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GIS-ASSISTED COASTAL ZONE PLANNING *)

Hans J.B. Rooseboom,

Euroconsult Marine Resource Evaluation and Planning Project

ABSTRACT

In this paper we opine that a geographic information system can provide essential and much needed support to integrated coastal and marine resource management, provided, however, that a number of preconditions have been met.

Detailed and highly accurate geo-referenced digital data are available to the coastal zone manager. If required, sub-meter accuracy can be introduced into the planning process. We would, however, like to propound that the most effective mapping scale for integrated coastal and marine resource management [in Indonesia] is 1:250,000, which would hardly warrant sub-meter accuracy.

The necessity to include the motivations and activities of a multitude of stakeholders further diminishes the need for detailed and sophisticated systems, as their disorderly, random and often haphazard behaviour defies attempts at accurate modelling.

We therefore believe that GIS for coastal resource management is best used as a system to monitor events, and to interpret the results there of through querying the database by way of algorithmic as well as visual methods and techniques. The resulting information should then be presented as an easily accessible and friendly decision support tool to the coastal zone managers.

A GIS, in other word, should be a management support tool, not a device to spout answers (decisions) derived from mathematical calculations performed on a "model" of the marine and coastal zone.

By designing the system to monitor events and change at a scale of 1:250,000, the managers would be forced to concentrate on the main trends and developments, and see the coastal zone in its relation to its wider surroundings. They would moreover avoid the collection and loading of superfluous details, which generally result in data-overload and system slow-downs, if not failures. And most importantly, a manager would be forced to use his creativity and imagination in guiding, directing and controlling the utilisation of marine and coastal resources.

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CLARIFICATION OF TERMINOLOGY

The most important terms used in this presentation are:

- GIS / geographic information system, and
- planning

Both terms are easily and widely used, in a variety of interpretations and meanings and therefore easily the cause of wide misunderstanding.

GIS, as a system, is without fail a computerised system for storage, manipulation and retrieval of geo-referenced data. **GIS, in terms of utilisation and function,** does, however, vary widely. The most common applications are for monitoring of performance and progress and the subsequent analysis of change; the construction of models of the real world for trend analysis and identification of potential conflict; the planning of physical features such as road infrastructure, and utilities networks; and the management and planning of natural resources.

GIS is a particularly useful tool for the monitoring, and modelling of *physical* features.

Planning, in its widest definition, covers the formulation of any future scheme or activity with a specified goal—eg, we plan a meal, a holiday, the construction of a building, the socio-economic development of an area, region or country. The complexity of plans increases with the length of the period covered, and the number off issues, elements and people involved.

Integrated coastal zone planning would be one of the more complex planning activities.

Coastal Zone Planning as meant in this paper could be defined as integrated socio-economic development planning of a region. A region could be a group of provinces, a province, or part of a province. Regions are delineated by administrative or natural boundaries.

Coastal and marine zones would thus qualify as a region

Integrated regional development planning typically consists of three levels of detail:

- **development policy**-which outlines the main objectives, for exam-ple, economic growth with social justice and national stability;
- **development strategies**-stating the general way to reach the objectives, eg, further development of agricultural staple and cash crops, industrial development, strengthening of commercial services, transmigration;
- **development programmes and projects** - detailed descriptions of individual activities, including engineering designs and blueprints, estimated costs and revenues, short and long term benefits and the like.

Integrated regional development planning would furthermore use a mapping scale of 1:250,000 for provincial / regional overviews, trend analysis and the monitoring of programmes; larger scales would be used for the planning of individual projects.

PREPARATORY STEPS

Although it would appear that *geo-referenced data* [of a geographic information system] and *planning modules* as outlined above would be perfectly suited for each other, it is essential to carefully design the contents of the GIS database in order to avoid a mismatch between the planning modules and the data.

Based on our MREP experience, we must conclude that this is more difficult than expected.

In MREP we did not only face the problem of unreliable and inaccurate data, but reaching a common agreement and understanding of what data would be needed was even more difficult. Data producers interpreted data needs from their own perspective and data users were not really sure about their actual needs.

In the days before computerised information systems, the data used for planning were obtained from statistical publications of mixed origin, collected and formatted by statisticians who did not necessarily have a clear understanding of the needs of the end-user. Where specific details were an absolute necessity, special surveys were conducted to fill that specific need. Maybe because, in that pre-electronic past, planners did not expect the level of detail that nowadays [under optimum conditions] can be made available through a geo-referenced database, specifying the data requirements was never an issue. When population figures per village were not available, kecamatan figures would be used, and one had to live with the fact that income figures were notoriously out of date and pretty unreliable for administrative units smaller than a province. But somehow broad assumptions were conjectured, and details were calculated with ratios that appeared to make sense. Data overload did not affect the planning performance, only the desks of the planners would sag under the weight of the statistical publications.

Now, in the high-tech days of GIS-assisted planning, we have to prepare the whole sequence of activities in great detail. Particular care will have to be taken to avoid the unfortunate but universal habit of asking, knowingly or unknowingly, for more data and greater detail than needed, as this will lead to data overload and break-downs, or sluggish performance of the system. Limiting the data volume will, from a financial point of view, be advantageous as well, as the collection of data typically is a costly activity.

Regarding the proper preparation we, firstly, have to decide **what data will be needed** and **what specific planning module will be used**. A highway planning exercise, for instance, will require a DEM (digital elevation model) together with data on land use, soils, present and expected cargo flows, public transport, private car movements and other related matters. Data details will depend on the planning scale—eg, the general alignment of a planned road and a rough cost estimate needed for a multi-year funding proposal, can be derived from a DEM based on satellite imagery; the detailed engineering design would, however, need greater accuracy and a higher resolution.

In the process of data selection and specification it is advisable to include considerations of speed and cost of data collection. Where collection will be extremely lengthy or costly, it would be advisable to look for alternative collection methods or data.

Secondly, we have to decide **the way of presenting geo-referenced data on a map**. This issue is particularly important in those cases where the GIS database contains socio-economic planning data. Land use, vegetation cover, roads, waterways, settlements and population distribution, for instance, are readily shown on a thematic map. The mapping of irrigated areas with one, two or three rice crops per year is not difficult either. Depicting yields per hectare and the complexity of mixed crops, levels of employment/unemployment, and/or household incomes, however, are. In general, the mapping of these indicators would only be meaningful if the data were available per village, which is exactly the administrative level with the least reliable data.

Even if a meaningful method of mapping can be found, we have to remember that access to the system's specific information generally improves when data is kept to a minimum. With that objective in mind it might, for instance, be considered to record the highest and the lowest observations only. These are, in contrast to the medial observations, the most revealing anyway, and rather than cluttering maps with meaningless matter, we believe that mapping of the data at the outer ends of the frequency distribution would constitute "information enhancement". Stated differently, in the same way that the visual interpretation of imagery is facilitated by contrast stretching and spatial filtering, the information value of thematic maps is increased by excluding the middle range of observations.

PLANNING: VISUAL versus ALGORITHMIC

In our discussion of GIS-assisted planning, we can draw upon the experience gained with econometrics—a mathematical approach to economic development planning. Econometrics attempts to model the interaction between economic sectors, production factors, national / regional income, exports, imports, government spending and the like, in order to calculate (estimate) the effects and impact of a specific action—eg, investment, increase in taxation, changes in currency exchange rate—on the economy. Econometric models were made for market driven as well as for socialist economies. The most extensive and complex models were made for the economy of the former Soviet Union. The difficulty of transferring the operations of a model to the practical reality of factories, shops, workers and consumers is very adequately illustrated by the failure of the Soviet economy.

When embarking on GIS-assisted planning we have to be alert to the many difficulties and pitfalls that would typically be associated with modelling. We have to avoid making the same errors as econometric modellers, that is, we should avoid to rely too much on mathematical formulas and algorithms. A mathematical model can only advance along its programmed path of pure logic. Unlike the human mind, a model is neither able to move beyond causal relations nor formulate assumptions; and unlike a model, the human mind is capable of imaginative speculation.

In cases where GIS is purely concerned with physical entities, such as calculating the cut-and-fill of a road alignment, or the maintenance schedule of a utilities network, a modelled algorithmic approach is fully justified and strongly recommended. Human motivation and actions are, however, difficult to capture in a formula and will frustrate the certainties implied by the formulas.

Example: The cause of the degradation of coral reef "XX-YY" is fairly clearly identifiable:

⇒ **anchoring, bombing, sedimentation** ⇐

The degradation is the effect of human actions.

The physical deterioration of the reef, and the most likely culprits, can easily be geo-referenced and entered into the information system.

To illustrate:

1. *Subsistence fishermen from village A, population – '000', income level – 'minimum / below minimum', use the occasional bomb at the western and inside part of the reef.*
2. *Carpet-bombing, every five to six months at the outer part of the reef, carried out by boats from town B and financed by dealers with inter-regional connections; local population complains, but unable to take action and afraid of retaliation.*
3. *Some anchor-damage, mainly by tourists from the capital, in the eastern bay.*
4. *Sedimentation plume visible on satellite imagery, particularly pronounced during West Monsoon; historical sequence shows worsening of the situation and direct link with the logging concessions in the upper reaches of the catchment area*

Decision makers can thus be provided with a graphic presentation of the problem. Being able to see the issue in its geographic context and socio-economic linkages, facilitates the coastal zone manager's analytical and decision making burden.

We believe that for the purpose of integrated coastal and marine resource [planning and] management, GIS is best used as a monitoring system. Monitoring allows the linking of *current results* to past situations and performance (backward linking), as well as to an anticipated future situation (forward linking). Backward linkages to historical/archived data would, for example, indicate the direction and rate of change. Forward linking could be used to assess the practical implications of a proposal—for instance the location of a new hotel—in terms of existing zoning regulations and/or the potential for conflict with other projects. The resulting information, presented to the decision makers in an accessible and user-friendly format, would allow them to formulate a solution and initiate action.

Continuing monitoring will show whether the solution and its implementation are successful.

It should be emphasised that the interpretation of survey and monitoring data, and their conversion into information, would be carried out by *visual* as well as *algorithmic methods*, and that both methods have an important function to perform. However, during the next step in the management process—ie, the formulation of integrated programmes for coastal zone resource management—the as yet unequalled flexibility and creativity of the human brain would necessarily play the main role.

This latter statement is very important. In contrast to the secondary data used in yesterday's planning process, a GIS database creates the impression of great accuracy by combining a set of tailor-made digital data with the ability to operate mathematical models. This has resulted in the mistaken belief that the uncertainty of projecting and predicting future events has largely been overcome, and that the task of assessing and analysing, projecting a course to a desired future, and decision making could be referred to the computer's electronic "brain".

We strongly object to that approach because:

- it takes the fun out of planning,
- it reduces the process to a mechanical operation with a limited, pre-programmed range of possibilities,
- it is likely to lose itself in unnecessary detail.

The fun of planning is in its opportunity to be creative, while an algorithmic-approach restricts creativity. Past attempts at GIS-assisted planning moreover show that irrelevant and unnecessary details have been utilised as query-criteria. Salinity and/or pH levels of the marine environment, for example, have in certain cases been used to determine the suitability of a beach location for tourism development. Not only do these levels vary seasonally, but it is also nearly impossible, as well as irrelevant, to establish an upper or lower suitability-limit. It should be remembered that success or failure of an investment is not only dependent on the physical conditions of the site and surroundings, but even more on the entrepreneurial talents and managerial skills of the investor/operator.

When comparing the coastal zone to a leaf we can observe a number of similarities. A leaf consists of (1) a leafstalk growing from the stem of a plant, (2) a framework of veins branching out from the leafstalk, and between the veins (3) a spongy mass of green cells. Water and dissolved minerals are carried [from the soil] into the leaf through the roots, stem, leafstalks and the veins, and liquid food material, formed in the leaf, is carried back into the plant. Access to and from the leaf is thus through the leafstalk and control of this access does not only control the events in and health of the leaf, but because of the leaf's food-producing function, the overall well-being and development potential of the whole plant as well.

According to the above, the coastal zone constitutes an active and important part of the province or nation, receiving from and contributing to the well-being of the larger entity. The coastal zone manager should now position himself on the "leafstalk". And rather than interfering with single project issues, the manager should direct, support and supervise the flow to and from the veins. In other words, integrated coastal and marine resource management should best be restricted to activities such as creating the support facilities for private initiative; monitoring the compliance with a wide range of regulations; anticipating requirements for social services; and the like.