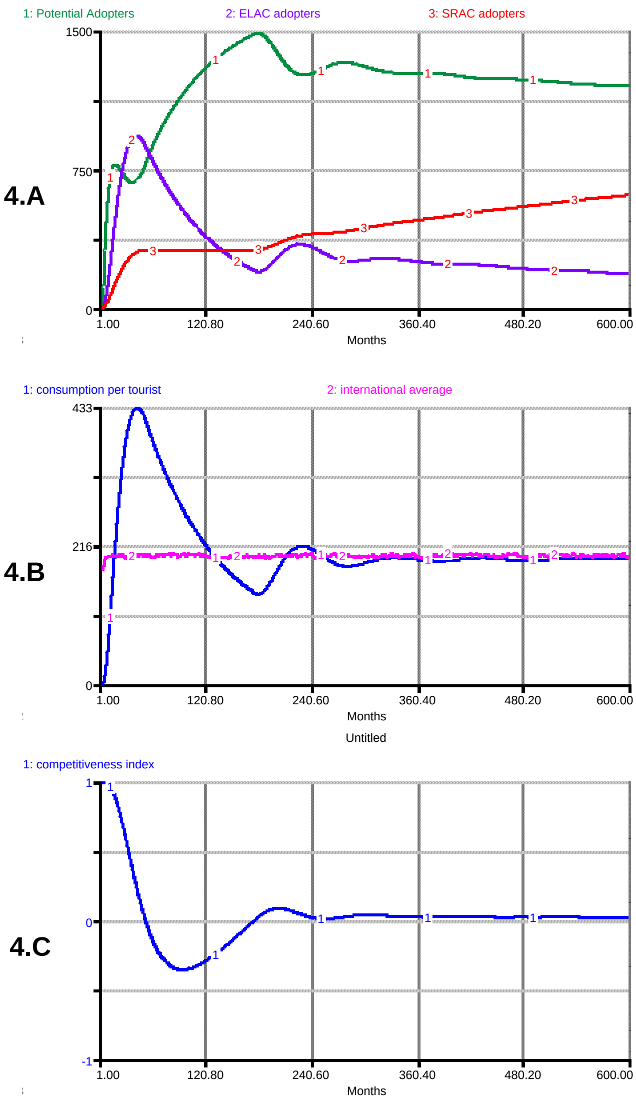

Figure 4: Test run of extended diffusion

Figure 4 presents the ‘phase diagrams’ for a series of model parameters (indicated at the top left of each graph). At the start of the simulation, the competition indicator has maximum value in graph (4.C) since there are no units at all to provide the cooling service thus the competitive imperative to install is high. On the top graph (4.A), the arrival of tourists (Line 1) exerts system pressure and eventually the consumption per tourist overshoots the regional average, illustrated on graph (4.B)/Line 1. Once there is the need to install, ELAC adoption grows faster since the price favours it on graph (4.A)/Line 2. By the 5th year of the simulation (60 months), there are 751 tourists in ELAC and 312 in SRAC. Also, there are 875 people in the “potential adopters” pool that cannot yet enjoy the service despite their hosts having realised the benefits of the installation but are yet to install. The three numbers together total 1,938 people.

By year 10 (month 120 in the simulation graphs), these three numbers changed to 388, 312 and 1,300 respectively. The sum now is 2,000, i.e. as much as the carrying capacity.

That is the effect of delays in the system such as the "time to realise need" auxiliary function that defines the delay the tourist industry service providers need to make up their minds on the usefulness of the service, and the ‘adoption delay’ in the model that represents the time it takes for commercial adopters to actually purchase the equipment once they have justified its superiority.

There are a number of qualitative observations to be made. Once the system overshoots the international average (4.B) in its momentum to live up to the expectations, there is a similarly steep decline in a goal seeking type of behaviour that would be expected from such a system. In the uphill period both adopter pools grow rapidly until roughly month 48, 4 years into the simulation. The system then has to decrease its consumption. The only outflow from the consuming stocks of the adopters occurs in ELAC and is due to the equipment reaching the end of its life and being discarded. There is no replacement as it can be deduced from the flat curve of SRAC (Line 3) in (4.A) for quite some time, just more people flowing out of ELAC that is steadily reducing.

The curve in (4.C) confirms this through the competition comparison. Around the 4th year, the indicator becomes negative ceasing any flow to the two stocks. Qualitatively, this reads as follows: Commercial agents even though realising the need and having moved the share of carrying capacity they command to the “potential adopters” stock, do not feel any pressure from competition since a falsely sensed alignment to the average presides over. Similarly, those that did discard their equipment do not believe there is a need to replace it immediately; thus the released tourists return to the “potential adopters” and stay there until the drivers for adoption are ripe again. Policy-makers can easily misinterpret this situation as equilibrium since it is statistically observable despite the Greek government not gathering the specific data at present.

Back to graph (4.B), consumption continues to decrease as more equipment is taken out of the system and consequently the system now undershoots the regional average. It takes time for the competition indicator to rise again due to sampling and reporting delays in its estimation. It takes about four years from the first time the local cooling capacity is found under the average until the indicator gains a positive value (4.C) that effectively allows adoption to resume (4.A – appr. 180 months). This delay has accumulated in what can be referred to as *pressure to adopt* in the system, therefore the slope increases again, albeit of lesser magnitude, in ELAC and SRAC adoption. That draws people heavily out of the potential adopters’ pool. The oscillations caused by the delays in the system ultimately die out and the system reaches equilibrium with the competition indicator settling close to the average with a healthy replacement rate for SRAC (4.A).

4 TESTING THE MODEL’S BEHAVIOUR & APPLICATIONS

This section is running a number of scenarios to validate the structural logic and assess the behavioural sturdiness of the model. The aim here is not to produce conclusive runs since this is just a sub-model in the overall research but assess the usefulness of the multi-disciplinary diffusion sub-model and its success in dealing with the required specs. The testing is performed under three critical headings:

1. Validity – aiming to ensure model produces logical behaviours
2. Robustness –to confirm it can adjust to possible changes of conditions
3. Policy-making – to evaluate the model as a tool for testing strategies

Each section of the test runs draws policy making hints for decision makers.

Figure 5 is a service sector diagram of the model showing its conceptual components. For robustness in extreme events, a function that allows closure of commercial premises in prolonged periods of arrivals being less that the carrying capacity has been added. That is the only case when the carrying capacity is allowed to reduce. At the same time, the efficient variant is experiencing learning effects leading to reductions in price as installations grow (assuming an 82% learning rate). A ‘promotion scheme’ can be seen that can be designed to provide a single programme of installations over a period of time or a series of annual installations during the course of many years.

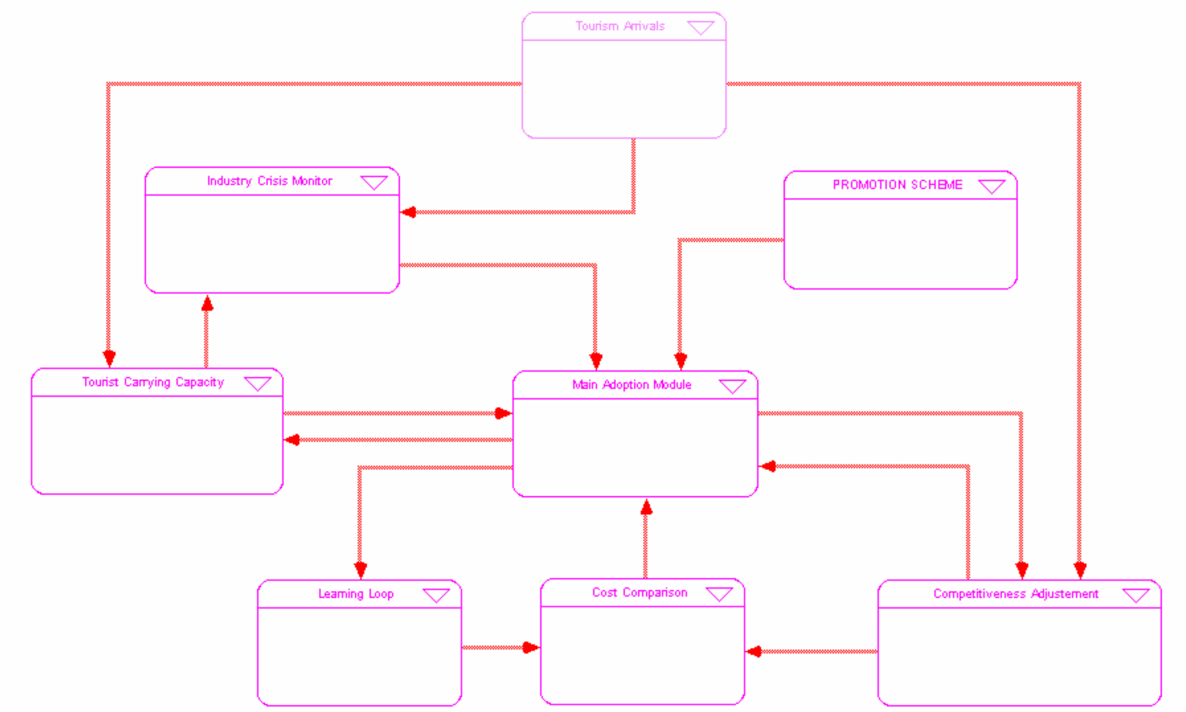

Figure 5: Sector diagram of the diffusion model

4.1 VALIDITY : TESTING STRUCTURAL BEHAVIOUR

4.1.1 INFORMATION DELAYS & SYSTEM CONTROL

There is a significant amount of time from the moment a survey is taking place until the statistics are published and eventually reach decision makers in the private or public sectors. In the diffusion model, the existence of a regional average of cooling capacity per visitor is assumed to require three years (or touristic seasons) from the time it is collected subsequently processed, checked and published until it reaches the island's commercial sector through national tourism institutions and media. The main consequence of delays in case studies of the System Dynamics bibliography is the creation of oscillations in the system (Forrester 1961;Sterman 2000). This behaviour is met in the model as can be seen in Figure 6 (sensitivity type graphs, i.e. one graph depicts a single parameter on separate test inputs).

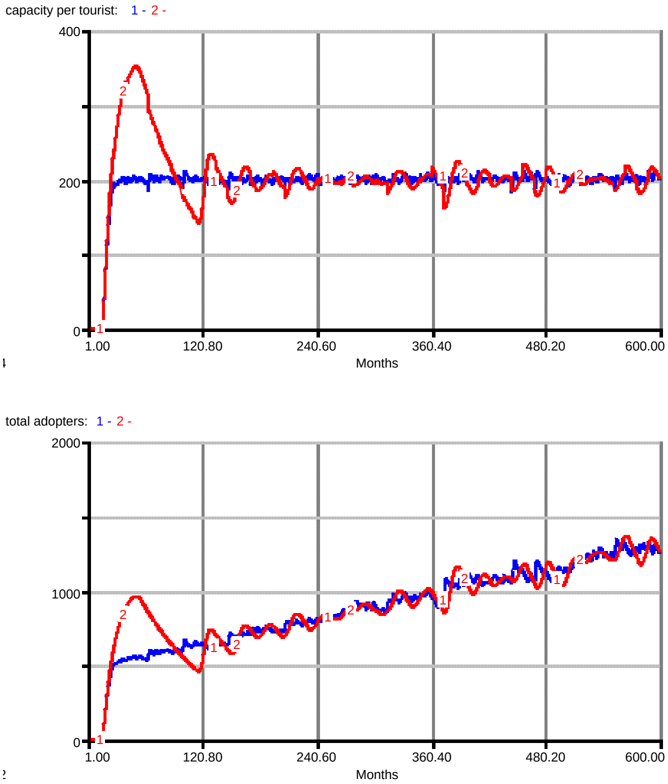

Figure 6: The oscillations due to information delay

Line 1 (blue) in both graphs represents the case where the comparison of the local to the regional capacity performance is done almost real time on a monthly basis. It is noticed the system is very well controlled. On the other hand, Line 2 (red) represents the three-business seasons delay where the momentum gathered is not properly adapted when the goal is eventually reached and it overshoots the regional average around which the blue line evolves. The bottom graph of Figure 6 sketches the total adopters, i.e. the market, and indicates a market with booms and busts for Line 2 (red). A downhill curve signifies a stall in purchases as equipment reaching the end of serviceable life exits the adopters stock and there is no replenishment.

In the real world, great variations between business cycles will deteriorate efforts of policy makers to establish an efficient & controllable market. An objective of the policy makers should therefore be to reduce information delays in critical positions of the system and be as close to the ideal behaviour of Line 1 (blue).

4.1.2 THE TIME TO RESPOND & OSCILLATIONS

Once the information reaches the commercial operators of an island, there are more delays to be faced in their reaction to the news. In the model the reflex gain has been formulated to vary depending on the extent of the deviation from the regional average. The lines 1-4 in Figure 7 (sensitivity graph) represent test runs of an increasing minimum reaction time threshold – from 1 to 36 months (Line 1: 1 months, Line 2: 12 months, Line 3: 24 months & Line 4: 36 months). The impacts are easily observed despite the effect dying out in all cases as the gap narrows and adjustments become marginal.

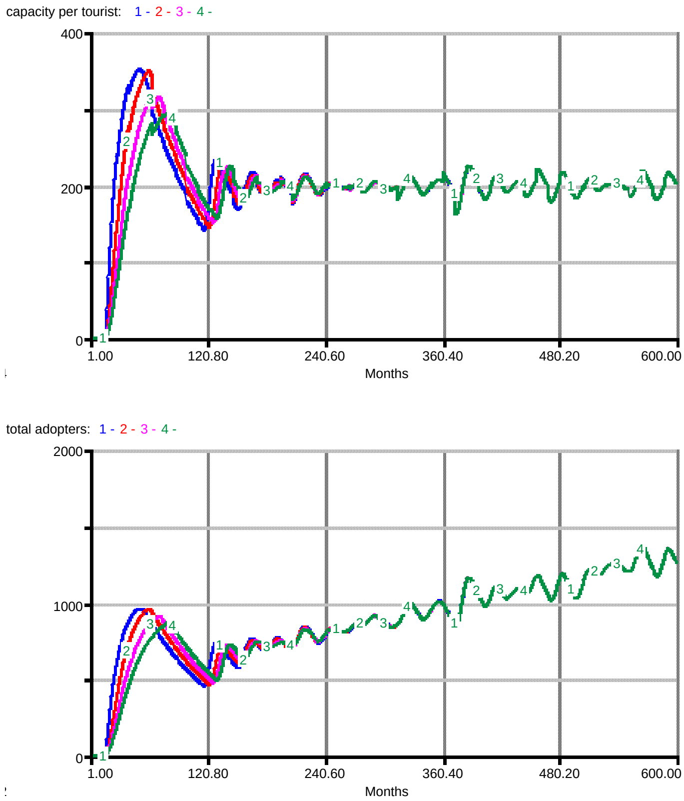

Figure 7: The impacts of operators' reaction

In real life Line 4 (green) reveals a sector that is very restrained and cautious in adopting a new technology. On the contrary, Line 1 (blue) would represent a risk-taking group of commercial operators.

Despite the apparent ability to control the oscillations as in the previous case, the access of policy makers to this parameter is limited. The perceptions of risk in economic sectors are highly subjective and peer behaviour can only be changed through years of stable policy aiming to influence those perceptions. The final model will adopt the one-month response time that characterises risk-taking agents and competitive economies such as those of the Greek islands.

4.1.3 DIFFUSION & REPLACEMENT OF EQUIPMENT

Graph (8.A) of
Figure **8** illustrates the dynamics of replacement between the two equipment variants in Line 3 (blue) and Line 4 (green). Initially, there is only the early power-consuming variant (Line 3). At some point around the course of the 7th year a scheme is introduced that sees the installation of 200 efficient units. The size of the scheme is such that causes the cost of the new equipment over five years (purchase and operation) to drop below that of the conventional technology as observed in graph (8.B). As soon as installations commence, SRAC is the favourable choice therefore its rapid growth (8.A/Line 4) and the parallel decline of the ELAC stock.

What is the impact to the system however? Graph (8.C – sensitivity) compares the scenario with (Line 2 – red) and without (Line 1 – blue) the introduction of the efficient variant. The number of total adopters, i.e. visitors who enjoy the cooling service, has increased dramatically in the former case. The improvement in coverage is achieved in line with the competition requirements of the regional cooling capacity per person as can be confirmed in graph (8.D - sensitivity) between the two scenarios which has been estimated to be at 200W (par. 3.1).

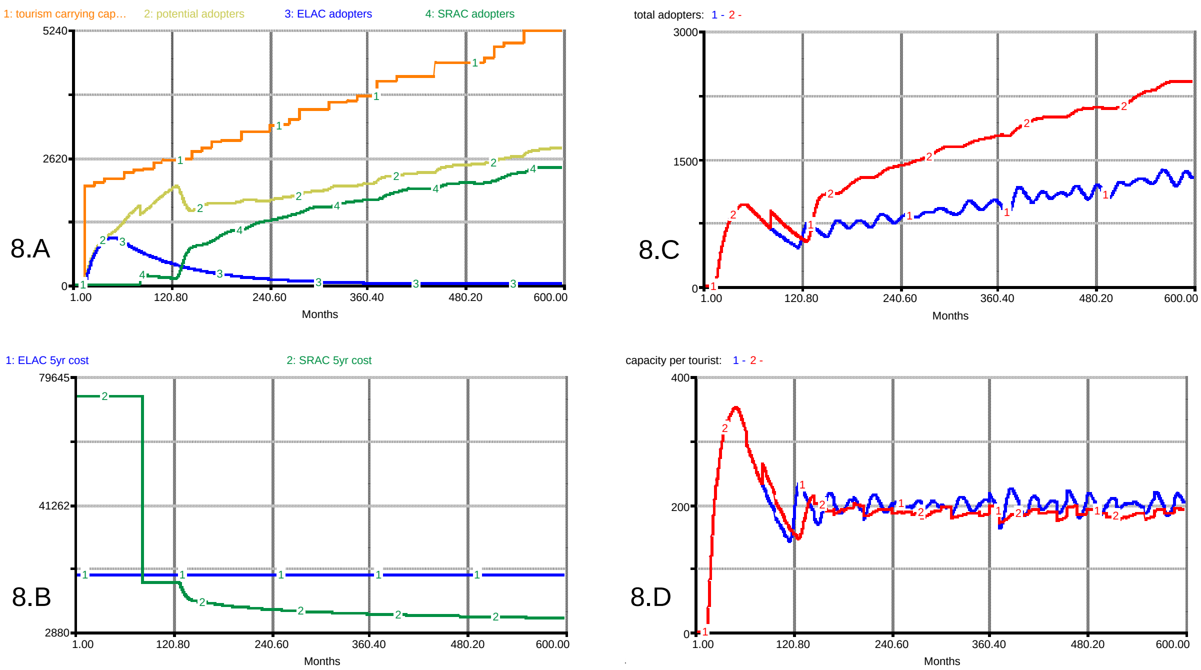

Figure 8: Observing the competition of equipment

4.1.4 Unit Rating and Service Coverage

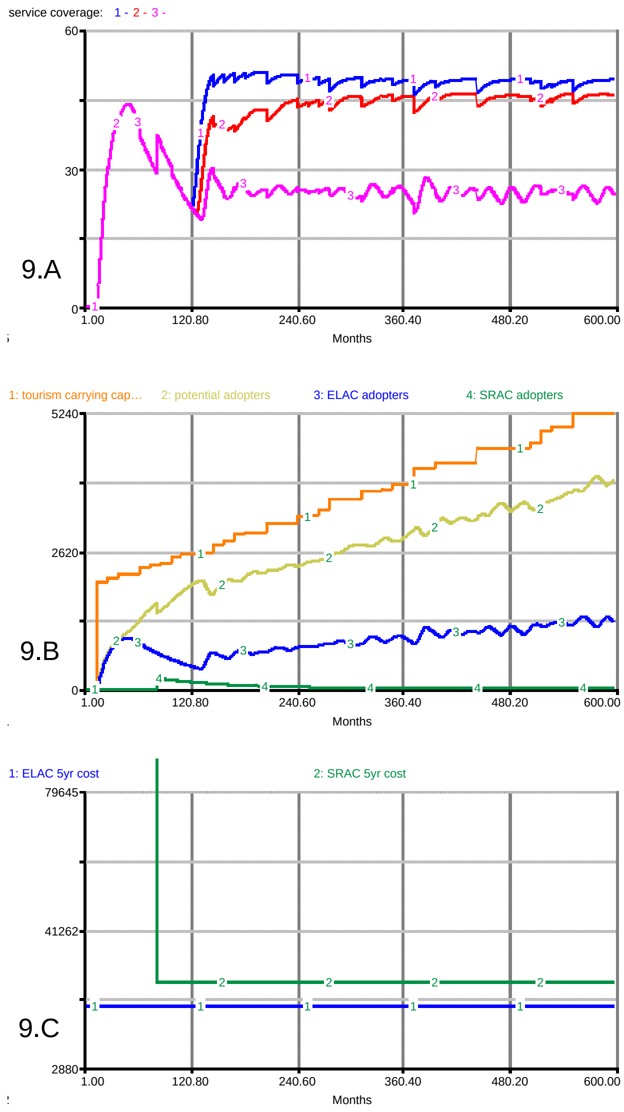

Figure 9: Assessing the sensitivity of efficiency gain

The simulation runs in the previous paragraph assumed the new equipment needed half the wattage rating to provide the required cooling load. In Figure 9 (9.A) examines the sensitivity of service coverage for a range of SRAC ratings – namely ¼, ½ and ¾ of the ELAC capacity. A quick look reveals that the relationship is not linear; the impacts are disproportional to the rating step (Line 1 for ¼, Line 2 for ½ and Line 3 for ¾).

Taking a closer look of the last run at the ¾ rating in graph (9.B), it is revealed that the SRAC support scheme in the 7th year failed to establish the market (Line 4 does not pick up after the intervention). The reason can be found in graph (9.C) where the five year cost of the SRAC for this rating is still higher that that of the ELAC units even after the financed installations.

4.2 ROBUSTNESS : TESTING RESPONSE TO EXTREME EVENTS

4.2.1 KEEPING UP WITH IMPOVED COMPETITION

So far it has been assumed that the regional competition average has been fluctuating randomly between a given set of values. This simulation run explores the situation of a major and abrupt service upgrade in competing destinations expressed as a step improvement in the average regional capacity per tourist. The left hand-side column of graphs in

Figure **10** [(10.A) and (10.B)] explore the sensitivity of the level of competitors' service upgrade – scheduled for month 120) to the capacity per tourist and the total adopters of the island system under examination. The larger the step of improvement in competing destinations (ascending from lines 1 to 4) the longer it takes until the local tourist sector to respond indicating there is a period that the system re-adjusts the relevant shares of ELAC and SRAC stocks to face improved competition. Line 1 (blue) is the reference case at 200W per person.

The right hand-side graphs [(10.C) and (10.D)] look into the impacts of the timing of the step improvement of competitors' performance. The timing of the step decrease is not showing any unexpected behaviour. The regional average is accepting the same service upgrade each time at 100 months interval for each line from 1 to 5, Line 1 (blue) being the reference case again. The response is immediate and after few cycles the relevant values balance around their new reference state. In both cases, it is observed that the system adjusts its competitiveness by reducing the number of total adopters of the service. In the real world, that would reduce the coverage of the service and may alter the island's attractiveness. This is valid danger for a tourist destination that has not

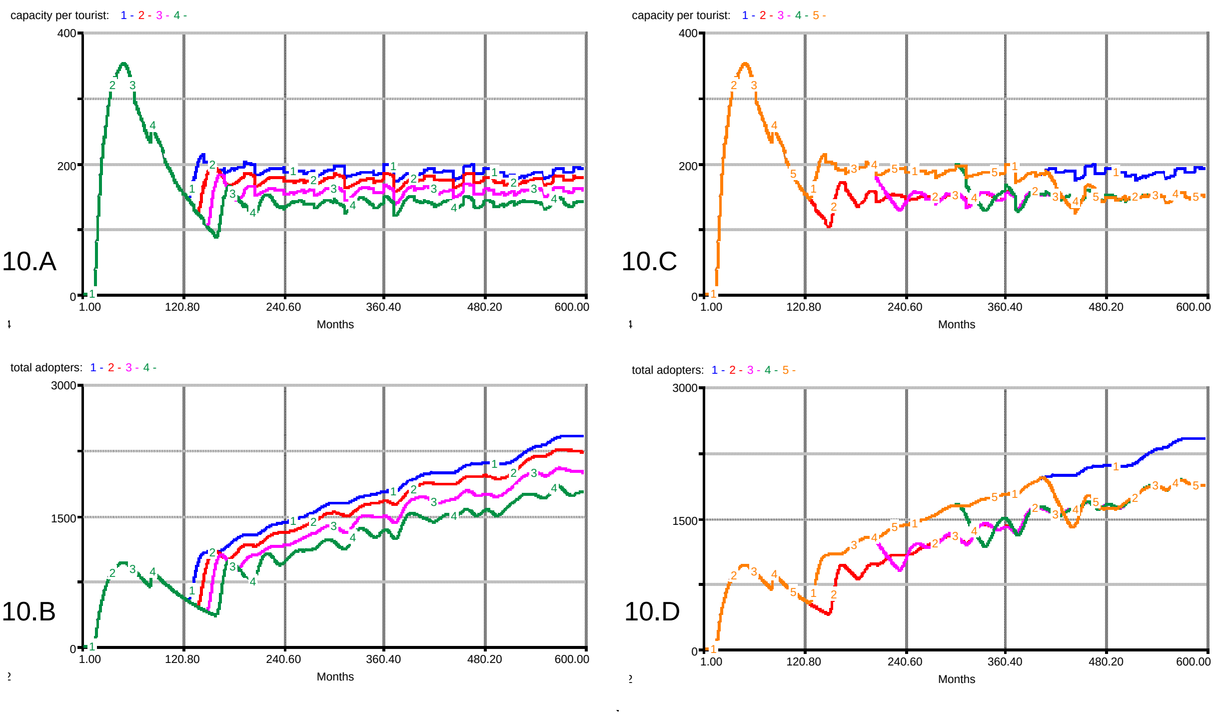

Figure 10: Exploring a changing competitive environment

been upgrading its services in line with the competition. Policy-makers being pro-active on their strategies can alleviate such situations and assist the local economy to be flexible and agile.

4.2.2 INDUSTRY CRISIS : FACING REDUCTION IN ARRIVALS

The tourism industry is quite volatile (WTO 2003;WTO 2004). Despite the 2004 Olympic Games in Greece, the tourism industry had a very bad year overall due to bad press due to expectations of preparedness of the country to host the Games prior to the event, the threat of terrorism and the inflation impacts of the Euro zone (Ktenas 2004). The model has been design to confront prolonged periods of tourism crisis by allowing the exit of commercial establishments from the market thus reducing the available cooling capacity for the tourist population.

Starting from the top left corner of
Figure **11** a sudden crisis occurs in the tenth year (120 months) of the simulation. Arrivals are kept low for a period of fifteen years after which a new era of touristic popularity begins as portrayed in graph (11.A). The occasion of an industry crisis is the only situation when the model allows the carrying capacity to scale down as in graph (11.B/Line 1). The delay observed until the carrying capacity reduces, in month 180, is due to an internal loop that first needs to confirm that the crisis is a persistent phenomenon. Similarly, the relevant stocks of the potential adopters and ELAC/SRAC adopters adapt to the new market conditions.

As expected, keeping the same facilities for a much smaller tourism population initially soars the local capacity per tourist availability as Line 2 (red) indicates in graph (11.C) – Line 1 (blue) being the reference case. The system responds and eventually stabilises around the regional values in blue (11.C & 11.D) albeit a long period of abrupt

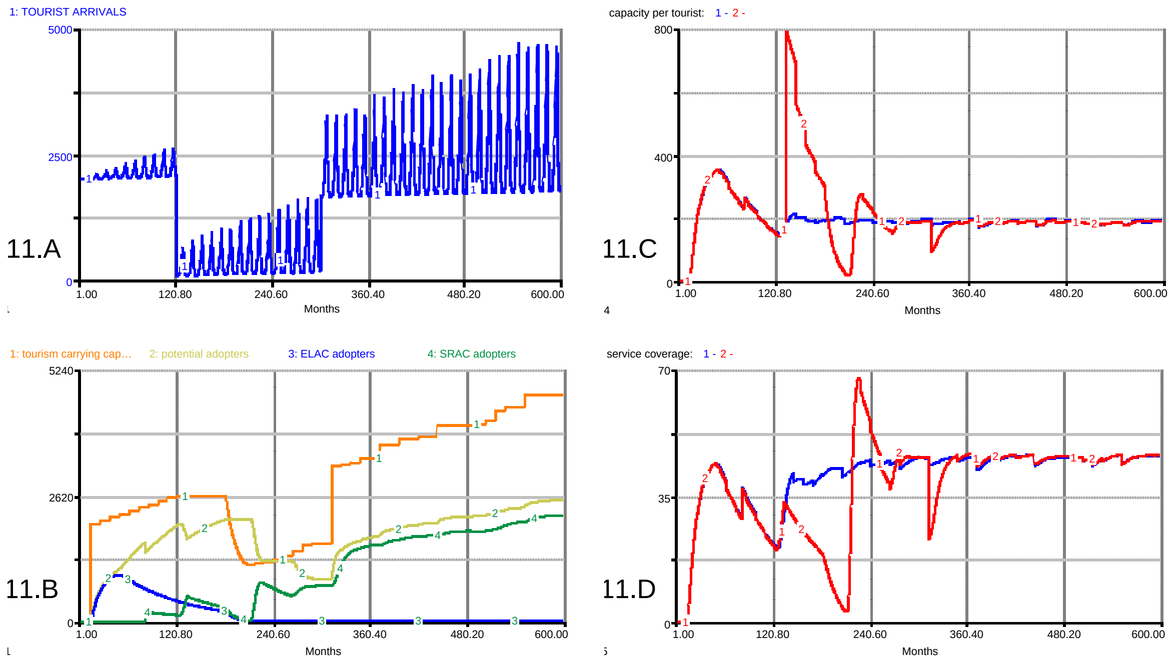

Figure 11: Confronting a prolonged industry crisis

adjustments (red line). The corrective actions of the model return the system to it previous competitive state. What is not described here however is the impact of a crisis in the planned and existent power capacity of the island. Such issues shall be examined in a follow up paper.

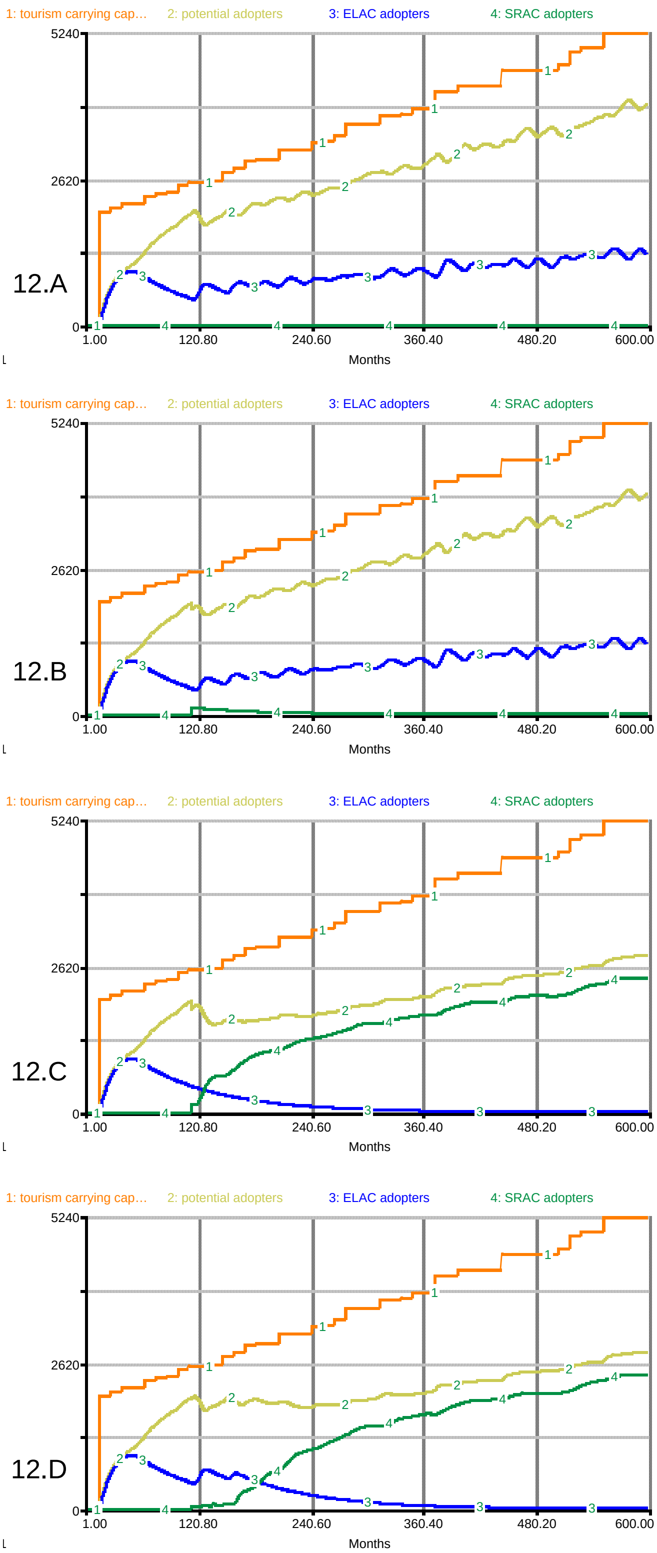

Figure 12: Assessing promotion plans

4.3 POLICY-MAKING: TESTING UTILITY IN DECISION-MAKING

4.3.1 EVALUATING PROMOTIONAL STRATEGIES

What is the best promotion strategy for new equipment? How do policy-makers know which alternative scheme will work? The sub-model gives the ability to design a promotional policy albeit not yet containing the costs involved or potential sources of funding. Qualitatively though, the demands of a programme can be observed through the graphs in Figure 12. Despite attempting the introduction of the new equipment in graph (12.B) as denoted by Line 4 (green), there is practically no impact compared to the reference case represented in graph (12.A). The technology fails to break into the market, as the cost effects are not significant enough to establish the viability of the new equipment variant despite the planned installations set to 25% of the dominant variant at the time. However, raising the installations to roughly 28% puts the appropriate learning effects in motion and the new technology has a startling development as described graphically in (12.C).

The final graph (12.D) depicts an alternative policy design. Instead of a single large-scale demonstration scheme, the policy-makers decide on an annual small-scale installation scheme as low as 6% of the installed variant in the first year. The consideration behind this is the smaller budget required and a fractional approach that would allow closer monitoring of the procedure. The choice between the two and a number of other potential schemes will depend on conditions of available funds, institutional organisation and commitment, and the financial profile of the commercial actors involved.

The choice will also depend on the rapidness of substitution desired as demonstrated in the sensitivity graph of Figure 13, where lines 1 to 4 represent each of the cases from (13.A) to (13.D) above comparing their service coverage. Line 1 (blue) is the reference case of (13.A) and Line 2 (red) is (13.B) in the previous. Line 3 (pink) and Line 4 (green) correspond to graphs (13.C) and (13.D) respectively. Although these two balance at similar percentages of coverage, their path is different due to the modular approach of the latter. This shows that a possible saving in funds for the modular scheme has to be balanced against the time to achieve the result.

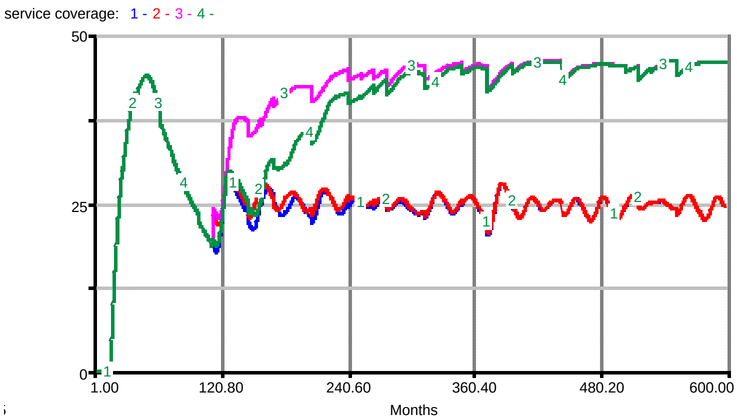

Figure 13: Sensitivity of system response to promotional schemes

4.3.2 RESTRUCTURING THE TARIFFS

This policy choice is one of the most interesting ones despite politically sensitive and not likely to be a realistic option for the Greek islands where cross-subsidy of their tariff is considered a social right by island populations. Nevertheless, it is worthwhile examining how the model reacts to such an intervention. It should be expected that the new efficient technology would pay back its initial investment much quicker if the tariffs where to reflect the real cost of electricity in the islands. Since it has lower running costs, its market potential will be fulfilled sooner than in the reference case.

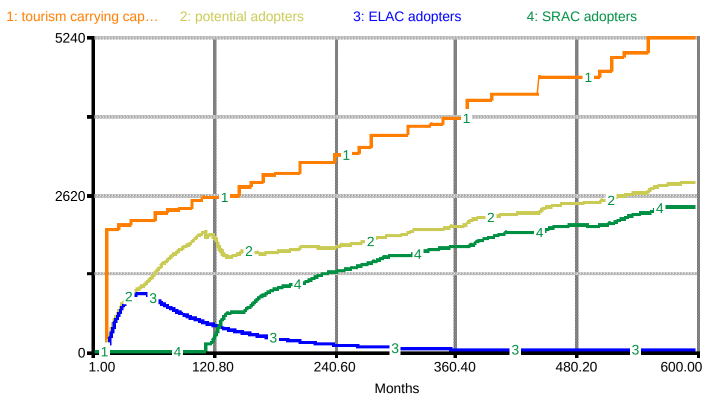

Figure 14: Restructuring the electricity tariff

Looking back at Graph (12.B) where the market for the efficient variant failed, a 20% increase of the tariff is introduced. The previous scheme does now become potent and produces the desired dynamics of substitution (Figure 14).

5 CONCLUDING REMARKS

The paper has worked through the construction of a simulation model for the diffusion of power-saving equipment in the touristic sector of the Greek islands. Drawing a conceptual diagram (Figure 1) at the start, the simulation model has been realised (Figure 5) following very detailed steps of conceptual design and methodology from relevant bibliography. The model has been sized to the specific aims and objectives of the general research laid out in the beginning of the paper. It has also been shown that the model is able to confront a number of disrupting situations likely to arise in the islands and can have an impact on the diffusion of a technology confirming its validity and robustness. Finally, the model can be a useful to tool for policy making and understanding the operation of a system seemingly remote from conventional energy policy making as it simultaneously relates elements of tourism development, services, technology diffusion and tariff structure.

It still remains that the diffusion simulation model is linked to a demand-and-supply model. That will allow the discussion to stretch into utility economics and the financing of the demonstration and support schemes. These shall be assessed in a follow-up paper in the near future.

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