HOW TO INCORPORATE UNCERTAINTY AND RISK INTO DECISION-MAKING

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Policy-makers and planners have to make decisions in the face of varying degrees of uncertainty and risk. SimCoast™ is an intelligent computing system designed to addresses these problems explicitly. Here we look at how fuzzy logic and expert systems - two of the fundamental approaches within SimCoast™ - can be used to improve decision-making in relation to conditions of high levels of uncertainty, subjectivity in data and inexact reasoning.

Introduction

In most of today's institutions there is a belief that the effects of an intervention can be predicted. This supposition occurs because most existing resource and economic planning models allow managers to simulate, or in a crude way, anticipate the future. But this implies not only that all the interactions within the system are adequately understood, but also those processes that will direct its forward evolution. This assumes that all future states are contained within the dynamical description of the present system.

Unfortunately, this is generally not the case.

For example, the inner dimensions of a planning model that included all possible future states would contain so much working detail that in practice it could not be developed. Secondly, the outer dimensions would have to reflect the fact that complex living systems are open and hence have significant exchange of materials across their boundaries. Remarkably, most planning decisions have ignored these two issues, concentrating instead on a highly restrictive view of what is actually happening. Thus in many parts of the world we see situations where researchers and planners have been forced unremittingly into a role where they are trapped by their own knowledge. They might think they know what the system is doing, but rarely do they know why or even how it is doing it.

In areas outside policy and planning, researchers have learned to cope with such problems. One way has been simply to use error bars when estimating variables. But errors can derive from uncertainties in a wide range of processes and objects, e.g. in the instruments themselves, calibration, design, lack of skill and general confusion about the theoretical foundations of particular measurements. When a problem becomes more and more complex, simple inexactness cannot fully describe the situation, and uncertainty must be dealt with explicitly.

Uncertainty is not merely the spread of data around some arbitrary mean, known with confidence, but rather a systemic form of error that can swamp an otherwise easily calculated random counterpart. Achieving certainty then, even in a quantitative science, relies largely on managing the different sorts of uncertainty affecting performance. Because uncertainty cannot be removed it has to be clarified.

The errors associated with data points represent the *spread*, i.e. the tolerance or random error in a calculated measurement. *Confidence limits* refer more to risk; for example, in a risk analysis of future scenarios resulting from different policies, confidence limits are reflected in estimates when they are qualified as optimistic, neutral or pessimistic. An *assessment* based on historical estimates of some quality or resource thus acts as a *qualifier* on the numbers used and on the spread of data points. An assessment represents unreliability and relates to our knowledge about the processes involved, whereas the spread represents inexactness and relates to our knowledge of the behaviour of the data.

Another important concept is *ignorance*; this is a measure of the gaps in our knowledge. These gaps may simply be anomalous results that are exposed when a new advance in understanding occurs or simply reflect the maturity of the subject.

The boundary of ignorance is very difficult to map; one approach has been to assess the *pedigree* of a quantity (see below). This describes the state of art of a particular field from which the quantity derives. For example, in the case of theory of relativity, there was a progression from an embryonic field in 1905 through to the 1950s when experimental results had corroborated the theory and all but cranks had accepted it. Resource management on the other hand relies on data that are highly qualitative and heterogeneous. Well-structured theories, common in many branches of science, are conspicuous by their absence.

In the table below, colleague consensus describes the social strength of the paradigms in which the information is cast, and hence the way that knowledge has and is being built about a particular subject.

Pedigree score	*Theoretical structures*	*Data*	*Peer acceptance*	*Colleague consensus*
4	established	experimental	total	all but cranks
3	theoretical model	historic/field	high	all but rebels
2	computer models	calculated	medium	competing schools
1	statistical procedures	educated guess	low	embryonic field
0	definitions	uneducated guesses	none	no opinion

Thinking that we can make exact predictions under highly complex circumstances is thus likely to be premature; leading those involved in decision-making towards a misdirected sense of concreteness in overall policy judgement.

Worse still is the fact that the credibility of science is also at risk because of the dilemma of uncertainty and responsibility. Neither can be eliminated, nor indeed would it be desirable: managing uncertainty in the context of responsibility cannot be sidestepped. Unfortunately, many of today's institutions have been developed to undertake planning and policy development from the standpoint of determinacy rather than complexity.

One of the major difficulties in coastal zone management is that it requires an interdisciplinary approach, involving fields of varying states of maturity and with very different practices in their theoretical experiments and social dimension. Planners and policy-makers often find themselves having to use inputs from research areas with which they are potentially unfamiliar, thus making it difficult to apply the same sensitivity and quality of judgement as they would do in their own fields of expertise.

The result is a dilution of quality control on the planning process and a weaker quality assurance of results.

Scientists have tended to develop a healthy prudence about passing judgement on the results of others in areas outside their own expertise, with the result that any interference in others' fields is discouraged. Unfortunately, in an interdisciplinary policy-related area such an approach rapidly becomes counterproductive, because criticism, the lifeblood of science, does not properly occur.

The problems created in policy-related research by uncertainty are increased by its societal dimension. Here research is judged by the public, including bureaucrats, on its performance in sensitive areas such as the economic returns on foreign aid, returns from the exploitation of natural resources, the dumping of hazardous wastes, the dangers of oil spills or environmental pollution. All involve much uncertainty, as well as inescapable social and ethical aspects, so simplicity and precision in predictions or even setting safe limits are not always feasible.

Yet policy-makers tend to expect straightforward information to use as inputs into their own decision-making process. In such circumstances, the maintenance of confidence amongst policy-makers, planners and the community becomes increasingly strained, with the researcher often caught in the middle.

The problems become manifest at several levels, the simplest one being the representation of uncertainty in only qualitative estimates. Any advisor knows that a prediction such as a "one in a million" chance of a serious accident or health incident should be hedged with statements of many sorts of uncertainty so as to caution any user as to the reliability of the numerical assertions. But if these were all expressed, policies would become tedious and incomprehensible, and if omitted then the same policies could convey a certainty unwarranted by the facts.

Besides low-frequency hazards, there are also problems relating to higher probability events such as the failure of an investment/development programme, diffused hazards such as the long-term usage of chemicals or possible large scale environmental perturbations such as global warming. The dilemma is that any definite advice is liable to go wrong: a prediction of danger will appear alarmist if nothing happens in the short term, whilst reassurance can be condemned if it retrospectively turns out to be wrong. Thus the credibility of research, based on the supposed certainty of its conclusions, is endangered by advice given on inherently uncertain issues.

But if the researcher prudently refuses to accept vague or even qualitative expert opinions as a basis for quantitative assessments, and declines to provide definitive advice when asked, then research itself is regarded as obstructionist, not performing its public functions and its legitimacy is called into question.

It is not surprising then that most policy and planning institutions have been unable to respond in a locally adaptive way; in many cases the organisations are suffering from a chaotic mixture of hierarchical, non-hierarchical, academic and industrial research modes.

A major component of integrated coastal zone management must therefore be to create new settings in which to evaluate evidence from a broad array of sources, so as to provide clear and explicit guidelines for analysis and public action. SimCoast™ aims to resolve many of the ambiguities concerning data, knowledge and information in the decision-making process by using *fuzzy logic* within a *rule-based expert system* and help to generate data for an analytical approach to for multi-objective decision-making known as *issue analysis*. The combination of different methodologies in this way represents an example of an intelligent soft computing system.

Intelligent soft computing systems

In fact intelligent soft computing systems are now employed to address many practical issues such as control and consumer electronics (e.g. auto-focus cameras), decision support in medicine (e.g. computer-assisted management of child birth, automatic interpretation of brain activity, intensive care monitoring) and business and finance decision support (e.g. credit rating, stock market analysis and forecasting, direct marketing). An important goal of such systems is to simulate one or more forms of natural intelligence e.g. learning, knowledge and skills, expert behaviour, adaptive and evolutionary strategies.

Three key intelligent systems techniques are now generally available: neural networks, expert systems and genetic algorithms. Interactions between these techniques and approaches such as fuzzy logic and qualitative multivariate data analysis can be built into intelligence systems to provide even more power. For example, we find that fuzzy logic is used heavily in expert systems to handle uncertainty and imprecision in the knowledge and data; expert systems combined with neural networks are used to provide the explanatory capability lacking in neural networks; neural networks are used in neuro-fuzzy systems to learn about hidden patterns within data sets to generate membership functions for a fuzzy logic system; and issue analysis combined with an expert system is used to allow rigorous analysis of multivariate qualitative data for setting policy priorities.

The design of the interrelationships between the different forms of knowledge gathering, analysis and interpretation is highly flexible in SimCoast™ so that a wide variety of users can exploit its structure and operation. The design concepts themselves have been rigorously tested as separate elements as well as part of a combined system to ensure that if there are non-unique solutions to problems, their effects can be qualitatively told apart. The basic building blocks of the system include: the use of fuzzy logic to identify the elements within a system, the creation of linkages through fuzzy-logic rules

Fuzzy logic

In our everyday life we continually provide descriptions of entities, events, processes and issues, using imprecise, linguistic phrases which are understood clearly, e.g. pollution levels are **getting worse**, fish are **becoming scarcer**. One way to utilise such qualitative, linguistic or imprecise information is to adopt a *fuzzy logic* approach to system characterisation, using *fuzzy sets*. Developed by Zadeh (1965), fuzzy set theory follows the principles of conventional set theory with one major exception: in conventional set theory elements are divided into two categories *i.e*. those that belong to a set and those that do not. The conventional, non-fuzzy or crisp set, thus maintains a clear difference between elements which are members and those which are not. In fuzzy set theory, the linguistic variables are context-dependent variables whose values are thus words or sentences, for example **oil spill size** (*small, medium, large*); **age** (*young, middle age, old*) etc. The range of possible values is known as the universe of discourse. Elements within the universe of discourse are assigned a grade of membership between 0 and 1, although in some cases the membership functions can be single values, or *singletons*.

Initially, all input variables are converted into fuzzy variables using membership functions- a process known as *fuzzification.* The shape of the membership function (*e.g*. a simple vector, S-function, triangular, trapezoid) is optimised through successive observations and may differ depending on the application and the need to capture different levels of uncertainty. For example, in an area where oils spills ranging in size from 10 – 100 km^2 have been observed, the fuzzy set “about 50km^2” can operate over the entire range of 0 to 100 km^2. The membership value decreases progressively from 1 to 0 as the distance from the set point (50 km^2) increases; thus at the 25km^2 position, the membership is 0.5. In conventional set theory, this point would have been assigned a membership value of 0.

Fuzzy set theory thus allows lesser points to be recognised within the universe of discourse which may signify other key attributes, e.g. heterogeneity in growth due to nutrient status. It also allows uneven observation of ecosystem components to be taken into account. For example, given sufficient time and access to a school of fish it would be possible to assign it to a particular crisp set of school sizes e.g. 100, 200, 300 etc. However, it is more likely that even with repeated observations, the observer would only be able to provide an estimate of the size of the school in the field; in this case a fuzzy set can be created e.g. where “100” = 50 – 149, “200” = 150 – 249, “300” = 250 – 349 etc. so that a fish school estimated to contain 120 fish is assigned to the fuzzy set 100, a school of 210 assigned to fuzzy set 200 and so on. The measure of the observational uncertainty in assigning a particular school to a particular crisp set is thus taken into account. This situation is akin to one where it is difficult to assign sets in the first instance, e.g. as with ecological trophic groups where membership can change due to migration or omnivory. In this case the trophic groups are placed in a fuzzy set from the start, and this can then also include observational uncertainties.

Uncertainty in the basic definition of a set or the observation of it can be further captured through the spread, shape and overlap with adjacent fuzzy sets through the manipulative operations of union, intersection and fuzzy relationships. The union operation, when applied to two fuzzy sets both of the same universe of discourse, is equivalent to a connective OR: the operation of union is indicated by the use of "+" sign instead of the conventional ∪ sign. For example, in the fuzzy sets describing **oil spill size**, sets linguistically named *small* and *medium* can be defined (see Figure 1.1a). Applying the principle of union to the sets *small* and *medium* creates a *small* OR *medium* set (see Figure 1.1b).

In a similar manner, the operation of intersection when applied to two fuzzy sets of the same universe of discourse is equivalent to a connective AND; the operation of intersection is indicated by the sign ∩. By the application of the operation of intersection to the fuzzy sets *small* and *medium* describing oil spill size, a new small AND medium set is created (see Figure 1.1c).

Figure 1.1a Fuzzy sets small and medium

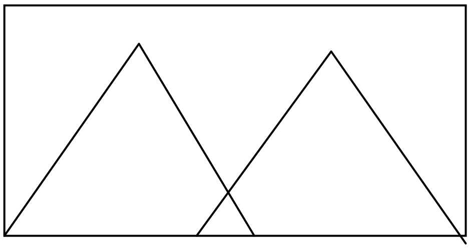


Figure 1.1b Union of fuzzy sets small and medium

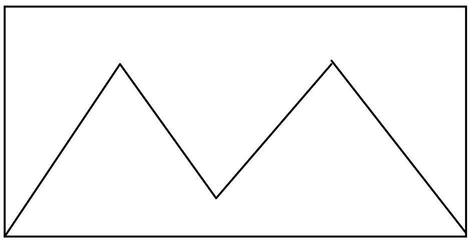
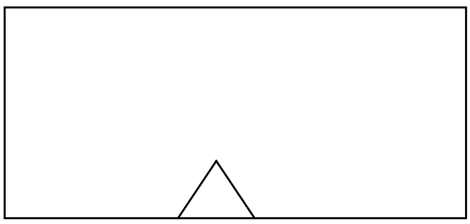


Figure 1.1 c Intersection of fuzzy sets small and medium



Hedges are used to emphasise (*e.g.* to reflect the phrase *very*, as in *very large*) or de-emphasise (e.g. to reflect *somewhat*) the fuzzy shape of the set. The two common ones are *intensification* (i.e. use the square of an expression) and dilation (i.e. use the square root). Finally, to extract a crisp out value for practical needs, *defuzzification* is undertaken e.g. using the centroid or the maximum value of the set.

In fuzzy logic, as in conventional logic, the functions AND, OR and NOT are used to combine the fuzzy variables in the premise (the IF part of a rule). Examples of such inputs are normal, abnormal, high, low, very low. Fuzzy rules use the same natural language terms as experts, making it possible to develop an heuristic rule set . An example of a simple fuzzy rule set would be:

IF television sound is too loud AND background noise is low
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THEN adjust the cold water.

Fuzzy rules with single premise and a single consequent have the inference form:

IF X is A
THEN Y is B

or more simply

IF A
THEN B

where A and B are fuzzy sets which are known in advance, X and Y are crisp or fuzzy measurements from the outside world or the outcome of another fuzzy rule in the inference net. Given the values of X and Y, fuzzy inference process is used to deduce the extent a rule will activate or the 'belief' in the conclusion of the rule.

The two common methods used for fuzzy inference are the *max-min* inference and the *max-product* inference. The max-min inference yields a clipped output fuzzy set, whereas the max-product preserves the shape of the output set. When the rules have multiple premises as in many rule-based systems, the induced fuzzy sets depend on whether the premises are joined by an AND function or an OR function.

In SIMCOAST™, after fuzzy inferencing, a crisp out value for the outside world needs to be produced, e.g. to activate a device or to write to a data file. The process of doing this is known as *defuzzification*. Two forms are used SIMCOAST™: the centroid and the maximum method.

Expert systems

An expert system is a computer-based system that contains specialist knowledge in a given area and is able to use the stored knowledge to solve problems or make inferences/deductions that would normally require human expertise. In simple terms, to build an expert system, the necessary knowledge is obtained from one or more experts and encoded into a computer system. A typical expert system contains a *knowledge base*, which holds the expert knowledge, an *inference engine*, which decides how the knowledge in the knowledge base should be used and a *user interface*, for communication with the user.

In the development of SimCoast™ the representation of knowledge is based on logic using syllogisms and sets. [There are many texts on expert systems to which the reader should refer in order to gain a clear understanding of the way in which premises are used and conclusions drawn.] Inferences are then made to derive new knowledge or information. A variety of methods of inference are used within SimCoast™ depending on the pedigree of the area and theories to derive knowledge. These include:

deduction:	logical reasoning in which conclusions must follow from their premises
induction:	inference from the specific case to the general
intuition:	no proven theory. The answer just appears, possibly unconsciously recognising an underlying pattern. Expert systems do not implement this type of inference yet, although a neural net will always give the best guess for a solution
heuristics:	rules of thumb based on experience
generate and test:	trial and error. Often used with planning for efficiency
abduction:	reasoning back from a true conclusion to the premises that may have caused the conclusion

default: in the absence of specific knowledge, assume general or common knowledge by default
autoepistemic: self-knowledge. This is always context-sensitive
nonmonotonic: previous knowledge may be incorrect when new evidence is obtained
analogy inferring a conclusion based on the similarities to another situation

The knowledge collected via these methods can be represented in a number of ways, for example trees, graphs and lattices.

Although not explicitly identified, *common-sense knowledge* may be a combination of any of these types. It is the type of reasoning that people use in ordinary situations but that is very difficult for computers. This is the reason why a fuzzy rule-based logic system for common-sense reasoning (see below) has been used as the overall basis for SimCoast™.

Induction can also be used to infer new rules and rediscover known rules. Once knowledge about a new rule is gained, it must be checked to see if it is compatible with similar rules. SimCoast™ has a rule model pattern of similar rules that it knows about and tries to fit the new rule into its rule model. The *metaknowledge* of SimCoast™ is of two types; *metarules* which then tells how the rules are to be applied and a *rule model type* of metaknowledge which determines whether the new rule is in an appropriate form to be entered in the knowledge-base.

Rules are long-term knowledge as they do not normally change during expert systems handling and processing of information. In a rule-based expert system, such as SimCoast™, determining if the new rule is in the correct form is *verification* of the rule. Determining that a chain of correct inferences leads to the correct answer is called *validation*. The general format for rules is:

(1) GIVEN *<feature >* AND
<activity >
THEN *<effect>*

(2) GIVEN *<feature> OR*
<activity>
THEN *<effect>*

In crisp systems, the variables for the rules (1) and (2) are either true or false. In fuzzy systems, the variables are words or sentences. Thus fuzzy, expert systems can operate with the same natural language phrases which experts use in practice.

Reasoning under uncertainty is the crucial issue that was addressed in the development of SimCoast™, mainly because of the heterogeneity of the information to be utilised and its pedigree. As indicated above, different types of errors can contribute to uncertainty:

ambiguity
incompleteness
incorrectness
false positive (i.e. accepting a hypothesis when it is not true)
false negative (i.e. rejecting a hypothesis when it is true)
imprecision (i.e. how well the truth is known)
accuracy
unreliability (if the measuring equipment supplying facts is unreliable the data are erratic)
random
systematic (introduced via some bias)
invalid induction
invalid deduction

Unfortunately even experts are not immune to making mistakes, especially under uncertainty. Different theories of uncertainty attempt to resolve some or all of these errors to provide the most reliable inference. But for example, in contrast to the other errors in the list, the last two are errors of reasoning. This can be a major problem in knowledge acquisition when the experts' knowledge must be quantified in rules, because then inconsistencies, inaccuracy and all other possible errors of uncertainty may show up.

The major quantitative way of dealing with uncertainty has traditionally been through probability theory. *Classical probability*, which was first proposed by Pascal and Fermat in 1654, also called *a priori* probability, deals with ideal systems. In such systems all numbers occur equally, so an experiment or trial involving tossing a die a number of times, will generate a number of equally possible *events*. When repeated trials give the same result the system is said to be deterministic.

An event is a subset of the sample space. A certain event is assigned probability 1 and an impossible event assigned probability 0. Mutually exclusive events have no sample point in common, e.g. a computer cannot be both working correctly and not working correctly at the same time. The corollary means that the probability of an event occurring plus it not occurring is equal to 1. These axioms, devised by Kolmogorov, refer to the *objective theory of probability*.

In contrast to the *a priori* approach, *experimental probability* or *a posteriori* probability, defines the probability of an event as the limit of a frequency distribution. The idea is to measure the frequency at which an event occurs for a large number of trials and from this induce the experimental probability.

Next there is *subjective probability*. This deals with events that are not reproducible and have no historical bias on which to extrapolate, such as drilling an oil well at a new site. However, a subjective probability by an expert is better than no estimate at all and is usually very accurate (or the expert would not be an expert for long). A subjective probability is actually a belief or opinion expressed as a probability rather than one based on axioms or empirical measurement. In the real world events tend to compound each other; so it is important to be able to be able to separate those events that really are pairwise or stochastically independent. For the remainder, the effect on calculating the mutual independence of events is to enormously increase the number of equations that need to be satisfied. In this case the *additive law* is applied.

Beliefs and opinions of an expert play an important role in expert systems, even though they cannot be explicitly described mathematically and the relative frequency method is impossible to apply.

Finally there is *conditional probability*, which describes the fact that events which are not mutually exclusive influence one another. Knowing that one event has occurred may cause us to revise he probability that another event will occur. In this instance the generalised multiplicative law is used. The conditional probability states the probability of event A given that event B occurred.

The inverse problem is to find the *inverse probability* which states the probability of an earlier event given that the later one has occurred. This type of probability often occurs where symptoms appear and the problem is to find the most likely cause. The solution to this problem is given by *Bayes' Theorem.*

Bayes' Theorem is commonly used for decision tree analysis in the social sciences and the method of Bayesian decision-making is also used in an existing expert system PROSPECTOR (Duda and Reboh 1979) to decide on favourable sites for mineral exploration. PROSPECTOR achieved a great deal of fame as the first expert system to discover a valuable molybdenum deposit worth $100m.

Prospecting is an obvious activity where it is appropriate to use Bayesian approaches for decision-making under uncertainty. Initially, the prospector must decide what the chances are of finding fresh water. If there is no evidence, either for or against water being present, the prospector may assign the subjective prior probabilities for or against water as both 0.5. With no evidence, an assignment of probabilities, which are equally weighted between possible outcomes, is said to be made *in desperation*. This term does not mean that the prospector is (necessarily) in desperate need, rather it is the term for unbiased prior assignment.

If there is a survey there may be some information to help make a decision. However surveys are rarely 100% accurate. The test may be false positive or false negative. Using the conditional and prior probabilities an initial probability tree can be constructed; and from this a set of expected pay-offs can be calculated at each event node, so that the overall best action can be determined

The decision tree is an example of hypothetical reasoning or "what if" type situations. By exploring alternate paths of action, the paths that do not lead to optimal payoffs can be pruned.

Reasoning about events that depend on time is called *temporal reasoning* and it is something that humans do very well. However, it is difficult to formalise temporal events so that a computer can make temporal inferences. Yet it is just such systems which could be most useful in determining policies and planning options.

Different temporal logics have been developed, based on different axioms (Turner 1984). The different theories are based on the answers to such questions as whether time is continuous or discrete? is there only one past but many futures? If the temporal reasoning is best dealt with using probabilities, e.g. for weather, storms, epidemics, a *Markov chain process* can be used.

A Markov chain process is defined as having the following characteristics:

having a finite number of possible states
the process can be in one and only one state at a time
the process moves or steps successively from one state to another over time
the probability of a move depends only on the immediately preceding state.

In integrated planning it is also important to consider the different temporal scales over which changes are likely to occur, and the possibility of history playing a key role in determining the future possible states. To achieve this, SimCoast™ is constructed as an *inference net* (see below).

So far we have only dealt with probabilities as measures of repeatable events. However in many instances the events or contexts are unique. In such a case the probability should be interpreted as the *degree of belief*, and the conditional probability is then referred to as the *likelihood*. It is thus important in determining the likelihood of some event occurring that the degree of uncertainty in the evidence is understood.

For example, suppose a householder discovers a source of oil under their property; at this stage it is not known for certain that there is oil under any other property. Conclusive evidence would be to drill a test well, but this is expensive, so the partial evidence is considered:
other people in the neighbourhood found water
there is some black ooze on the property but this could be due to local oil dumping
a stranger came to the door and offered the householder $20m to buy the house because of the view.

Based on this partial evidence, the householder may decide the likelihood of oil under their property is rather high, but in analytical terms the perception of that probability has become magnified. So one way to counteract this very human effect, is to use piecewise functions that separate the probabilities of each piece of evidence leading to a particular conclusion. Evidence can also be combined using fuzzy logic, as described above.

Inference nets

SimCoast™ involves the use of inference nets. For real-world problems the number of inferences required to support a hypothesis or to reach a conclusion are often very large. In addition many inferences are made under uncertainty of the evidence and rules themselves. An *inference net* is thus a good architecture for expert systems that rely on taxonomy or knowledge.

The basic idea in SimCoast™ is to encode the experts' knowledge of different models into the system. The data for each model are organised as an inference net, where nodes can represent evidence to support other nodes which represent the ideas or hypotheses of other experts. Each model inside SimCoast™ can be encoded as a network of connections or relations between evidence and hypotheses. Thus, an inference net is a type of semantic net.

Observable facts, such as the type of subsurface geology obtained from field exploration comprise the evidence to support the intermediate hypotheses and groups of intermediate hypotheses are used to support the *top-level idea. Certainty factors* are used in this process because experts often find it difficult to specify posterior probabilities or likelihood ratios.

SimCoast™ is not a purely probabilistic system because it uses fuzzy logic and certainty factors for combining evidence. SimCoast™ uses both *logical combinations* i.e. AND and OR nodes, as well as *weighted combinations* using likelihood ratios.

The weighted combinations are also examples of *plausible relations*. The term plausible means that there is some evidence for belief. Other terms such as impossible also have a clear meaning. For example:

impossible	evidence definitely known against
possible	not definitely disproved
plausible	some evidence exists
probable	some evidence for
certain	evidence definitely known supporting

SimCoast™ is able to create partitioned semantic nets to enable the user to group portions of the net into meaningful units. Partitioned semantic nets were developed by Hendrix (1979) to allow the power of predicate calculus such as quantification, implication, negation, disjunction and conjunction. The basic idea is to group sets of nodes and arcs in abstract spaces which define the scope of their relationships.

The important aspect of this is that most inference nets have *a static knowledge structure*; i.e. the nodes and connections between them are fixed in order to retain the relationships between nodes in the knowledge structure. However, SimCoast™ has been designed to allow a *dynamic knowledge structure* either with no fixed connections between rules or via changes in the probabilities associated with each node.

Probability theory as it is used in parts of SimCoast™ can be considered as a way of capturing and reproducing uncertainty. However in the context of integrated planning much of what happens is based on human belief rather than the classic frequency interpretation of probability. To address this, the expert system *allows inexact reasoning* i.e. where the antecedent, the conclusion and even the meaning of the rule itself is uncertain to some extent.

The main area where this plays a key role is in the weighting of rules; in SimCoast™ rules are weighted and combined according to their certainty factors; the problem addressed here is that one piece of evidence might give one value, whereas ten give another. The expert system should not then fire on the basis of only one piece of evidence. Certainty factors are a special case of the Dempster-Shafer theory which deals with inexact reasoning (Gordon 1985) but are only used in certain areas of SimCoast™ for the following reason.

A fundamental difference between the Dempster-Shafer theory and probability theory is the treatment of *ignorance*. Probability theory distributes an equal amount of probability even in ignorance. The Dempster-Shafer theory does not force belief to be assigned to ignorance or refutation of an hypothesis. Instead the mass is assigned only to those subsets of the environment to which the user wishes to assign *belief*. Any belief that is not assigned is considered *nonbelief*. Belief that refutes an hypothesis is *disbelief*, which is *not* nonbelief. Thus the difficulty for integrated planning occurs with normalisation, whereupon the system ignores the belief that a process being considered does not exist.

In many situations ignorance and belief are purely used, quantified and reasoned using natural language in which many words have ambiguous meanings. This is why SimCoast™ has been constructed as a fuzzy logic rule-based expert system.

Fixed Rulebase Fuzzy logic

Fixed Rulebase Fuzzy Logic (FRFL) has been developed from fuzzy set theory as a means of coping with those decision processes involving imprecise data. Obviously if rigid mathematical relationships between component parts of the system can be defined, then analyses and subsequent decision making can be undertaken with relative certainty of the outcome. However, in cases where such prior understanding is not possible, or a variety of views exists, and a realistic assessment of the decision outcome is required, the task is considerably more difficult to describe in quantitative terms.

A technique is thus needed which is capable of utilising qualitative, linguistic or generally imprecise information. The FRFL technique demonstrates this ability. As described above the manipulative operations that can be used include: union of fuzzy sets; intersection of fuzzy sets; and fuzzy relationships.

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where A and B are fuzzy sets which are known in advance, X and Y are crisp or fuzzy measurements from the outside world or the outcome of another fuzzy rule in the inference net. Given the values of X and Y, fuzzy inference process is used to deduce the extent a rule will activate or the 'belief' in the conclusion of the rule.

The two common methods used for fuzzy inference are the *max-min* inference and the *max-product* inference. The max-min inference yields a clipped output fuzzy set, whereas the max-product preserves the shape of the output set. When the rules have multiple premises as in many rule-based systems, the induced fuzzy sets depend on whether the premises are joined by an AND function or an OR function.

In SimCoast™, as in other practical systems, after fuzzy inferencing, a crisp out value for the outside world is produced, e.g. to activate a device or to write to a data file. The process of doing this is known as *defuzzification*. Two forms of defuzzificztion method are commonly used : the centroid and the maximum method, both of which are available in SimCoast™. The numerical results from this process then form the inputs into the *issue analysis*.

Issue analysis

Many of the problems encountered in setting policy in the coastal zone is that activities and features interact in such a way as to create positive and negative feedbacks amongst themselves. Each set of interactions has its own measure of impact on different targets such as biodiversity or tourism, so intercomparisons have to be made on the basis of some common scale. For example, a large oil spill could have a large, short and long term negative effect on fishing in that it could reduce a coral reef to below a level where it could regenerate itself: on a scale of -5 to 5, a numeric value of -5 might thus be assigned to this particular set of interactions.

However, given that the impact of different processes will alter according to the distance between processes along a transect, it is important to also be able to derive an interaction matrix between coherent zones. For example, if there is logging in an upland area that could lead to significant amounts of siltation in the intertidal zone and leading to a negative effect on artisanal fishing, the interaction matrix should contain a negative entry. But the actual value would depend on the terrain, surface geology, inclination and run-off, and precipitation. These can all be examined using numerical modelling, but the interactions between them may not in fact be obvious.

In addition institutional structures will also have a moderating effect on the values in the interaction matrix. For example in some parts of the world it is clear that emergency contingency plans exist to respond to oil spills; in the absence of such a capacity the impacts could be much larger.

Given the problems of planning in such a complex environment it is clearly necessary to provide policy and decision-makers with tools to identify the dominant processes, activities and issues that are likely to have a significant impact on the whole system.

The basis for realising such an goal within SimCoast™ has been to create an intelligence tool that combines the outputs of the fuzzy logic expert system, as described above, with an analytical tool designed to extract patterns from multivariate, qualitative data i.e. issue analysis.

Once the individual interaction terms between activities given the particular features of a transect zone with respect to a set target or issue have been identified and quantified via the expert system it is essential to examine the importance of them in terms of their relative influence on each other. An eigenvector analysis can be used to achieve this (see *A technical overview of an eigenvector analysis*). In short, this approach produces a weighting of impacts of different sectoral activities in terms of targets (e.g. biodiversity, fisheries, shipping, oil and gas exploration) given the biophysical and socio-economic features and processes characteristic of a particular area and a set of sectoral activities across the transect.

This impact list reflects all the intra- and inter-sub-zone interactions, and can be used as an indication of where and on what activities policy changes and plans need to be based and prioritised. Given that different communities are likely to have different perceptions of what the issues, problems and needs are, a similar exercise can be repeated by various peer groups and the results compared.
The calculations of the solutions of eigensystems can now be easily done on a PC using standard routines in packages such as Numerical Recipes or IMSL.

In SimCoast™ the following procedures are followed. The fuzzy logic expert system calls up the rules that link the activities with each other given

i) the socio-economic and bio-physical features within each transect zone
ii) the distance away from the primary zone where the activity is occurring with respect to the various targets (e.g. biodiversity).

Uncertainty or risk is explicitly dealt with inside the fuzzy logic of the system; however it is also possible to attach a probability density to the values. If the distribution is significantly skewed or non-normal then the operator can transform the data before deriving a set of normalised values to be fed to the issue analysis.

The rules are used to create a set of normalised values of the effects of each activity on itself and each other within each zone, even if the activity occurs in another transect zone. The values then make up a symmetric n x n matrix, which becomes the input data for the SVD. As explained briefly above the analysis attempts to seek out the patterns in the variance in the data that explain the relative importance of each activity with respect to zone and target. The results are then displayed both on the final transect screen and as output tables and graphs.

Given the targeted user community for SimCoast™ the system initially gives only the first dominant eigenvectors as these will enable policy-makers and planners to see the relative impacts of the various activities. However it is always possible to examine the entire structure of all the eigenvectors in the extended tables given within an option of SimCoast™.

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AN OVERVIEW OF EIGENVECTOR ANALYSIS

A matrix **A** made up of *n* x *n* elements is said to have an eigenvector *x* and a corresponding eigenvalue *l* if

$$\mathbf{A.x} = \boldsymbol{l}\ .\ \underline{\mathbf{x}}$$

This equation can be written in the following form

$$(\mathbf{A} - \boldsymbol{l}.\mathbf{I})\ .\ \underline{\mathbf{x}} = \mathbf{0}$$

where *I* is the identity matrix. The general theory of simultaneous linear Algebra shows that there is a non-trivial solution is and only is the matrix (*A* -1.*I*) is singular i.e.

$$\mathbf{det} \mid \mathbf{A} - \boldsymbol{l}.\mathbf{I} \mid = \mathbf{0}$$

The determinant on the left-hand side of this equation can be expanded to give an *n*th order polynomial, as

$$a_0 + a_1\, l + \ldots a_{N-1}\, l^{N-1} + (-1)^{N}\, l^{N} = 0$$

This last equation is called the characteristic equation of the matrix **A** and will have *n* roots which are the *n* eigenvalues of **A**. Corresponding to any eigenvalue *l*, the second equation has at least one non-trivial solution **x**. It is evident that if there is a solution of the second equation then *k*.**x** is also a solution for any value *k*. It is convenient to choose this multiplier so that the eigenvector has some desired numerical property; such vectors are called normalised vectors. The most convenient form or normalisation which is used is that the sum of the squares of the moduli of the vector components is equal to unity.

Root searching of the characteristic equation is usually a very poor computational method for finding eigenvalues. There exist many different standard methods including the Jacobi and singular value decomposition (SVD). The first involves plane rotations designed to destroy the off-diagonal matrix elements. Accumulating the product of these transformations gives the eignevectors and the final matrix the eigenvalues. The method is extremely robust for real, symmetric matrices (the input covariance matrix is real and symmetric). SVD decomposes matrix **A** such that:

$$\mathbf{A} = \mathbf{U}.\ \mathbf{W}\ .\ \mathbf{V}^{t}$$

where **U** is an *n* x *n* column orthogonal matrix, **W** is an *n* x *n* diagonal matrix and $\mathbf{V}^t$ is an *n* x *n* orthogonal matrix transpose). In this case the eigenvalues are given by the diagonal elements of **W** and the eigenvectors are given by the columns of $\mathbf{V}^t$.

PERCEPTUAL TRANSECTS

H. J. MacArthur (in McGlade et al. eds. 1996)

EU-ASEAN Workshop Managed Ecosystems, Manila, Philippines, 18-23 August 1997

Summary

The notion of a perceptual transect is developed as a means of describing and comparing the mental perceptions of the environment held by different stakeholders and natural resource users in a given area. Building upon the conceptualisation of physical transects that emerged from agroecosystem analysis and farming systems research, the perceptual transect is suggested as a way of graphically visualising how individuals perceive and relate to the immediate and larger environment in which they live and earn a living. It is hypothesised that: 1) villager-drawn transects will tend to emphasise those aspects of the environment and natural resource base upon which an individual is most dependent and has the greatest degree of control; and 2) that individuals frequently make resource management decisions and order their lives on the basis of their "perceptions", rather than objective measures of their social and physical environment. Field strategies designed to elicit perceptual transects or mental resource maps from different stakeholders are described. From a management perspective, it is suggested that understanding the perceptions that different stakeholders have of a resource, of themselves and each other, may be critical in identifying areas of common agreement and resolving issues of competition and conflict in resource use and conservation.

Development and use of transects in coastal environments

Two lines of scientific inquiry -- agroecosystems analysis and farming systems research -- provide a basis for the concept of coastal cross-sections analysis (Pauly and Lightfoot 1992). As commonly used in development research and area appraisal studies, a transect is a visual cross-section of a particular environment. It highlights the different micro-environments or subsystems within the area or unit under investigation. A traditional vertical transect can contain several interacting micro-environments and resource systems. In transect analysis, the focus is often on the various flows of energy, resources, knowledge and materials within and between different environments covered in the transect.

The advent of farming systems research (FSR), in the early 1980s (Norman 1980; Shaner et al. 1983) signalled the beginning of a movement in agricultural research that focused on systems perspectives and farmer participation in problem identification and technology evaluation. Rapid Rural Appraisal (RRA) techniques were developed within FSR to facilitate initial diagnostic assessments of target areas.

RRA (SUAN 1984) is generally used to refer to an interdisciplinary team exercise that results in the generation of timely and cost effective information for the design of rural research and development efforts. It is one of the most widely used techniques for interacting with villagers and conducting community-level diagnostic surveys. As such, it is both a process for learning and a way of organising people and resources for collecting and analysing information, (McArthur 1994). Many RRA reports commonly use transects as a visual summary of researcher observations and informal interview data on a particular farm, community, or watershed.

Continued emphasis on the involvement of farmers and villagers in the design and monitoring of research and development projects lead to the emergence of Participatory Rapid Appraisal (PRA). This is a process based on the assumption that for lasting change to occur, community residents must be involved in an active co-learning process with researchers (Chambers 1990).

PRA practitioners have developed techniques that emphasise the role of resources maps drawn by farmers and villagers, rather than those constructed by researchers (Lightfoot 1990; Mascarenhas 1991, 1992). The emphasis is on empowerment and on the use of visual, as well as oral, interaction as a medium for co-operative learning.

Agroecosystems Analysis (AEA) developed by Gordon Conway (1984, 1985, 1987) and further modified by Rambo (1988), Marten and Rambo (1989) and the Southeast Asian Universities Agroecosystem Network (SUAN), Rerkasem (1989) and Patanothai (1991), elaborated a framework for understanding agricultural ecosystems. It uses transects to facilitate a "pattern analysis" of system properties.[1] Employed in this fashion, transects represent a combination of researcher and villager perceptions of the impact of human management strategies on a given bio-physical resource system.

Applied to small agricultural villages, it is assumed that the transect can serve as a kind of composite representation of the key issues and constraints faced by most, or all, farmers sharing the same resource base. In extending the concept of transect analysis to coastal resource management (CRM), this assumption can be questioned, given the diverse range of individuals and groups who have different, and often conflicting, interests in the same set of environmental resources (Pido 1992).

Standard RRA and PRA techniques that have proven useful in upland agricultural settings must be adapted to capture a higher degree of complexity that surrounds the harvesting of a fishery resource. McCracken (1990) reports that unlike agriculture, where there are relatively few technology choices available to the farmer, fishermen can often choose among a variety of methods for harvesting the fishery resource. Fisherfolk in the Bay of Bengal, for example, make choices between a range of different gear or craft, and choose a particular time of day to fish, depending on their assessment of the weather and fishing conditions. In this sense, fishing is not just a risky technical activity, but a complex social process.

Ramirez et al. (1994) suggest that in the Philippines, PRA approaches are useful at the barangay and municipal levels but are of limited utility in generating qualitative data at the provincial and regional levels. This is attributed to the fact that provincial and regional officials have less direct contact with the environment and are hesitant to illustrate openly operational linkages, opting instead for descriptions of official agreements and protocol.

It is possible to construct generalised transects that reflect a complex array of resource and material flows within and between the terrestrial and marine environments. Unlike, the small scale transects of a given upland farm or village, that can easily be walked by a single group of researchers and farmers, the coastal transect will often cover considerable physical distance and contain multiple distinct environmental zones. Given this constraint, much of the physical and ecological information contained in coastal transects can often be obtained through use of topographical maps, aerial photography GIS, and remote sensing techniques (Pheng et al. 1992).

As a diagnostic and management tool, coastal transects should be designed to generate and display a range of information that complement, rather than duplicate what can be obtained through visual observations and GIS and satellite imagery. Where research is focused on the identification of development strategies, it may also be useful to generate a set of transects that reflect the perceptual reality of the different stakeholders. Current thinking with respect to PRA suggests a need to understand how social difference (due to age, genera, status, wealth, political influence, etc.) affects perceptions, actions, and access to and control of resources, including ideas and information. (Scoones and Thomson 1994).

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[1]These properties include productivity, stability, sustainability, equitability, autonomy, solidarity, diversity and adaptability.

Perceptual vs. physical and measurable reality

Whereas the physical environment can be observed, photographed, measured, and quantified, the perceptual reality reflects an unseen mental organisation of environmental knowledge, past experience and current management practices. Perceptual transects should reflect differing levels of experience and immediate interaction with the environment among the various stakeholders.

The role of perception in relation to environmental impact assessment is discussed by Hyman and Stiftel (1988). They note that human interaction with environment is not solely driven by a desire to maximise material well-being, but also involves a range of personal emotions and values.

Information-processing theory, from the field of psychology, offers important insight to how people perceive and react to the environment in which they live. The theory is based on concepts of human perception and reaction. Perception is seen as a process of receiving and becoming aware of sensory information. It is characterised by man's ability to orient, filter, categorise and manipulate information. Reaction involves the recall of stored information, and the physical, logical, and emotional responses to the perception of stimuli (Ittleson 1973; Proshansky et al. 1976). Reaction follows perception, but prior reactions can influence perceptions.

In addition, individuals, because of differences in personality, education and cultural background, may perceive and react differently to the same stimulus (Rosenberg 1960; Moore and Gollege 1960). Hyman and Stiftel (1988) suggest that there may be systematic difference between the perceptions and reactions of experts and those of the general public. It can be further hypothesised that commercial fishers, artisanal fishers, part-time farmer-fishers, tenant farmers, the local political and commercial elite, and absentee investors, will have significantly different perceptions of the same physical environment, because of their varying levels of investment in and interaction with key natural resources.

Rambo (1991 suggests that the notion of "resource" is a social construct and that an object or element in the environment must have an identified social value or utility to be considered as a resource. A natural resource thus gains some of its "resource" features through human recognition and intervention -- by knowing it is there, by knowing (potentially) how it can be used, and by seeing how it links with some societal need (Svedin 1991) A natural resource is not necessarily a resource for everyone, it is actor selective and a part of an individual's active interface with nature. How man interacts with nature varies not only at the individual level but also, and perhaps more fundamentally, at the cultural level.

Much has been written on how cultures influence and mould human thought and action. Many Western cultures take a very analytical and deterministic approach to nature. They tend to divide the universe into a series of analytically sharp categories of events or phenomena and then look for ways in which these can be managed or controlled. On the other hand, many Eastern cultural traditions are built upon world views that emphasise gradients of difference, rather than sharp distinctions between categories. Emphasis is not so much on being able to separate and control aspects of the environment but on an understanding and adjusting to a constantly changing arrangement of natural phenomena.

Some cultures view the environment as a vast array of inanimate resources to be utilised and managed by humans for individual and societal gain. Other societies, such as the ancient Hawaiians (Smith and Pai 1982) view themselves in a coexisting, rather than controlling relationships with the environment.

Local conceptualisation of the marine environment can differ radically from scientific understanding. For example, Charles Zerner (1994) reports that fisherfolk in the Maluku Islands of Eastern Indonesia believe that the marine world is populated by a community of invisible spirits. In this system, a fisherman's luck in fishing depends not on his skill and knowledge, or the resource conditions, but on his relationships to the spirits. Such fundamentally different orientations towards the environment can result in resource management practices that are in conflict with external market driven development or national conservation schemes.

A perceptual transect, or "mental map"" and the qualitative data upon which it is built, should highlight those aspects of the physical environment and spiritual realm that have the most value or meaning, in one's life. Such transects provide not only an indication of which elements in the environment are most important to different stakeholders but also how they relate to these "resources" -- i.e., in a largely controlling, co-existing or protecting mode.

Within a transect, flows of energy, material and knowledge, can be analysed in three different perspectives, or dimensions -- spatial, temporal and perceptual. Flows can be analysed spatially, across two or more sites; temporally, across two or more time periods; and perceptually, across two or more stakeholders. This last dimension captures the degree of dissonance that may exist between movement and changes that can be quantified and the different perceptions people have of what has happened, is happening, or likely to happen in the future.

The spatial and temporal dimensions are critical to understanding the dynamics of the resource system. The perceptual dimension is important in assessing opportunities for human intervention. Human decisions to act, or not to act, and how to act, are often based on a commonly held belief, or perception, of what has happened or is about to happen, rather than on the analysis of objective data or measurements.

Perceptions, a lasting force

Perceptions generally reflect an ideal, or desired state, which may not necessarily be consistent with actual conditions. In a recent discussion with a group of artisanal fishermen in the Central Philippines, there was a general consensus that if only "illegal" trawling and the use of dynamite could be controlled, there would be enough fish for everyone. This view was not borne out by an objective assessment of the local fishery by marine biologists and fishery specialists (Pullin et al. 1994). None the less, this perception is likely to be the driving force behind the management behaviour and fishing strategies of the community.

This is so, not because it accurately mirrors local conditions, but because it reflects what people want to believe. It is a common aspect of "human nature" that what is unpleasant, or uncontrollable, will be denied as long as possible. Such denial, or non-recognition, often results in a lag between what people believe or say is happening, and what is actually occurring, in terms of physical measures and documented events. The more important and useful a perception is to a particular group, the longer it is likely to be maintained, in spite of concrete evidence to the contrary. This is not only true with respect to environmental change, but also applies to a broad range of beliefs and events that structure people's view of themselves and groups of significant others, be it families, communities or nations.

Information-processing theory views people as individuals who are capable of expressing and acting upon their preferences and perceptions. Kaplan (1978) suggests that people:

1. Crave information and want to learn, but only seek a certain amount of information;
2. Do not want information that conflicts with what they already know;
3. Prefer to discover things rather than being told, and;
4. Handle concrete examples and visual images better than abstract words."

An example of resistance to information that conflicts with existing perceptions was recently illustrated in a series of articles in a Manila newspaper (Custodio and Francisco 1994) entitled.

"Perceptions on U. S. Presence in Asia: The Myth of Imperialism." The authors attempted to counter a prevailing perception, dating back to the 1950s, of the United States as a neo-colonialist power bent on maintaining its economic and military influence in Asia. The article suggested that this perception "has remained virtually unchanged and unmoving despite the fact that world-wide events have continuously transformed the relationships between nations." The authors documented specific events and actions taken by the U. S. that are not consistent with the notion of the United States as an imperialist nation. None the less, the perception endures, particularly among a large group of politicians and academics because it provides an important justification for a growing nationalist sentiment.

Perceptual transects as a management tool

In working towards effective management and conservation of an open access fishery, understanding the perceptions that different stakeholders have of the resource, of themselves, and each other, may be critical in identifying areas of common agreement and resolving issues of competition and conflict. Stakeholders vary in their interaction with the fishery resource base. Such variation results in different perceptions related to such factors as traditional turfs, choice of gear, enforcement and adherence to rules and regulations, and influence in the market. The different roles that a common and open access resource plays in peoples' lives can present strong barriers to effective co-operation and co-management.

Strategies designed to elicit perceptual transects or mental resource maps from different stakeholders may provide an important information base from which stakeholders can first recognise and then deal openly with their common and differing interests in the resource base. A comparison of perceptual transects may enable management facilitators to identify a set of judgement types, or groups of people who place similar value on a specific set of attributes (Hammond et al. 1975). A classification of stakeholders into judgement types may be useful in conflict resolution since it makes explicit the differences between groups. It would also enable one to work from a point of common shared interest to specific nodes of conflict among stakeholders.

Conflicts must first be recognised and understood before they can be resolved. Resolving conflicts in the management of common resources require a careful analysis of the nature of the resources in dispute, and the interests, concerns, needs and priorities of the various stakeholders (Caldecott 1994). Perceptual transects can help to identify what different stakeholders feel they have to gain or lose in the resolution of a dispute. And perhaps more important, understanding the different perceptual realities, can help in distinguishing between conflicts that arise from competing interests and those that emerge from different value orientations. Caldecott suggests that competing interests (which generally involve substantive, tangible, and quantifiable factors) can often be resolved through study, sharing or compensation. Value conflicts, on the other hand, concern differences in ideologies and beliefs and are much harder to resolve, short of "agreeing to differ."

Perceptual Transect Analysis should provide important insights concerning the nature of the conflict between different stakeholders (competing interests, conflicting values, etc.). Such analysis should also provide an indication of appropriate conflict resolution strategies -- education and awareness rising, arbitration, regulation that reinforces mutual interests, recognition and acceptance of different ideologies.

In discussing the role of value perspectives in natural resource allocation, Higgs (1987) suggests that there is an important "oscillation" between two sorts of decisions that society must make about the management of a scarce resource: how much of it will be developed or utilised, and who will get what portion of the good. This distinction has been referred to as "first order" and "second order" decisions (Calabresi and Bobbit 1978). First order decisions have traditionally been reviewed as technical issues, where rational assessment and accounting methods have been used to assist managers in ascertaining the size and structure of the resources. The second order decisions involved in determining how to allocate the resource are not simply a matter of utilising technical knowledge. They involve a host of normative assumptions about how society values a particular resource.

In a similar way that perceptions can persist in the face of contrary physical and historical data, second level allocation decisions are resistant to technical judgements. Higgs (1978) further notes that in some cases distribution of a resource among different users and consumers follows patterns that derive from issues of moral acceptability and political climate, rather than technical knowledge of the size, nature and economic value of the resource. As a resource management tool, it is expected that perceptual transects approximating the "world view" of different stakeholders will assist in the identification of:

a) different views of the resource, and its various uses; and
b) various societal and value based norms that influence distribution and allocation patterns.

Silvia (1992) notes that various analysts have criticised traditional approaches to fishery management because they have tended to focus almost exclusively on the behaviour of fish, while generally ignoring the behaviour of the fishermen (Hilborn 1985; Opaluche and Bockstael 1986; Wilen 1979). It has been suggested that ignoring the interrelationships of fish, men and regulators invariably leads to management strategies that fail to meet long-term objectives (Silvia 1992).

The inclusion of perceptual transects in the management data base should produce a closer balance of focus on both prey (fish) and predator (human fisher). The goal is not only to look a what the fishermen are doing but also at what they "think" the fish are doing. This sort of multidisciplinary, multi-objective approach should result in strategies that build upon measured assessments of the fishery base, as well as perceptions and perceived expectations of the fishers and the regulators. The focus of management analysis is on the relationship between controls (regulatory strategies governing harvests and fishing effort), objectives (yield, efficiency, community income, environmental quality, etc.) and constraints (biological information, agency budgets, restrictions or limitations on stock sizes, etc.), Cohen and Marks 1975).

Proposed steps in developing perceptual transects

Because people tend to deal best with concrete examples, the process used to generate perceptual transects should be highly participatory in nature and build upon indigenous. categories, experience and beliefs. A range of tools and techniques associated with RRA, PRA and Participatory Learning Methods (PALM) can be utilised to help individuals generate their own perceptual transect. Informal interviews, resource maps and transects, geographical and historical transects, cropping (and fishing) calendars matrix ranking, case studies and time lines (Grandstaff & Grandstaff 1987; Chambers 1992; Mascarenhas 1992) can be used to generate a qualitative data base from which to build a perceptual transect.

Informal ("talk story") interviews provide an excellent way of establishing rapport with different stakeholders and learning important aspects of the local history of the village or seacoast under investigation.

Having key informants or groups of villagers draw their own resource maps can often result in the identification of many important aspects of the environment and resource base that may not have emerged in the informal interview. The resource maps and transects indicated in Ferrer et al. (1994) demonstrate that coastal fishers can graphically depict perceptions of their resource base in both space and time dimensions. Comparisons between the present and past transects provide a striking summary of the changing conditions to which the fishers of Dewey Island (Bolinao, Pangasinan) in the Philippines are having to adjust.

Such maps, which are often drawn on the ground, can provide an excellent base for further discussion concerning the nature and quality of the resource base now and at previous times. Observation of the map making process often provides important information on the level of local environmental knowledge/awareness and the degree to which this is shared across a village community, or between different stakeholders. The Dewey Island maps and transects suggest that artisanal fishers have extensive knowledge of current and past conditions in their immediate area but may not be aware of, or in a position to influence, the larger array of external factors which impact on their environmental resource base.

In collecting qualitatively rich information from relatively small populations, it is important to generate two or more independent data points that will allow for the cross-checking and verification of information obtained from different sources and processes. This kind of validation is called "triangulation." Such planned triangulation, which is a basic principal of RRA (Grandstaff et al, 1989; Chambers 1987) provides a strong internal reliability check to a process that some feel lacks the objectivity and rigor of quantitative survey methodology.

Once the informants feel that the individual or group-generated maps accurately reflect the existing environment and array of natural resources that are important to them, the facilitator can begin to ask questions concerning how the different resources may interact. Perceived relations, or interactions among different elements in the resource base can often be elicited by asking if the location or quantity of a particular resource has changed over time, and if so, how and why?

From this point, the facilitator can pursue issues related to current patterns of tenure, ownership, and/or access to the different resources and how they are used. This can be done through questions or by asking the map-makers to add additional information to their map to reflect who owns or has primary access to a particular resource and where they live (in the village or town or outside the community). This line of inquiry can generate social maps and a set of stakeholder perceptions related to the system properties of autonomy, equity and solidarity.

In order to reflect the range and complexity of biophysical, social and economic factors that influence the management of a particular coastal zone resource system, it may be necessary to construct a set of composite vertical and horizontal transects from GIS and/or aerial photo data. The perceptual information concerning flows and interactions between different elements in these belt transects and access to or differential use of the resources, can be added to or overlaid in a way that they can then be verified and/or corrected by the different informants.

It is assumed that an individual stakeholder's perceptual transect will focus the greatest detail on those aspects of the resource based that are most useful or meaningful to her or him. The rest of the surrounding environment will most likely be compressed and exhibit much less differentiation. As a management tool, it might be possible to construct a composite perceptual transect based on the detailed portions of several individual stakeholder resource maps. Such a transect would help in identifying areas of potential complementarity in resource management as well as nodes of competing or conflicting interests.

Building upon the physical transect, colour-coding or some other technique may be used to indicate dominant ownership patterns or access to a particular resource. In a similar fashion, coloured or coded arrows might be used to indicate which group of stakeholders has primary control over particular extraction technologies, market structures, and channels of distribution. The amount of information that can be effectively presented in a single transect is greatly increased if the data can be converted to a software format that is capable of producing a series of transect overlays. In addition to quantitative measures, the software should be capable of representing a range of qualitative indicators related to general environmental awareness and perceptions.

Analysis of perceptual transects

The analysis of perceptual transects is in essence an exercise in comparative analysis. It is assumed that the perceptual images will vary. What should provide a degree of consistency in the analysis is the process by which they are generated and interpreted. If two transects, produced by the same or very similar methods, vary in terms of their content, this variance is likely to reflect fundamental differences in the resource perceptions and management practices of the stakeholders from which the data was generated. It is therefore, of critical importance in the analysis of transects to document the step-by-step process by which the images and perceptions were generated.

Since, the process is highly participatory and the resulting data generally qualitative in nature, it can never obtain the same level of uniformity and control that is employed in traditional survey research. The particular phrasing of certain questions or probes may need to differ somewhat to insure comprehension by different informants, but the guidelines that are given by the facilitator must be as unobtrusive and non-directed as possible. Each stakeholder must be presented with the same opportunity to "paint" as broad, or as narrow, an environmental picture as they wish. The important criteria is that the image particular informants create represent as best as possible, all aspects of the environment that are important to them, or in some way impact upon their quality of life.

In comparing the different perceptual transects, it may be possible to identify distinct judgement or interest groups among the different stakeholders. In assessing the work of Higg (1987) on fishery allocation policies in the Great Lakes basin, H. A. Regier suggested the existence of three interest groups, each with their own priorities and practical objectives with respect to the fishery resource and environmental management. He saw the population of key stakeholders being comprised of "economic resourcists", "predatory mutualists", and "life-affirming environmentalists."

Each group is associated with a particular general objective from which operational priorities emerge. The economic resourcists are primarily concerned with material well-being defined in terms of economic return. At the other end of the continuum, the environmentalists follow strategies that reinforce environmental harmony. Taking a more middle of the road position, the mutualists attempt to achieve an acceptable balance between extractive, or "predatory" strategies and activities that place a value on preserving nature.

It will be interesting to see to what degree a similar set of groupings can be identified among stakeholders in key coastal resource systems in various developing countries. In looking at the Philippines, most of the fishers, including both artisanal and commercial operators, could probably be seen as "economic resourcists". Various NGOs might be seen as an emerging force of "environmentalists" while national policy and the objectives of various donor-driven development projects represent a pragmatic "mutualist" position.

One of the key objectives of perceptual transect analysis will be to determine the nature of the key groupings of stakeholders in the resource base and the key philosophical positions they hold. An analysis of the perceptual transects of the different stakeholders should help to clarify the multidimensional and multidisciplinary nature of issues related to coastal zone management (Soderbaum 1991). It should help in the identification of the monetary as well as non-monetary resources and the degree that these impinge on other issues such as market transactions and property rights.

The combined analysis of geographic, social, economic and perceptual transects should provide an indication of the spatial and sectoral dimensions such as the number of municipalities and social and economic sectors that both impinge on and are influenced by a given resource base. This information will be important in both the development of generic transects of different types of coastal resource systems and in suggesting appropriate avenues for management intervention in particular systems.

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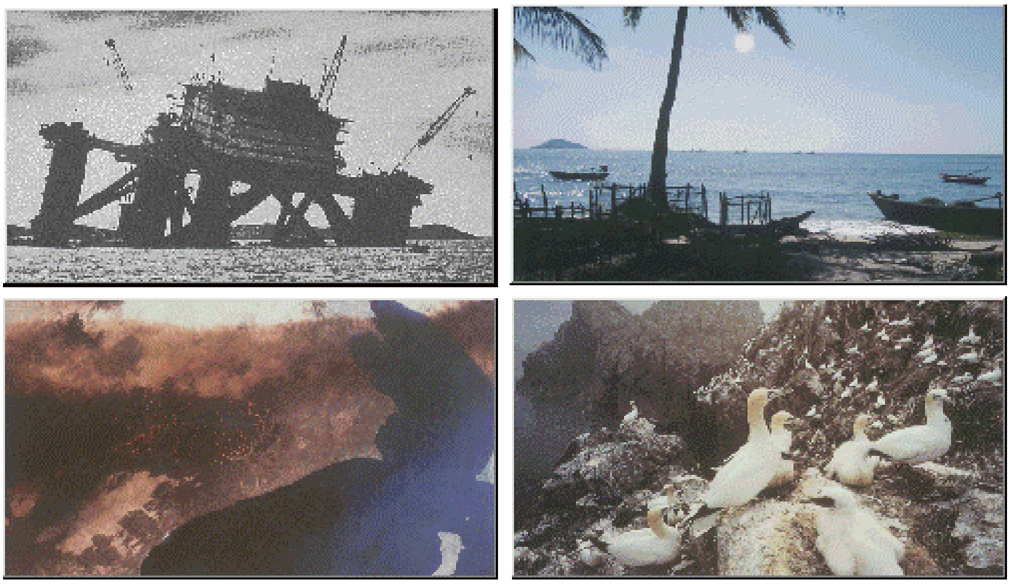
SimCoast™

Fuzzy Logic Expert System for Integrated Coastal Zone Management



ASEAN - EU Second SimCoast™ Workshop
Construction and Transport
Workshop Preliminaries

Natural Environment Research Council

FUGRO

ASEAN - EU Second SimCoast™ Workshop "Construction and Transport"

The development of a coastal management expert system Hosted by

The National Center For Social Sciences and Humanities Of Vietnam, Human Geography Research Council (HGRC), Vietnam

10 - 15 December 1997

Experts from ASEAN and The EU assembled for the workshop at The Halong Bay Hotel, situated adjacent to Halong Bay, which is designated as a world heritage site.

The opening speech was presented by Prof. Dr. Nguyen Duy Quy, President of the National Center for Social and Human Sciences, Vietnam and the ceremony was also attended by Prof. Nguyen Duy Thong, Director of the International Co-operation Department, National Center for Social Sciences and Humanities, Vietnam.

From Right to Left:

EU–ASEAN Project Co-ordinator:
Prof. Jacqueline McGlade,
NERC-CCMS, United Kingdom.

SimCoast™ Programmer:
Mr. John Marshall,
NERC-CCMS, United Kingdom.

SimCoast™ Project Manager:
Ann Novello Hogarth,
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SimCoast™ Participants:

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Malaysia:
Mr. Ahmad Azahari b. Ahmad
Philippines:
Mr. Benjamin Nonoy O. Fontanares, Eng. Darby M. Macabata
Singapore:
Dr. Kam Tin Seong, Dr. Parthipan s/o Krishnan, Mr. Loo Yong Ying
Thailand:
Mr. Sirichai Roungrit, Mr. Ramate Sukpum
Vietnam:
Dr. Nguyen Ngoc Tuan, Dr. Pham Thi Mong Hoa, Dr. Dang Huu Luu, Dr. Lam Thi Mai Lan, Dr. Dang Duc Phuong, Dr. Nguyen Lan Huong, Dr Vu Van Thanh, Dr Le Van Giao, Prof. Pham Van Ninh, Mrs. Tran Thi Ngoc Duyet, Prof. Nguyen Duy Quy, Prof. Nguyen Duy Thong, Dr. Nguyen Minh Son

Workshop opening speech

Presented by Prof. Dr. Nguyen Duy Quy

President of the National Center for Social Sciences and Humanities.

Dear Prof. Jacqueline M. McGlade
Leader of ASEAN-EU SIMCOAST™ Co-operation Program

Dear Mrs. Nguyen Hong Cuong, Vice President of People's Committee of Quang Ninh Province.

Dear International and Vietnamese Participants.

Ladies and Gentlemen,

On the behalf of the National Centre for Social Sciences and Humanities of Vietnam, I am greatly pleased to welcome you, the international and Vietnamese Scientists and representatives of State management Institutions to this event. Who take part today in the "Construction and Transport" workshop, which focuses on one of the central issues of coastal area management? This Workshop hosted by the Human Geography Research Centre, National Centre for Social Sciences and Humanities of Vietnam, is a collaboration between scientists from ASEAN and European countries.

Ladies and Gentlemen, as any nation, Vietnam is facing big challenges in the field of sustainable development requirements. This has especially been the case during recent years and has underlined a worldwide tendency. Our country has always put forward socio - economic development plans in close association with ecological and environmental protection and exploitation management programs. Sensible use of natural resources based on effective organization and management has also been taken into consideration.

The development of the SimCoast™ software, which has been funded through an ASEAN-EU Co-operation Program on coastal management and the study contents and issues relating to the scientific basis for its creation have created a framework of workshops. These workshops such as this "Construction and Transport" workshop, are good opportunities for both international and Vietnamese scientists and managers to learn and discuss their experiences and practices in their different important fields of expertise.

On this basis of analyses and distillation of experiences and study, put forward today by International and Vietnamese specialists in coastal management. I hope that all participants in this workshop will put forward effective proposals, which can assist in the implementation of SimCoast™ software. By making rules for the system through scientific based policy and creating sensible solutions we hope that the requirements of coastal management in the sustainable socio - economic developmental protection are satisfied.

In this hope, I open the Second SIMCOAST "Construction and Transport" Workshop.

Many best wishes and happiness to Prof. Jacqueline M. McGlade, Leader of ASEAN-EU Cooperation Program on Coastal management.

Many best wishes to all international and Vietnamese guests and participants.

I hope the Workshop will be successful.

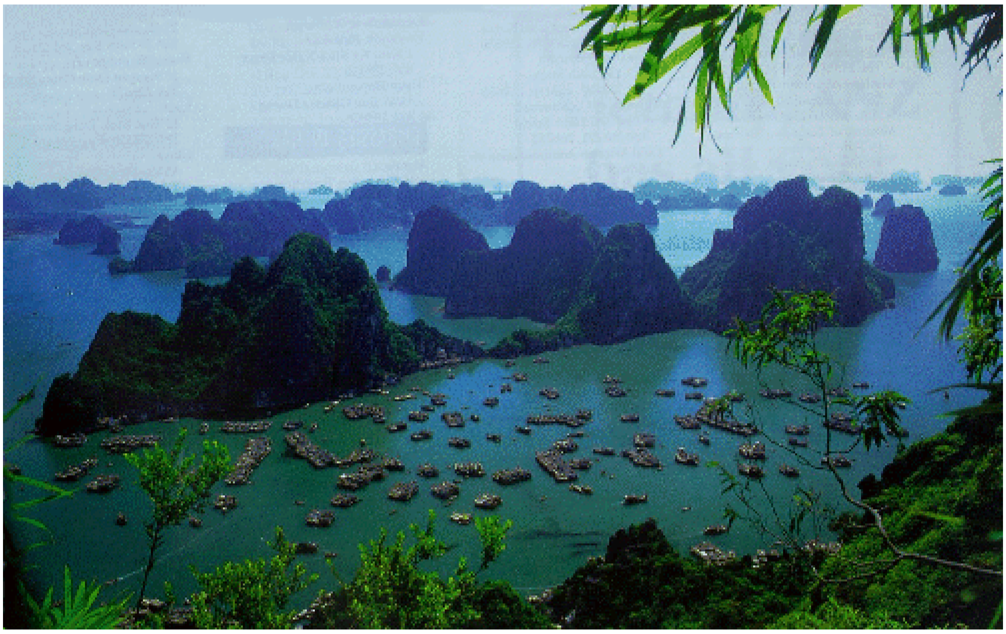
Thank you.

Background Information About Quang Ninh Province

Quang Ninh Province is located towards the North East of Vietnam and covers an area of approximately 5938 km2. Its boundaries are with China to the North, HaBae and Lang Son to the NorthWest, Hai Phong City to the West, Hung Yen to the SouthWest and borders the sea in the Eastern and Southern regions.

The province is situated in the Dong Tren Mountain Region of Vietnam, which is near to the coast and ranges from 100m to 500m above sea level. The mountain and hill areas cover approximately 79% of the total province, with the rest of the region being comprised of low lying areas running down to the sea.

The water resources of Quang Ninh Province comprise HaLong Bay, Bai Tu Long and part of Tonkin Bay with a total coastline exposure of almost 250km. The river system of Quang Ninh Province is however restricted, with the largest watercourse having a length of only 200km. In HaLong (Meaning, "where the dragon descends into the water") Bay itself there are 1969 islands protected by UNESCO, which declared the area as a World Heritage Site.



The World Heritage Site – HaLong Bay, Vietnam.

The population of the region is over 900,000, with 40% of this figure being clustered together in urban developments. Quang Ninh Province has many natural resources for socio-economic development. There are many mineral deposits located near to HaLong Bay, such as coal, of which 3.5 billion tonnes is produced annually. Limestone for cement is also mined in the region, as is kaolin in Tan Mai and sand in Van Hai. These products are used throughout Vietnam as well as within the province, particularly in the construction and development of seaports, such as those in Cai Lan.

The Government of Vietnam considers Quang Ninh Province, to be part of the central economic development triangle in North Vietnam. As a direct result of this some of the most urgent issues associated with the development of the province today include completion of infrastructure and transportation systems, good urban planning and industrialisation. The Master Plan of socio-economic development for Quang Ninh Province (as outlined previously in the maps) was approved by the government in 1995 and includes concentration on the areas of tourism, industry, inland developments and sea ports. All of which are to be located towards the centre and outskirts of HaLong Bay.

Urban And Infrastructure Development

Urban development and the creation of industrial zones has been, and still is, occurring along the coastal zone. To date this has been closely monitored and closely connected, with natural factors pertaining to the coastal ecological system, particularly within HaLong Bay. Construction in the area can be attributed to three main requirements for the regions industry: "Urban Building Developments", "Industrial Activity" associated with mineral exploitation and "Transportation" (both sea and inland) associated with the transfer of minerals and aggregates from the area.

Recently the urban and industrial areas have expanded rapidly, but land for urban construction is limited. To increase the amount of urbanisation, it will be necessary to expand from the hill areas presently occupied into the existing communities in the coastal zone, such as HaLong City, Cam Pha Town, Cua Ong etc. In some places like Gai and Bai Chay, the urban areas have already developed over the lower hill terrain and forested areas. We therefore have to take into account the following points when considering the effects of future urban developments:

- Quang Ninh Province has no detailed plans for different areas within the region. However rapid urban development has taken place in many places, without any form of control being maintained. The urban space is very limited and the lack of guidelines for development has lead to a crowded transportation system, which creates much noise and pollution.
- Poor use of land and space has meant that in the centre of the city, houses are very close to each other, and the form of construction used has created difficulties for the installation of an urban waste treatment system. As a result of this, houses in the centre of the urban developments have no sewage treatment system, and this has lead to increased wastewater pollution in the sea. In some places, land erosion has also led to heavy sedimentation in the sea, which in turn has prevented natural sewage breakdown.
- The water supply, electricity and transport systems already constructed do not satisfy the needs of the present urban developments. There are many reasons for this, but one of the most important lessons in this process, is that the Master Plan for wastewater treatment in the Province did not meet the requirements generated by the urban developments.
- The unregulated use of land in coastal and mangrove areas has had a great influence on the coastal environment. During recent years many urban buildings have been built along the coastal zone, degrading the ecological systems and affecting socio-economic development. For example the mangrove forests of Uong Bi and Bach Dang river areas are heavily degraded and due to this there has been a negative effect on the crab culture industry in the area.

Construction And Other Activities Within Industrial Areas

Much of the urban development in Quang Ninh Province has been created around the areas of coal mining. However there are many other industrial activities in the region such as food processing, engineering, dockyards, construction and material extraction. However, exploitation of charcoal, together with the coal industry and its associated services, generate most of the province’s income.

Geographically, most of the charcoal areas are located in the high mountains and upstream regions. Where as other industrial activities and developments (such as electricity plants, agroforestry product processing, import export handling) are distributed in the coastal zone and in city centres. Some concentrated industrial zones such as Cai Lan, Dong Dang, Hoanh Bo and Mao Khe are also located near to urban areas. The main sources of environmental pollution from these activities are:

- Deforestation due to coal exploitation
- Marine sedimentation emanating from residential area developments
- Marine sedimentation from industrial coal waste and other industrial pollutants

- Degradation of brackish water and underground water supplies caused by infiltration of industrial wastewater
- Loss of special ecological resources such as areas of upland forest, mangroves and coral reefs.
- Air pollution due to mineral exploitation, cement production and thermal electricity generation
- Land degradation due to erosion as a result of deforestation
- Loss of biodiversity through over fishing

Transportation Development

Inland And Railway Transportation

In general, transportation in Quan Ninh Province is not properly developed. National road No. 18a for example, passes through the coastal zone and links together all the urban areas within the province. Due to the dense population of people located along the length of the road, and the bad quality of the road itself, there is much noise and air pollution. Other local roads are in a similar condition and again much pollution occurs around areas of mineral exploitation and cement production.

As shown in the previous plans, most of the charcoal areas are located in the high mountains. Due to their geographical location the transportation activities associated with the exploitation have lead to severe land erosion, particularly during the heavy rains that occur in the summer months. In the area of charcoal and mining exploitation, there is also a dense system of railways, which carry the products to the seaports. This in turn has also created environmental problems over a large area, and outdated technology has also contributed to air and noise pollution.

Sea Transportation And Port Systems

Important components of the Quang Ninh Province goods distribution system are the seaports located in Cai Lan, Hong Gai, Cua Ong, Van Don, Mui Chua and Hon Net. Due to the lack of effective management, the sea transportation system has created and continues to contribute to pollution in the coastal environment through many different means:

- Sedimentation due to dumping of coal dust, cement and sand
- Waste products consisting of petroleum, waste from sea transport and public services
- Construction and development of sea port system in the province affecting local socio-economic development and environmental protection plans.

Solutions and Proposals

In response to the previously mentioned problems, some proposals and suggestions on how to protect the coastal environment in Quang Ninh Province from construction, transportation and urban developments can be recommended:

- Socio-economic, construction and development planning should be based on environmental protection and management criteria. Areas designated for charcoal exploitation should also be well planned and optimal technology should be selected to preserve the environment and optimal use should be made of the sea port system at all times.
- Building and institutional regulations should be enforced during any further planning exercises, which impose constraints on construction and design of urban, industrial and transport projects, inline with sustainable development strategies
- Conservation of natural resources should be emphasised, especially those in the coastal ecosystems and areas for protection should be pinpointed

- Undertake basic surveys and investigations of the coastal environment, including studies into the levels of environmental pollution, processes causing environmental pollution, levels of biodiversity and potential for exploitation and/or preservation of coastal ecosystems
- Positive solutions concerning environmental protection in the charcoal industry should be applied. Complete environmental assessments and feasibility studies on environmental protection for each mine should be undertaken prior to the development of the area. Suitable financial policies should be established for environmental protection in charcoal mine areas. Optimal resource mechanisms should also be put in place and co-operation between local and central institutions should be encouraged
- Creation of an observation station for the coastal environment
- The technological and management capacities of management institutions in the locality should be improved
- Design and construction of residential areas should take place in accordance with the Master Plan of the city, making sure a suitable distances is placed between buildings
- Infrastructure systems in urban areas, such as the water supply, sewage and waster water treatment, should be designed and constructed along rigorous guidelines
- Economic stimulation should be applied to enterprises which have solutions to the problems of pollution in the coastal environment

Acknowledgements

Many details given here have been taken from a speech presented by Dr. Vu Van Thanh, Director of Science, The Department Of Science Technology And The Environment, Quang Ninh Province, Ha Long City, Vietnam. On the subject of "Transport Construction Development and Environmental Management in the Coastal Region Of Quang Ninh Province". At the SimCoast™TM "Construction And Transport" workshop held in HaLong Bay during 1997.

WORKSHOP OUTPUTS

Biophysical Features

- Land……………………………………………… Mountains, Upland, Lowland
- Estuary
- Forest…………………………………………… Seagrass, Terrestrial, Estuarine
- Natural Resources…………..………………….Coal
- Port Facilities………………………………... Wharves, Warehouses, Superstructure
- Infrastructure………………………………… Vehicles, Factories, Bridges. Roads
- Green Buffers
- Coastal Water System
- Utilities
- Waste Treatment Facilities
- Ships
- Scientists
- Policy Makers

Biophysical Activities

- Clearing
- Excavating
- Reclaiming
- Dredging
- Surcharging
- Mining/Extracting
- Constructing
- Transporting
- Manufacturing
- Infrastructure Upgrading
- Landscaping
- Coastal Engineering
- Power Generating
- Discharging
- Shipping
- Environmental Monitoring
- Managing

Biophysical Processes

- Pollution (Chemical, Biological, Heavy Metal, Air, Thermal)
- Habitat Destruction (Seagrass,Mudflats,Mangroves, Coral Reefs)
- Sedimentation
- Eutrophication, Innundation
- Erosion, Abrasion, Accretion
- Rehabilitation (aesthetics), reforestation
- Hydrodynamic Modification (Current Diversion, Wave Pattern Changes, Erosion)
- Fish Production
- Environmental Protection

Socio-economic Features

Construction Period

- Industries
- Families Resettled
- Land Acquired
- Compensation Packages
- Labour
- Labour Types
- Hospitals
- Social Service Centres
- Schools
- Languages
- Festivals
- Enterprise Organisations
- Foreign Investment
- Tourists
- Environmental Costs
- Technology
- Construction Costs
- Local Pride & Identity

Operation Period

- Imports/Exports
- Foreign exchange
- Factories
- Hotels, Resorts - Diving, Restaurants
- Dockyard
- Training Centres
- Taxation Income
- Property Prices
- Local Pride/ Industry
- Hospitals
- Social Services Centre
- Schools
- Enterprise Organisations
- Jobs

Socio-economic Processes

Construction Period

- Rehabilitation
- Pollution
- Compensation
- Land Development
- Eco-Attraction
- Social Development
- Education
- Social Integration
- Eco-Diversification
- Innovation
- Capital Investment Provision
- Image Building

Operation Period

- Eco-generation
- Eco-diversification
- Eco-generation
- Image Building
- Social Development
- Eco-Attraction

Institutional Features

• Country	Philippines, Vietnam etc.
• Government Departments	Environment, Defence, Transportation & Communication, Finance, Health, Public Works, Local Government
• International Conventions	IMO, Agenda 21, IPCC, ILO
• Policies	Direct, Indirect
• Laws	Direct, Indirect, Traditional, Land Tribunal
• Regulations	Code of Practice, Standards
• Organisations	Community Associations, Co-operatives, Communes, NGOs, Unions, Trade, Associations, Media, Political, Research, Quangos, State Religion, Commercial (Small-Medium Enterprise, Trans National Corporations)

Institutional Processes

- Legal Action, Litigation
- Legislation
- Statistical Data Collection
- Social Cohesion
- Globalisation
- Regionalisation
- Education
- Institutional Cohesion

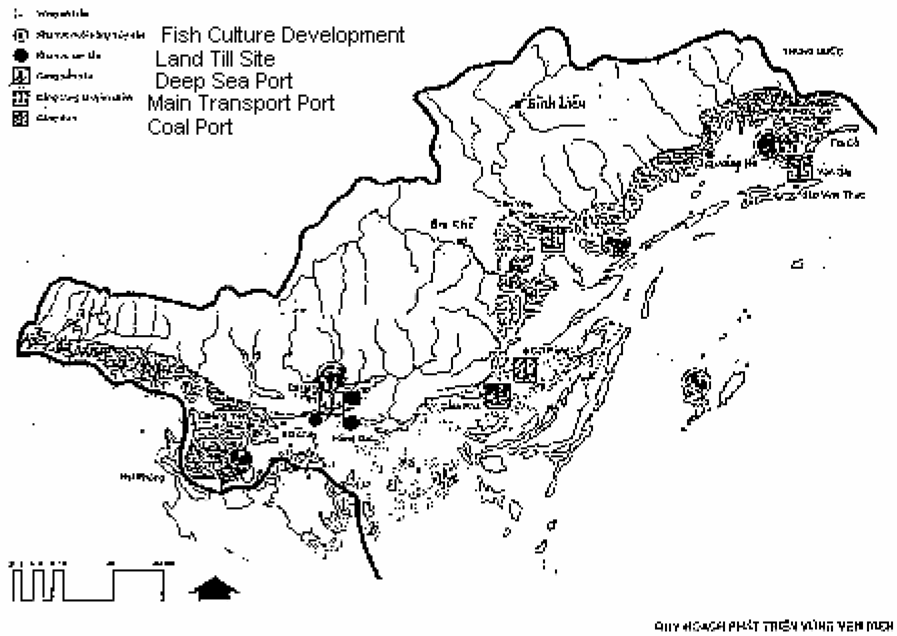
Mapped Information Of HaLong Bay Vietnam

Focus: The focus for the workshop centred on the underlying problems that are associated with construction and transport developments within an area of natural beauty such as HaLong Bay, which is designated as a world heritage site. The authorities in Vietnam have addressed many concerns and much thought has also been given to proposed developments in the region (as the following master plans for the region indicate).

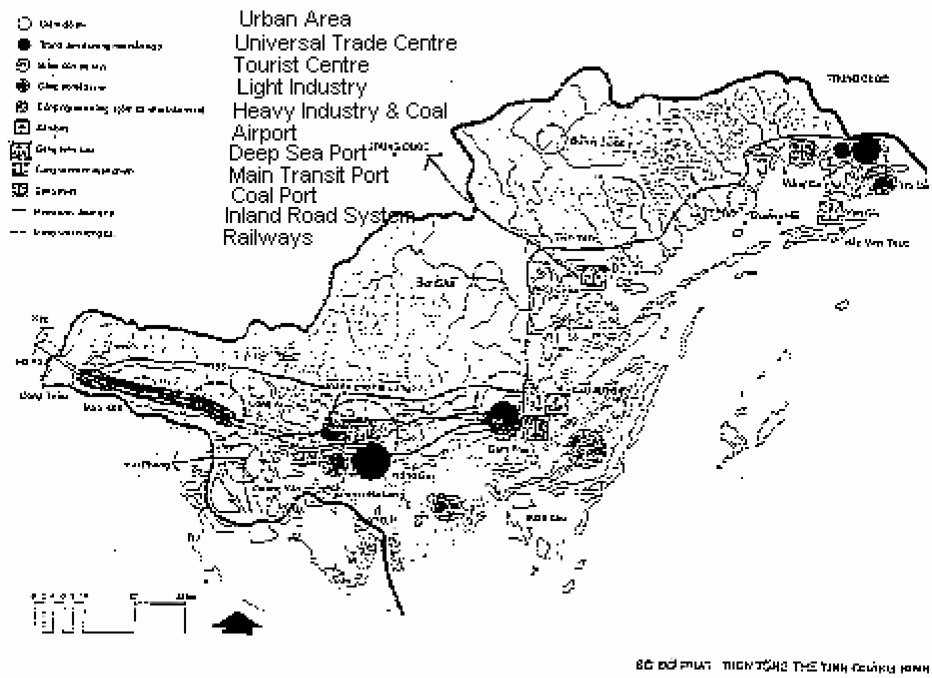
Mapped information on the coastal zone fringing Halong Bay:

- Master plan for coastal zone development
- Master Plan of Quang Ninh Province
- Master Plan Of Important Urban Sites
- Master Plan Giving Estimated Positions OF Main Ports
- SimCoast™ Digital Map Extract of the Area

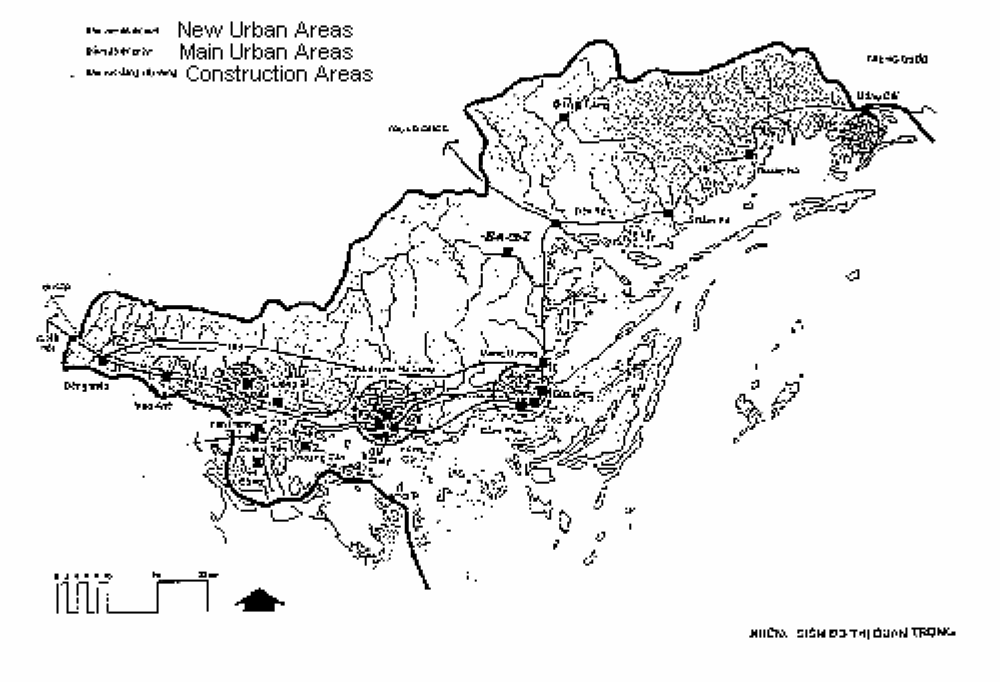
Master plan for coastal zone development



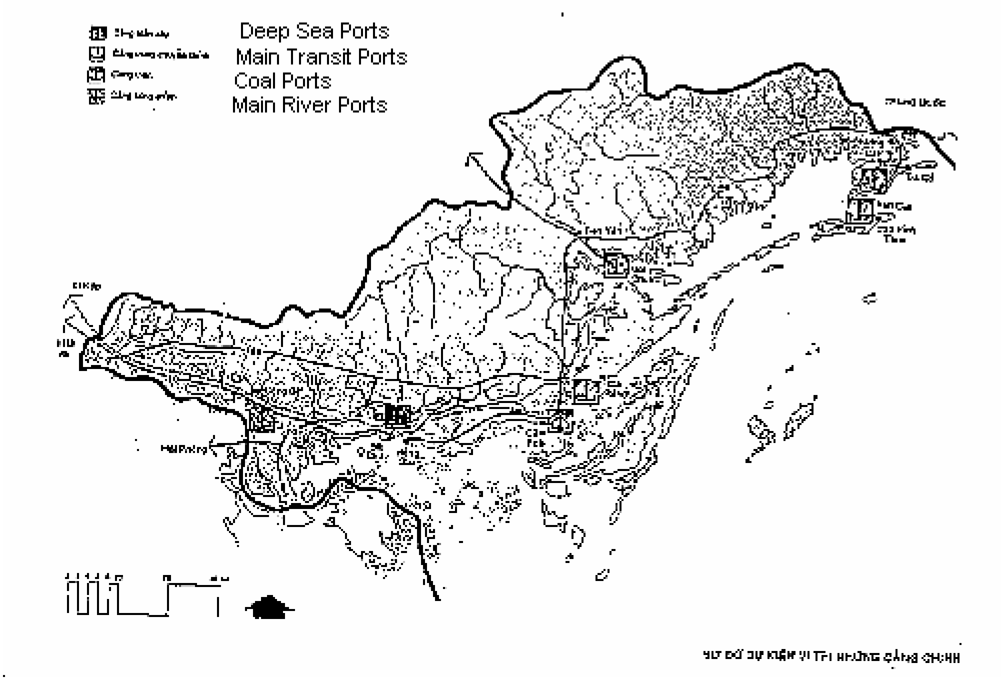
Master Plan of Quang Ninh Province



Master Plan Of Important Urban Sites



Master Plan Giving Estimated Positions OF Main Ports



SimCoast™ Digital Map Extract of the Area

This is a map of the area as retrieved from the Digital Chart of the World that comes supplied with SimCoast™.