Proceedings of the Australasian Conference on Business and Social Sciences 2015, Sydney
(in partnership with The Journal of Developing Areas)
ISBN 978-0-9925622-1-2

GREEN ECONOMY PLANNING IN TOURISM DESTINATIONS: AN INTEGRATED, MULTI-METHOD DECISION SUPPORT AID

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ABSTRACT

The term ‘green economy’ refers to the realization of material wealth without major, consequent environmental and social problems. Many tourism destinations are currently pursuing green economy strategies but development of appropriate policies is complex and, consequently, decision support technologies can be used to advantage here. The design of one such decision support system is described in this paper. The research approach is based on the notion that the development (and use) of an information system can be considered a legitimate research activity in its own right and, in particular, a parallel is drawn with case study research: specifically, that systems may evolve through a series of prototypes with results of each stage informing requirements for the next and subsequent iterations. Innovative features of the system are that its design is underpinned both by a need to effectively manage the inherent complexity of the analysis domain and to allow iterative development with minimum impact on previous versions (i.e. to minimize ongoing maintenance costs). An additional important feature is that, while various subsystems may be developed using whatever software platform is deemed most appropriate, an abstracted conceptual schema facilitates effective integration of all components. To date, this application has been employed in strategy development exercises at a number of tourism destinations and, in this paper, its use within one specific field setting (Bali) is described in some detail. Early indications are encouraging (with respect to realization of our major design objectives).

JEL Classifications: M150, E170, O210
Keywords: Decision Support, Green Economy, Tourism, Managing Complexity
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INTRODUCTION

An increasing number of tourism destinations have investigated the adoption of ‘green’ strategies as a means of addressing a variety of critical concerns and issues (Simpson et al., 2008; Scott et al., 2008). These include: i) climate change and its current and future impacts (Scott et al., 2009); ii) severe environmental and social problems such as pollution, degradation and loss of forest, bushland and coastal land areas, critical energy, water and land shortages, acute traffic congestion and other major infrastructure problems, and rising unemployment, crime and delinquency rates (UNEP, 2010); iii) the need to rejuvenate destinations that have reached the stagnation or decline stages of their life-cycles (Butler, 2006); and iv) an apparent willingness on the part of visitors to pay a premium where tourism business operators have adopted sound environmental practices (Hawkins and Bohdanowicz, 2011).

Development of appropriate strategies is, however, not a simple matter. In part, this is because the policy development process demands that a substantial volume (and diverse range) of data be analyzed. In addition, the policy domain contains a large number of variables, covering the economic, environmental and social dimensions, with variables interacting with each other in a complex myriad of ways; i.e a classic case of a “wicked’ or ‘messy’ problem (Buchanan, 1992; Vennix, 1996).

Obviously, information technology can assist in managing this complexity and, in addition, the analytical tools, scenario generation functionality and simulation capabilities characteristic of modern decision support systems (DSSs) can be used to advantage in evaluating the possible impacts of proposed strategies. This assumes, however, that required data can be captured, organized and accessed conveniently. Moreover, given that an iterative approach is required for DSS development and maintenance (because of the need to use the software sequentially in a range of destinations), the system design must allow for convenient modification with minimum impact on previous versions. Furthermore, since each successive application of the DSS should be able to utilize previously developed functionality and data, a system architecture that facilitates this sharing capability is essential.

In this paper, the design and application of a DSS that meets these requirements is detailed. The system is called *GETS (Green Economy Tourism System)* and, to date, it has been applied in the field in separate studies at two locations; Sharm El Sheik in Egypt and Bali, Indonesia. For a detailed description of the Sharm El Sheik study, the reader is referred to (Law et al, 2011). This paper is more conceptual and technical, with a focus on the system features that permit iterative development, low-impact maintenance and functionality, and information sharing. In particular, the importance of data abstraction (Feldman and Miller, 1986) and the use of the ISO 3-schema architecture (van Griethuysen, 1982) are highlighted.

The paper is organized as follows: some necessary background is presented in the following section. The research approach is then overviewed and this is followed by a discussion of the system architecture and the framework employed to integrate system models at different levels of detail. The Bali case study is then introduced and examples of how different GETS components share data and utilize previously-developed functionality are outlined. The final section contains concluding remarks.

BACKGOUND

Green Economy Tourism

Countries worldwide are attempting to meet ambitious greenhouse gas (GHG) emission reduction targets and adapt to their individual climate change risks. The UK, for instance, has announced plans to reduce carbon dioxide (CO_2) emissions by 60% by 2050 (compared to 1990 levels) and Germany has committed to a 40% reduction by 2020 (Kannan, 2009; Röttgen, 2010). Such ambitious targets require significant changes, not only in a country's energy system (Kannan, 2009), but also in all other GHG producing sectors (such as tourism, which is a major user of fossil fuels, particularly through transport as well as heating, cooling and lighting (Becken and Hay, 2007)).

Currently, tourism is estimated to contribute around 5% to the world's total anthropogenic GHG emissions (Scott et al., 2008; WEF, 2009). However, it is the tourism sector's growth potential that is giving reason for concern. Estimates show that tourism's GHG emissions could grow by 161% by 2035 in a 'business as usual' (BAU) scenario (Scott, et al., 2008). In the context of global decarbonisation trends, such estimates highlight the need for climate change mitigation and adaptation in the tourism sector and emphazise the need to adopt a more sustainable path with significant changes in policy and strategy.

Of course, all industry sectors (and society in general) stand to be impacted substantially by climate change (UNEP, 2010). However, tourism faces some unique challenges and must contend with a number of specific factors and variables that make it a domain of considerable interest. These include:

- Tourism is highly energy-intensive with current UNEP (2008) estimates suggesting that the industry generates around 5% of GHG emissions annually, primarily from transport (75%, especially from international air transport) and accommodation (21%, mainly from air-conditioning and heating systems). UNEP (2010) also predicts that under a BAU scenario, tourism-generated GHG emissions for the next 30-50 years can be expected to increase by a factor of 2-3. It is possible that this could be mitigated somewhat by a trend towards tourists taking fewer trips, but with longer stays.
- Gossling (2005) asserts that direct water use in tourism varies substantially, ranging between 100-2,000 litres per guest night. High water usage tends to be in resort-style hotels and, in particular, those with golf courses. In some locations, water demands from tourism severely limit the supply available for local domestic and agricultural needs. Instances have been reported where long-term damage to the local water supply has occurred, caused by overexploitation of aquifers and reservoirs and the lowering of groundwater tables (Gossling and Hall, 2006; UNEP, 2010).
- As a result of flow-on impacts (e.g. in amenities, ancillary services and infrastructure development), tourism can play an important part in local economy development and, in some cases, poverty reduction. An increasing body of evidence suggests that sustainable tourism both increases local

tourism multipliers and decreases local economic 'leakage'. For example, GHK (2007) have estimated direct and indirect green tourism multipliers at between 1.69 and 2.13, and the Rainforest Alliance (2009) have argued that a move to sustainable tourism in Nicaragua has resulted in an employment multiplier of the order of 2.0.

- As with energy and water, tourists tend to generate more waste than the population at large (see e.g. Hamele and Eckhardt, 2006). Improved waste management (e.g. through recycling) can increase financial returns for hotels (in particular), create local job opportunities and improve destination attractiveness (which may well lead, in turn, to an increase in visitor numbers). Improvements also have the potential to reduce demands on precious land (for landfill waste handling) and to provide an additional source of renewable energy supply. UNEP (2010) estimate that higher rates of waste recycling and recovery have the potential to reduce global net waste disposal by 57 million tonnes by 2050.
- Among visitors, destination choice is increasingly being influenced by green economy commitment. For example, according to a *TripAdvisor* survey, 38% of travellers stated that environmentally-friendly tourism influenced their choice of destination, 38% had stayed at an environmentally-friendly hotel, 9% specifically looked for such hotels and 34% were willing to pay more to stay in these (Pollock, 2007). While the precise economic benefits that result from destination commitment to green economy and sustainability are difficult to quantify at this point, there is an increasing body of evidenced that suggests that the phenomenon does indeed exist (see e.g. Naidoo and Adamowickz, 2005; CESD and TIES, 2005; SNV, 2009). As such, any green economy DSS must somehow take this variable into account. In addition, the related issue of local goodwill to visitors should also be factored into relevant system models and schemas.

All the above factors have contributed to the recent interest in green economy tourism but green economy planning is a complex process, characterized by high levels of uncertainty. For instance, tourism is not included as a sector in traditional emission inventories, and as such, little information is avaiable on sources and the magnitude of the sector's GHG emissions (Becken and Hay, 2007). Thus, there is a lack of information available for destination policymakers and planners to understand the dynamics behind required changes. For targeted adaptation strategies, the relationship and interdependencies between the green economy drivers must be understood. However, a planning framework (of this type) for a green economy transition in tourism destinations does not currently exist. In addition, the domain is extremely complex, making strategy development even more difficult. We turn our attention to this important aspect in the following (sub) sections.

Domain Complexity

The green economy tourism domain is extremely complex. Reasons include:

- A large number of variables must be considered. These encompass the economic, environmental and social dimensions, and interactions between variables (within and between dimensions) need to be taken into account. Many of these interactions involve complex feedback loops and time-related dependencies (Jackson, 2003: 70-74).
- Not all variables are relevant to each case (or destination). For example, a tourism region that derives a good deal of its income from non-tourism industries (e.g. agriculture or forestry in a rural setting) is likely to have to confront different issues from a seaside resort destination, dependent almost entirely upon tourism for its prosperity. For a useful classification of tourism location types, see (Buhalis, 2000: 101).
- The problem domain is 'messy', defined by Vennix (1996) as characterized by complexity, uncertainty, interrelated sub-problems, recursive dependencies and multiple interpretations of the problem's essence. He then goes on to make the claim that among the key factors that impede our ability to resolve messy problems are: i) limitations on our cognitive powers; ii) a tendency to grossly oversimplify or circumscribe complex problems; and iii) an inability to comprehend multiple, related feedback loops.
- Strategic, scenario planning must be supported by a substantial volume of data, all of which needs to be modelled, captured, structured and stored in a way in which it can be conveniently retrieved and utilized.
- There are substantial differences between destinations in terms of their size. These range from global regions to small, local areas. Hence, it is imperative that the DSS is 'scaleable' – a non-trivial issue (Mueller et al., 2009).

ISBN 978-0-9925622-1-2

We now turn our attention to the issue of managing this domain complexity in the design and development of the GETS DSS.

Managing Complexity in IS Design and Development

The information systems (IS) field is not primarily about the production of computer software: it is about the modelling and analysis of the processes, functions and data that are of relevance in whatever domain is of interest – whether that be a business organization or an increasingly diverse range of environmental and social settings (Pearlson and Saunders, 2010). From the origins of the very first modern IS (circa 1960s), these 'domains of interest' have become increasingly complex. As such, a variety of techniques, processes and methodologies have been developed in order to manage this complexity.

Most approaches to managing complexity in IS design and development rely to some extent on *modularization* – i.e. breaking down a problem into more manageable subparts. Serious attempts at specifying rigorous and systematic methods for accomplishing this were reported as early as the 1960s (see e.g. Dijkstra, 1968) and this early work led to some very important developments in the 1970s (and beyond) in what is generally referred to as *structured analysis and design* (Aktas, 1987). *Functional decomposition* (Blaz et al., 1997) and *data flow diagrams* (DeMarco, 1978) proved to be particularly popular methods for breaking down processes into smaller units and remain so to this day. On the data side, *abstraction* and *generalization* (Feldman and Miller, 1986) have been put forward as one approach to decomposing *entity-relationship diagrams* (Chen, 1976) and, more recently, *object-oriented* techniques (Pressman, 1997) allow data and processes to be broken down and levelled as a unified whole.

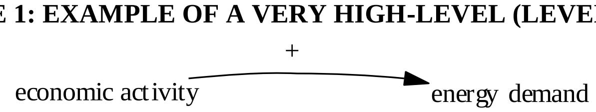
Reference was made earlier to the holistic nature of the tourism domain and the importance of taking a systemic approach to the analysis of any combination of variables. *System dynamics (SD)* (Maani and Cavana, 2000) is very well-suited to this task and many (but not all) GETS models have been specified and implemented using SD techniques and software packages. As such, we shall now provide a brief overview of SD models (and decomposition of same).

The seminal work on SD is that of Forrester (1961). Later, largely due to Peter Senge's (1990) very influential work on 'the learning organization' the approach enjoyed something of a resurgence. The release onto the market of powerful, SD-based software modelling and simulation software packages (such as *iThink*™, *Vensim*™ and *Powersim*™) also assisted here. There are a number of examples of where SD has been used effectively in the tourism domain, including the tourism multipliers model of Loutif et al. (2000), a destination management simulation package developed by Walker et al. (1999), the hotel value chain modelling work of Georgantzas (2003), and a tourism change management package specified by McGrath and More (2005).

The simplest and most convenient way of specifying a SD model is as a 'causal-loop diagram' (CLD). For a detailed introduction to CLDs, the reader is referred to Manni and Cavana (2000) but, in their simplest form, only one modelling construct is employed; an arrow connecting two domain variables, indicating a causal connection between them. Arrows are generally annotated with either a '+' or '-'; a '+' symbol meaning that both variables move in the same direction (i.e. increase or decrease together) and a '-' symbol meaning that the variables move in opposite directions. Generally, when developing a SD model though, the customary method is to firstly specify it in CLD form and then to translate it to the more complex *stock-flow* form used by the software products referred to earlier. In this section we restrict ourselves to CLDs. Examples of stock-flow model constructs (implemented in *Powersim*™, 2003) will be introduced in later sections.

A very simple example of a causal connection is that, as *economic activity* increases, so will *energy demand*. This is represented as illustrated in Figure 1.

FIGURE 1: EXAMPLE OF A VERY HIGH-LEVEL (LEVEL 0) CLD



In CLDs, decomposition can be based on either variables or the connections (relationships) between them. In this case, there is obviously much more to the activity-demand relationship than the very high-level representation contained in Figure 1, so we may decompose the connection further into the CLD presented in Figure 2.

FIGURE 2: EAMPLE OF A 2ND LEVEL (LEVEL 1) CLD

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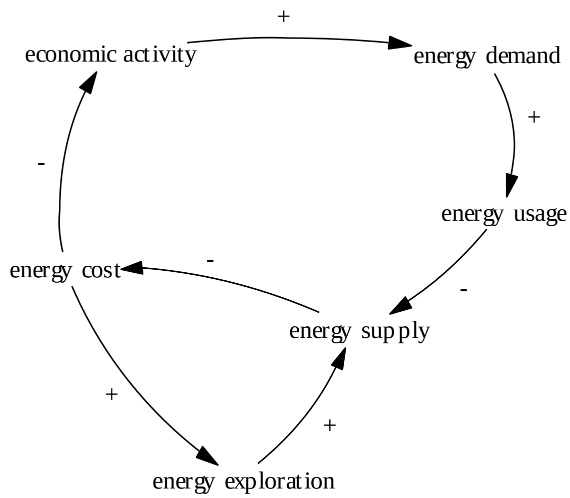
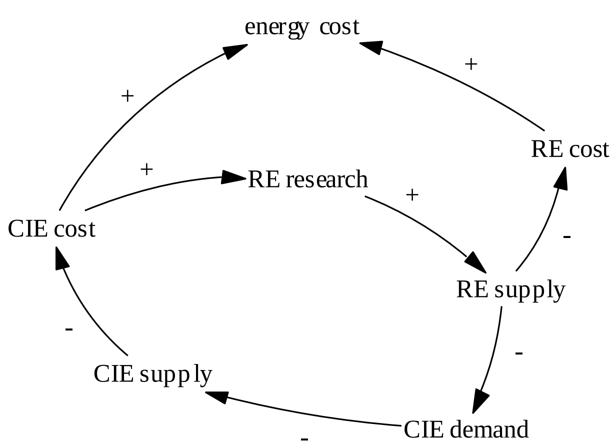


Here, high *energy demand* leads to greater *energy usage* (and vice versa) and greater usage, in turn, leads to a diminished *energy supply*. If *energy supply* is low though, this will probably lead to an increase in *energy cost* and this may have a consequent negative impact on *economic activity*. This leads us back to our starting point and completes the link to the top-level connection we have decomposed. Note though that there are additional constructs at the bottom of Figure 2: specifically, if the cost of energy is high, companies will be more inclined to involve themselves in increased *energy exploration* and, in turn, one would hope (and probably expect) that this will ultimately increase the *energy supply*.

Aspects of this model may be decomposed further however. Within a green economy context, a distinction needs to be made between traditional *carbon-intensive energy (CIE)* (oil, coal and natural gas) and *renewable energy (RE)* (hydro, wind, biomass, waste etc.) sources. The CLD in Figure 2 was the result of breaking down a connection into greater detail. As noted earlier, variables may also be decomposed and an example (specifically, *energy cost)* is illustrated in Figure 3.

FIGURE 3: A 3RD LEVEL (LEVEL 2) CLD INSTANCE



Obviously, the total *energy cost* is dependent on the respective CIE and RE costs. If the *CIE cost* is high though, it is likely that more will be invested in *RE research* and this, in turn, should increase the *RE supply*. If the *RE supply* is high the *CIE demand* may drop, thus placing less pressure on *CIE supply* and, finally, without this supply pressure, the *CIE cost* should be less. This, of course, is the rough basis for the various carbon pricing and taxing schemes being introduced (or considered) in many countries throughout the world (see e.g. Callan et al., 2009).

In all the examples presented above, both time and feedback loops are important. For example: i) RE research may well escalate as a result of increasing CIE prices but this will probably not be immediate; and ii) in Figure 3, *RE research* → *RE supply* → *CIE demand* → *CIE supply* → *CIE cost* → *RE research* is a classic feedback loop. Time dependencies (e.g. delays) and feedback loops are common in tourism models (see e.g. Ritchie and Crouch, 2003: 60-78) and Richardson and Crouch (1981) have noted that SD is ideally-suited to this type of modelling exercise.

In addition, as Vennix (1996) has noted, our cognitive limitations can lead us to dangerously over-simplify complex problems and this, in turn, may lead to unfortunate, unintended consequences. SD modelling, particularly using CLDs, can help prevent this, Moreover, as noted previously, a further strength of CLDs is their simplicity and this facilitates modelling sessions where key problem stakeholders can fully participate. Generally, however, translation to stock-flow form is undertaken by expert modellers, proficient in the particular SD modelling and simulation package employed. This process is more complex but it does allow the impacts of major external incidents to be factored into models (as well as providing the capacity to deal with phenomena such as queues, delays, step functions and other discrete events).

Having said that, the degree of complexity of a given problem domain will correspond (roughly) exponentially with the number of variables involved – and, even from the simple, illustrative examples presented above, it should be fairly apparent that the green tourism domain is extremely complex. Management of this complexity is, of course, the central issue to be addressed in the remainder of this paper. Before that, however, we briefly introduce our research approach.

RESEARCH APPROACH

The following is a brief summary of the research approach, which is based on the idea that development of an IS may, in certain circumstances, be considered a legitimate research strategy in its own right. A more complete account is presented in (Pornphol and McGrath, 2011) and that account, in turn, borrows heavily from earlier work by Gregor (2002) and Hasan (2003).

Hasan (2003: 4) claims that IS development, in many cases, should be considered a valid research activity (and method) because, not only is knowledge created about the development process itself, but also because "a deeper understanding emerges about the organizational problem that the system is designed to solve". Markus et al. (2002) put forward a similar case in arguing that IS development is a particular instance of an *emergent knowledge process (EKP)* and that this constitutes original research where requirements elicitation, design and implementation are original and generate new knowledge on *how to proactively manage data and information in complex situations.* Hasan (2003: 6) further contends that this often involves a staged approach, where "systems evolve through a series of prototypes" with results of each stage informing requirements for the next and subsequent iterations.

Nunamaker et al. (1991) take an approach consistent with the above but draw on an alternative research tradition in case studies and, in particular, action research. Again, using 'replication' strategies, each new instance (case or action research activity) builds upon and refines knowledge gleaned from previous studies (Yin, 1994). Nunamaker et al. (op cit.), however, nominate two features of IS development that distinguish it from more general action research: first, the techniques of IS development, the properties of the system itself and the situation where the system is to be deployed may all generate important knowledge; and, second, IS research projects are both constrained by the limits that current IT place on the development of systems and are enabled by the uniqueness of the technology (which can, as a tool, mediate knowledge generation and the communication of same).

The latter feature has been studied extensively by scholars in 'activity theory' (Vygotsky, 1978). Notably, activity theorists emphasize the holistic nature of the IS development process and, in particular, the critical nature of the cultural and social context within which systems are developed (see, for example, Engestrom, 1987; Nardi, 1996). The socio-technical view of IS, where hardware, software, people and processes are integrated into a complex, purposeful whole, is one of the key features that make information and communication technologies "like no other in the history of mankind" (Hasan, 2003: 4).

Thus, to summarize: the development of our DSS is a legitimate research activity in its own right, which draws on the more established, traditional research approaches of the design sciences and especially case study/action research. Each new application of the DSS (e.g. to a new destination) produces a new version of our prototype and extends our knowledge of the green tourism economy research domain. This is akin to employing a multi-case (study) research strategy - with each new case refining and extending results of previous iterations - and finally, many research findings and outputs are actually inherent in the various conceptual models (and implementations of these) that constitute the DSS.

MODELS: A UNIFYING FRAMEWORK

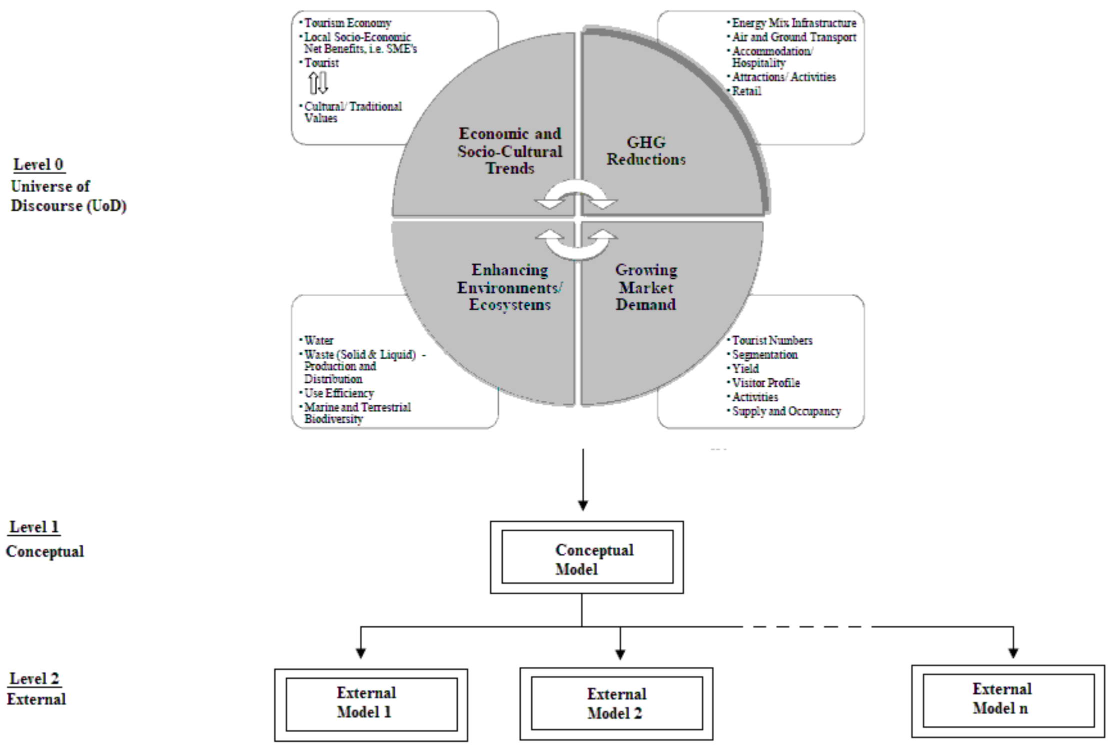
ISBN 978-0-9925622-1-2

Background

Over the years, there has been much debate and discussion related to the capabilities and suitability of various DSS modelling approaches (for an early work, see e.g. Brodie et al., 1984). As noted by Masuch (1992), hardware and software limitations meant that early DSS models tended to be highly-quantitative. Masuch though, further notes that much decision support work is highly-qualitative and the emergence over the years of extremely powerful and expressive artificial intelligence-based knowledge representation formalisms has resulted in a shift towards qualitative specifications. Despite this, however, he suggests that neither the quantitative or qualitative approaches are intrinsically superior and that the majority of non-trivial modelling exercises demand that a combination of both methods be employed. This is consistent with the view of Curtis et al. (1992) who have argued that different aims, disparate user profiles, contradictory requirements, the need to use the same model constructs in a variety of system components and the need for both large and small-grained levels of abstraction all demand decision support models permitting multi-paradigm representations.

A DSS modelling, 3-level framework that meets these requirements is presented in Figure 4. In developing this framework we have drawn on the work of IS0 Technical Committee 97 in defining the foundations of the 3-schema database management system architecture (van Griethuysen, 1982). We shall now briefly introduce the three levels in turn.

FIGURE 4: A DSS MODELLING FRAMEWORK



Level 0: The Universe of Discourse (UoD)

The *UoD* refers to *that collection of objects, from a real or postulated world that is* being described - in our case, the world of interest is centered on green economy tourism. The UoD representation at Level 0 was derived from the model described in detail by Law et al. (2011) and developed as part of a green economy tourism strategy, conducted with the Egyptian Government, at Sharm El Sheik. This study highlighted the following four key elements as being integral to a successful green economy transformation: i) GHG emissions reduction; ii) growing

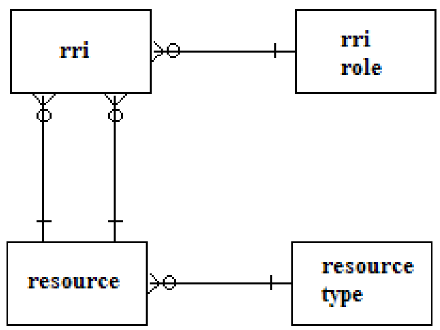
ISBN 978-0-9925622-1-2

destination market demand; iii) enhancing the destination environment and ecosystems; and iv) sustainability of the destination's economy and socio-cultural traditions. The model, as represented at Level 0 in Figure 4, highlights the domain complexity: all elements (and relationships between them) are characterized by the fact that they are very tightly integrated, reflecting that targeted strategies rely on a holistic and systemic view.

Level 1: Conceptual Model

The *conceptual model* defines *the objects of the UoD, including rules governing allowable classifications, states, transitions and constraints* (van Griethuysen, 1982). An illustration of part of the conceptual model is presented in Figure 5. The model is represented in entity-relationship form[i] (Chen, 1976), it is highly abstracted and it is a *common denominator* schema, as defined by Curtis et al. (1992): i.e. it consists of only the core domain constructs, without any peripheral or presentation-level detail. The entity-relationship approach has been employed not because of its intrinsic superiority (over alternative modelling formalisms) but because: i) it is ubiquitous within the information systems development industry and has been for over 30 years; ii) there is a well-defined abstraction process for entity-relationship models that employs much the same "super" entity types used within most data and process modelling; and iii) the principal motivation for Chen's (op cit.) original development of his approach was to produce a conceptual modelling approach that allows a unified view of data.

FIGURE 5: CONCEPTUAL MODEL (PARTIAL)



Implemented as a relational database application, the intersecting entity, *rri (resource-resource involvement)*, would translate to something like the *Access*™ table presented in Figure 6. This table details some of the important subtype relationships that need to be captured. In this case, *energy* is specified as a *resource* subtype, *energy* may be decomposed further into *airTransportEnergy*, *accmdnEnergy*, *attractionEnergy* and *activityEnergy* and these, in turn, may be broken down even further (as illustrated in Figure 6).

Representing the conceptual model in an abstracted form produces a number of benefits, including: i) where appropriate, common functionality may be coded around the abstracted view, leading to a reduction in system development effort; ii) integration of DSS applications, developed around external views, is facilitated because core data types are all mapped back to the common conceptual view (model); iii) better integration means that functionality may be more conveniently shared between applications (which also means less coding effort); and iv) ongoing system maintenance is reduced (again resulting in a reduction of total development effort).

FIGURE 6: *ACCESS* IMPLEMENTATION OF *rri* CONCEPTUAL MODEL RELATIONSHIP

ISBN 978-0-9925622-1-2

rri : Table

rriId	resType1	resType2	rriRole
22	resource	energy	subtype
23	energy	airTransportEnergy	subtype
24	energy	accmdnEnergy	subtype
25	energy	attractionEnergy	subtype
26	energy	activityEnergy	subtype
27	accmdnEnergy	hotelEnergy	subtype
28	accmdnEnergy	motelEnergy	subtype
29	accmdnEnergy	bedAndBEnergy	subtype
30	hotelEnergy	airConEnergy	subtype
31	hotelEnergy	lightingEnergy	subtype
32	hotelEnergy	appliancesEnergy	subtype
33	hotelEnergy	transportEnergy	subtype
(AutoNumber)			

The abstraction approach is based on the REA (resources, events and agents) framework of McCarthy (1982). Dampney et al. (1993) have observed that a problem with abstraction is that a model's meaning is not apparent without examining the underlying detail (e.g. relational tables). This is probably true of our conceptual model but, at the same time, generalization does result in the benefits listed in the previous paragraph.

The easier maintenance benefit is extremely important and, consequently, deserves additional attention. A common requirement in DSS applications of this type is to derive all subtypes (at whatever level removed) of a given super-type. Employing (quasi) *Prolog* (Bratko, 1986) as programming language, this functionality may be implemented as the following recursive procedure:

RT_x isaSubtypeOf RT_y ***if***
rri(RRIId, RT_y, RT_y, subtype).
RT_x isaSubtypeOf RT_y ***if***
rri(RRIId, RT_y, RT_z, subtype) ***and***
RT_x isaSubtypeOf RT_z.

Assume now that, in place of the decomposition illustrated in Figure 6, we wish to break energy resources down into carbon-intensive and renewable varieties (and at the next level into coal, gas, oil, hydro, biofuel etc.). With a more concrete conceptual model, this would require much code revision. With the abstract view however, this is not required and, as an example, the hierarchy retrieval procedure above still works perfectly well without any revision. All that is required is replacement of the Figure 6 table entries with a new set.

Level 2: External Models

An *external model* or user *view* is *a mapping from all or part of a conceptual model to a language or representational form of the user's choosing* (van Griethuysen, 1982). In addition, it must be possible to map in the reverse direction: i.e. from external to conceptual model. In the previous sub-section, part of a conceptual model implementation using *Access*™ and the very high-level programming language *Prolog* was presented. GETS contains external-level applications using these software products but additional packages (and associated modelling and coding techniques) are also employed. In particular (and as noted earlier), a number of key system functions are implemented as external components using SD and, specifically, the SD product *Powersim*™ (2003). We shall now illustrate the mapping process and provide an example of an external model/application through the levelled set of CLDs presented earlier in Figures 1-3 (specifying the economic-activity – energy-usage causal relationship).

Referring to Figure 3 again, this CLD contains the circular set of causal relationships: *REResearch* → *RESupply* → *CIEDemand* → *CIESupply* → *CIECost* → *REResearch*. At the conceptual level, these are also represented as *rri* relationships, as illustrated in Figure 7. In contrast to Figure 6 though, the involvement role here is *causal* (as opposed to *subtype* in Figure 6).

FIGURE 7: ADDITIONAL *rri* CAUSAL RELATIONSHIPS (SEE ALSO FIGURE 6)

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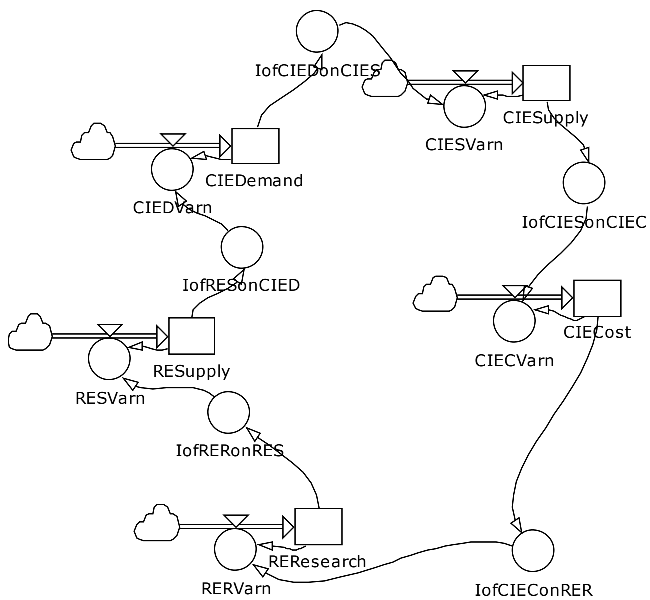
rri : Table

rriId	resType1	resType2	rriRole
34	REResearch	RESupply	causal
35	RESupply	CIEDemand	causal
36	CIEDemand	CIESupply	causal
37	CIESupply	CIECost	causal
38	CIECost	REResearch	causal
(AutoNumber)			

Part of the SD external application's model dealing with this particular set of relationships is presented in Figure 8. Specifically, this is a *Powersim*™ model and a major reason for converting the CLD to this particular form is to take advantage of the package's powerful simulation and scenario generation/evaluation capabilities.

FIGURE 8: STOCK-FLOW REPRESENTATION OF FIGURE 3 CLD (PARTIAL)



The basic building blocks of SD (stock-flow) models are *stocks* (represented as rectangles), *flows* (represented as arrows with circular flow regulators attached), *converters* (represented as circles) and *constants* (represented as diamonds). In our model, examples of stocks are *RECost* and *CIEDemand.* There is a level associated with each stock, which can be an actual value or a value bounded by some artificial scale. Stock levels vary with flows, which may be *inflows*, *outflows* or *bidirectional.* For example, *CIEDVarn* (CIE demand variation) is a bidirectional flow such that:

$$CIEDemand_t = f(CIEDemand_{t-1}, CIEDVarn_t).$$

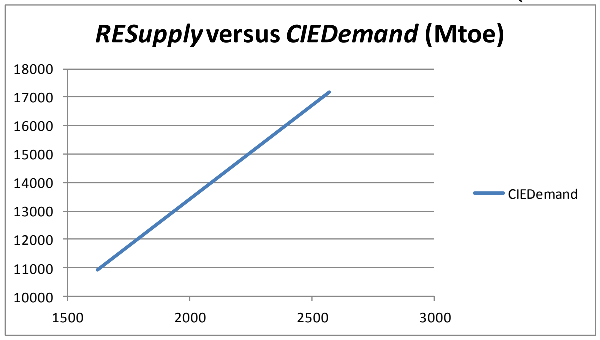
That is, in our model, the CIE demand level at time, *t*, is a function *(f)* of the CIE demand level at time, *t-1*, and its variation at time, *t*. These equations are the foundation of *Powersim's* formidable simulation capabilities. The third of our basic constructs, converters, serve a utilitarian role: they hold values for constants, calculate mathematical relationships and serve as repositories for graphical functions. In general, they convert inputs into outputs (hence, the name, 'converter'). A converter with double circles indicates an array and a diamond indicates a constant (essentially a converter that does not change its value during the course of a simulation).

The reader may have noted a similarity between each of the causal connections in Figure 8: in fact, they are identical in their basic structure, with each pair of stocks connected by a converter named, *IofXonY (impact of X on Y)*, representing a mathematical relationship between *X* and the variation to *Y (YVarn).* This type of structure is extremely common in SD models and the general form of a relationship of this type between two variables (represented as stocks), $S_1 \rightarrow S_2$, is:

$S_{2,t} = S_{2,t-1} + g_2(S_{1,t})$ - (1)

where g_2 is the input function, *Iof* $S_1 on S_2$. An example (derived from UNEP, 2010), illustrating the relationship between RE supply and CIE demand variation, is presented in Figure 9.

FIGURE 9: *SUPPLY* ON *CIE* DEMAND RELATIONSHIP (SOURCE: UNEP, 2011)



More generally, a sequence of *n* stocks, S_1,---, S_n ,causally connected by this type of impact relationship, has the general form:

$S_{n,t} = S_{n,t-1} + g_n(S_{n-1,t-1} + \text{----} + g_2(S_{1,t-1})))\text{----})$ - (2)

This is a classic recursive definition and within the conceptual model, using the very high-level, logic-based programming language *(Prolog)* we employ to manipulate basic relational data (implemented in *Access™)* at this level, it could be implemented as:

RT_x hasImpactOn RT_y ***if***
rri(RRIId, RT_x, RT_y, causal) ***and***
FnY(RT_X, RT_Y).
RT_x hasImpactOn RT_y ***if***
rri(RRIId, RT_x, RT_z, causal) ***and***
RT_z hasImpactOn RT_y.

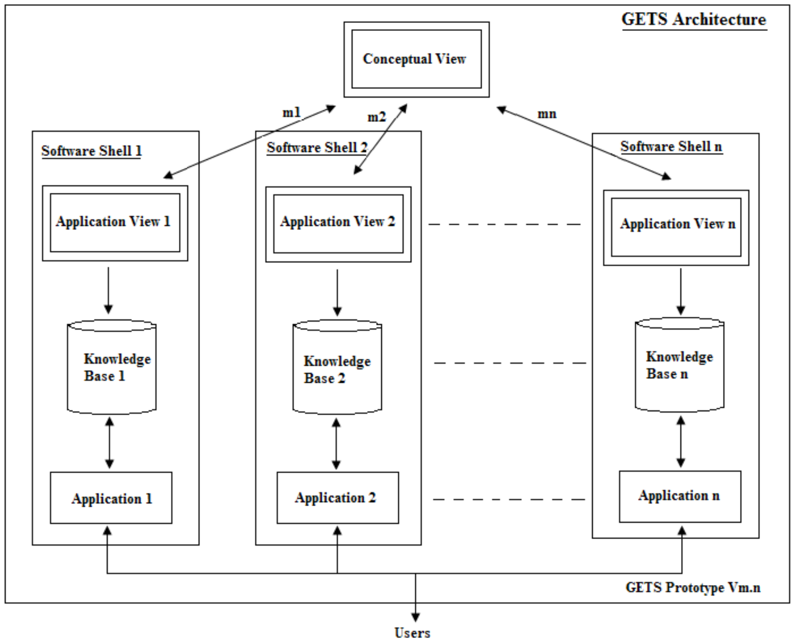
where *FnY* represents a call to the actual procedure used to compute the impact function, g_y.

Relatively simple recursive procedures such as the above are used to facilitate the conceptual – external view mappings discussed earlier. Moreover, recursion has long been recognized as a highly-effective means of managing complexity in IS design and development. As noted by Graham et al. (1990), recursion allows a solution for a problem to be derived through solutions to many smaller instances of the same problem. Furthermore, every recursive function can be transformed into an iterative procedure by replacing recursive calls with iterative control constructs (Kowalski, 1979: 107-129). Insofar as GETS is concerned, this means (for example) that the external SD model presented in Figure 8 (and the corresponding conceptual specification detailed above) may conveniently be respecified iteratively. This allows redevelopment of the function as an alternative external application, using a more conventional, procedural software development environment (e.g. for execution-time efficiency reasons or to take advantage of specific features available in an alternative software development shell).

System Architecture

A high-level view of the GETS architecture is illustrated in Figure 10. A fundamental objective of the GETS project is to produce a system that is iterative, scalable and open, *Iterative* (in this instance) means that each application (e.g. to a new destination or aspect of a destination) produces a new prototype that increases or refines our knowledge of the green economy domain; *scalable* means that the system must be able to cope equally effectively with large and small destinations; and *open* means that GETS must be capable of handling any type of data, irrespective of source or format.

FIGURE 10: *GETS* ARCHITECTURE – HIGH-LEVEL VIEW



One of the keys to realizing both an iterative and a scalable system is developing all code (and higher-order applications) around abstracted data models. Essentially, the aim is to allow new functionality to be added (e.g. as issues associated with a new destination introduce new system requirements) without having to revise existing applications. This was discussed in detail in the previous sub-section.

The open systems objective is realized by adopting a design for GETS consistent with ISO '3-Schema Architecture' principles (van Griethuysen, 1982). As noted previously, the *Conceptual View* is a highly abstracted model of the total system, completely free of any implementation-level detail. The *Internal View*, deals primarily with technical aspects of the various applications (relating to efficiency etc.) and is beyond the scope of this paper. *Application View 1, ----, Application View n* are external-level schemas developed for individual applications, implemented within specific software shells *(Software Shell 1, ----, Software Shell n).* Examples of these (used in applications implemented to date) are *Excel*™*, Access*™*,* a rule-based expert systems shell called *Flex*™ and the system dynamics simulator, *PowerSim*™*.* Illustrative examples were introduced earlier in this section. Further examples, taken from a study currently underway in Bali will be presented in the following section.

CASE STUDY: A GREEN ECONOMY ROADMAP FOR BALI

The case study is concerned with a recent research/consultancy exercise conducted by Victoria University's Centre for Tourism and Services research (CTSR) with Indonesian government authorities on the island of Bali, Indonesia. Specifically, the research team was commissioned to *"--- develop a strategy for Bali tourism to take an international leading role into the new green economy and tourism market and provide a road map for action and investment"* (Lipman et al., 2011: 3). The study was conducted during the latter part of 2011 and the major output was the 'green economy roadmap' detailed in (Lipman et al., op cit.).

Bali is an extremely popular tourism destination, with visitors attracted primarily by its warm climate and beaches, and also by a variety of other attractions and activities (ranging from exotic flora and fauna, lakes and volcanoes to local food, music, dance and other traditional cultural features). On the surface, Bali's future as a successful tourism destination looks extremely bright with, between 2011 and 2020: i) annual visitor numbers expected to increase from 7.1 to 14.4 million (Turner, 2011); ii) annual tourism GDP predicted to increase from $US2.95 billion to $US5.38 billion (Hoque, 2011); and iii) tourism-related employment demand forecast to increase from 1.1 million to 2.0 million (Hoque, 2011).

While the economic future looks extremely bright, the anticipated rapid growth is not, however, without its downside. The more significant potential problems and issues identified (Filep, 2011; Filep and Hendriyetti, 2011) include:

- Major traffic congestion;
- Excessive and unsightly waste and pollution;
- Cost-of-living increases induced by tourism activity;

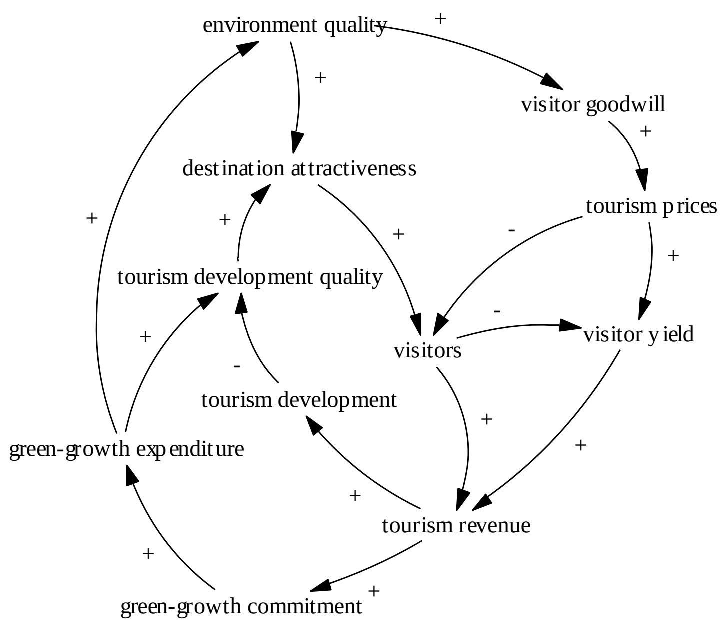
- Inadequate roads and infrastructure;
- Environmental damage;
- A lack of suitably-qualified tourism and hospitality industry staff;
- Tourism's impact on land and water stress levels; and
- Erosion of traditional Balinese culture.

Most of these problems already exist and are only expected to worsen over the next 10 years (especially with the rapid growth anticipated).

These problems have all been identified in the green economy roadmap, the bulk of which was devoted to specification of a hierarchy of objectives, strategies and actions, all designed to realize the overall vision of transforming Bali into one of the world's leading green tourism destinations by the year 2050. A key element is minimizing negative environmental impacts by attracting fewer tourists willing to pay more (i.e. increasing visitor yield).

This objective is encapsulated in the CLD presented in Figure 11, where (at the top of the diagram) it can be seen that an improvement in *environment quality* can reasonably be expected to result in an increase in *visitor goodwill* (Hawkins and Bohdanowicz, 2011) and this, in turn, should allow tourism operators to increase *prices*, resulting in both an increase in *visitor yield* and a drop in *visitors.*

FIGURE 11: SOME KEY RELATIONSHIPS IN INCREASING VISITOR YIELD

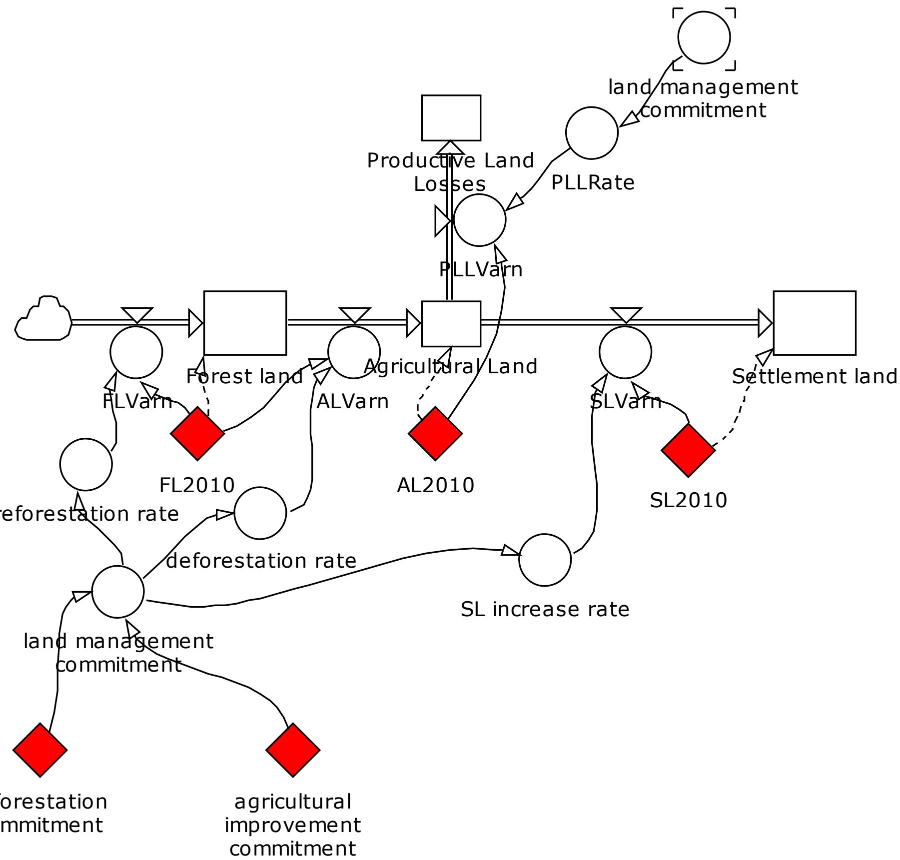


The roadmap identifies many strategies aimed at environmental improvement, covering water, waste, land and energy management. In general, *broad* strategies are broken down into *specific* strategies, these may be decomposed further into *sub-strategies* and, finally, strategies are supported by *actions* (all of which must be capable of being measured through appropriate KPIs).

One of the central, environment-related, broad strategies (Lipman et al., 2011: 7) is: *"Government is to strengthen implementation of waste, water and land management, and biodiversity conservation measures."* This is underpinned by the specific strategy (No.11 at pp. 37-38): *"Ensure the green growth tourism process is integrated into a stronger land use planning system for Bali"* and the sub-strategy (No.11.3 at p.38): *"Create open space, conservation and protected areas to enhance the tourism experience, community amenity and conserve biodiversity."* Finally, action *b)* (p.38), under this sub-strategy, is specified as: *"Based on the open space plan, establish more protected areas, having strong development controls and recognizing a minimum forest cover of 30%".*

The core of the external DSS application dealing with land use is implemented in SD and illustrated in Figure 12. It shows that, over time, forest (and wilderness) land is claimed for agricultural and farming purposes and this land, in turn, may be converted into settlement land. Alternatively, there is a direct conversion from forest to settlement land[ii]. Deforestation and settlement land increase rates determine the speeds at which these land conversions occur and a reforestation rate represents efforts to reclaim lost forests through replanting programs. Finally, some agricultural land is lost to desert forever (because of drought, over-harvesting, water stress, climate change etc.) and this is represented by the agricultural land – productive land losses transition.

FIGURE 12: LAND USE EXTERNAL APPLICATION (PARTIAL)



An initial, generic version of the application was implemented using data derived from (UNEP, 2010). This version simulates changes in global land categories between 2010 and 2050 and, under a 'business-as-usual' (BAU) scenario, the simulation suggests that the total global forest area will drop from 3,940 million hectares (Mha) to 3,700Mha during this period. Under a 'green' scenario[iii], however, total forest land is actually expected to increase to 4,500Mha.

This model was then customized for Bali. Overall, forest degradation in Indonesia has been recognized as a major problem for some time, with 40% of total forest area having been cleared between 1950-2000 (a drop from 162Mha to 92Mha) and an apparent, recent (i.e. from the mid-1990s) acceleration in the forest loss rate to around 2Mha/year (WRI, 1998). Different sources provide slightly contrasting views of the Bali situation but there is general agreement that, while Bali forests only comprise around 0.1% of the national total, past and current degradation rates are consistent with the national experience (at around 2.5%/year). This figure was used for the deforestation rate in the customized model, along with the most recent data that could be found for other model variables (specifically, from the Bali Province Statistics authority in (BPS, 2010: 193-198)). This resulted in forest, agricultural and settlement land stocks being initialized with 2010 values of 125,432ha, 356,023ha and 45,494ha respectively (corresponding to 22.3%, 63.2% and 14.5% of the land total). Obviously, the region has some way to go if it is to realize the 30% forest cover objective specified in the roadmap.

The very high rate of forest losses in Indonesia has received substantial publicity over the last 20 years or so (see e.g. WRI, 1998; FWI/GFW, 2002; ATBC, 2010) and there is probably a good chance that efforts to reverse this trend would be received favourably by future visitors to Bali; and particularly by the environmentally-conscious, higher-yielding target market identified in the roadmap (Hawkins and Bohdanowicz, 2011). This issue is of such importance to the realization of the roadmap's broad objectives that it was decided that it warrants a

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dedicated external application in its own right. Since this application though, is required to advise on actions and strategies (e.g. to reverse current land degradation trends), a rule-based, advisory expert system platform was considered to be a more suitable platform (than SD) in this case.

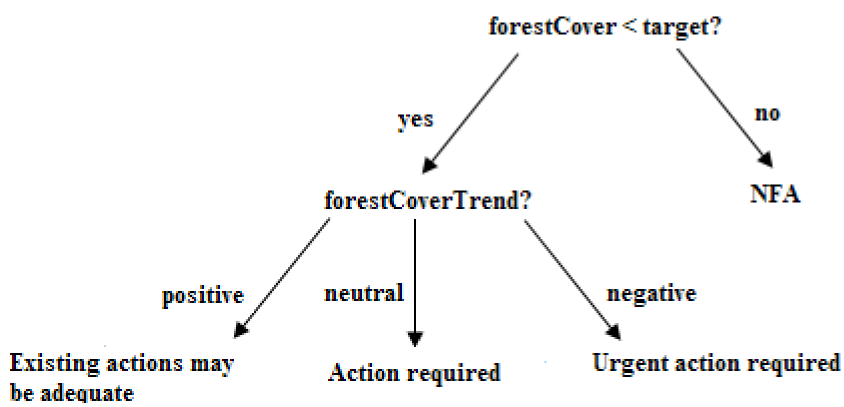
First, however, the new application requires land area trend data generated by the SD application discussed above and the abstracted conceptual model provides the basic framework for this transfer. That is, the SD application simulation produces streams of trend data on variations of areas of each land category over time and these and these are all specific instances of yet another *rri* subtype, with the general form:

rri(RRIId, RT_t*,* RT_{t1}*, timeChange)*

which may be viewed as a general schema for recording values (in this case, land area) of the same resource type (e.g. forest land) at times *t* and *t1*.

Within rule-based expert systems, the rules themselves can generally be represented as decision trees. An example, related to whether action to remedy predicted deforestation at some future time, *t*, is presented in Figure 13.

FIGURE 13: DECISION TREE FOR DEFORESTATION NECESSITY RULES



An example of a (typical) rule extracted from this representation is:

if *forestCover*$_t$ < *targetForestCover*
and *forestCoverTrend*$_t$ *is negative*
then advise *'Urgent action required at time t'*

and the underlying *Prolog* code (utilizing *rri* data generated by the SD application) required to determine if the forest cover trend is negative is:

forestCoverTrend$_t$ *is negative* ***if***
rri(RRIId, FC_{t-1}*,* FC_t*, timeChange)* ***and***
resourceType(RRIId, forestLand) ***and***
t – t-1 is 1 year ***and***
$FC_t < FC_{t-1}$.

Of course, the above code and set of rules derived from the decision tree in Figure 13 are only sufficient to provide the application user with an indication of whether or not a problem exists. The question of precisely what action is required requires another set of rules and a top-level view of a decision tree illustrating the complexity of this (sub) domain is presented in Figure 14.

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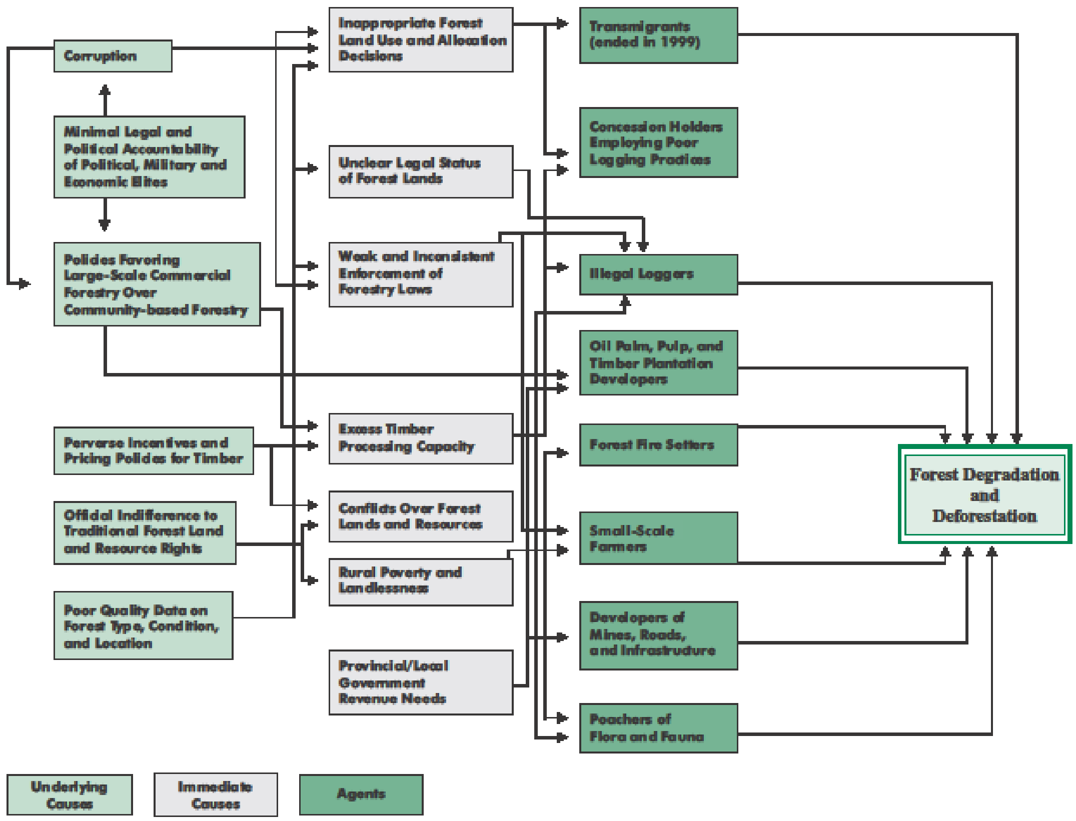
FIGURE 14: FOREST DEGRADATION IN INDONESIA (SOURCE: FWI/GWF, 2002: 25)



Digging a little deeper, the major causes of deforestation are industrial logging (whether for the timber itself or for the plywood, pulp and paper products that can be extracted from it), clearing for agricultural or other settlement land purposes and natural disasters (bushfire, drought, other climate change impacts etc.). As is suggested in Figure 14, inappropriate forest land use and allocation decisions are a major cause of current problems and, as an example, the WRI (1998) has reported that, in 75% of cases where forest land has been allocated for clearing and replanting, replanting has never actually taken place. This underpins one application rule which advises the user to explore ways (mostly legal or commercial) in which dormant land in this category might be freed up for its original purpose (i.e. for use as an industrial timber plantation).

This is only possible after (subsequent to consultative interaction with the user) forest land (current and cleared) has been classified consistent with the schema presented in Figure 15. This is a conceptual-level specification and, as such, outputs from this particular external expert system application can be transmitted to further applications which might require this data. Thus, in this example, we have demonstrated how external applications may both generate data for, and utilize data from, other applications (developed using different software platforms) and that it is, primarily, the abstracted, conceptual data view that makes this possible.

FIGURE 15: FURTHER *rri* SUBTYPES (FOREST LAND)

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rri : Table

rriId	resType1	resType2	rriRole
22	resource	land	subtype
23	land	forestLand	subtype
24	forestLand	clearedForestLand	subtype
25	clearedForestLand	loggingLand	subtype
26	loggingLand	plantationLand	subtype
27	plantationLand	replantedLand	subtype
28	clearedForestLand	agriculturalLand	subtype
29	forestLand	otherLostLand	subtype
(AutoNumber)			

CONCLUSION

Green economy strategy development is a highly-complex process, demanding that a wide range and considerable volume of data be captured, structured and analyzed. Furthermore, depending on the objectives of different aspects of policy development, certain information modelling and analysis methods may be more appropriate than others: i.e. a ‘horses for courses’ approach is required when developing specific decision support applications.

At the same time, whatever methods and software platforms are employed in developing various system components, the overall strategy development domain is so tightly integrated that some mechanism is required to allow information sharing between applications. In our DSS, this is realized through the use of an abstracted conceptual model and a system design based on the ISO 3-schema architecture. Examples of data sharing between external applications developed using the rule-based expert systems and SD paradigms (approaches that, on the surface, appear to have little in common) were presented and discussed.

To date, the DSS has been used in the field at two locations, the Sharm El Sheik resort in Egypt and Bali, Indonesia. The Bali experience was overviewed and a specific, actual, information sharing example was presented in some detail. The example was concerned with visitor goodwill, this concept’s link with environmental quality and the strategy objective of improving the environment through the establishment of more open space (especially forest land). Part of a SD stock-flow application used to support scenario generation and testing, related to this objective, was presented and the importance of *rri* data beyond this individual application was highlighted: specifically, expert system rules (from another application) utilizing this data were specified in detail. It should be noted that, potentially, outputs from the expert system analysis (e.g. details of proposed environmental improvement initiatives) could usefully be fed back into the original SD application.

Finally, parallels between DSS development and case study research were emphasized: in particular, it was noted that each new external application added to the DSS extends our knowledge of the overall study domain in much the same way as new cases build upon and refine previous iterations in multi-case study research. Thus, the version of the DSS described in this paper, the result of an initial system specification and two subsequent field applications, represents the beginning, rather than the end, of this particular green economy tourism strategy research project.

ENDNOTES

[i] In fact, the conceptual model may actually be viewed as a data model specified in entity-relationship form, surrounded by rules specified with a logic-based programming language (Kowalski, 1979). The rules are employed both to manipulate the data definitions and to provide additional meaning.
[ii] Excluded from the diagram for the sake of clarity.
[iii] With the equivalent of 2% of global GDP invested in various green and climate change mitigation initiatives.

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