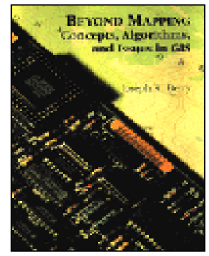
Beyond Mapping I

Topic 4 – What GIS Is and Isn't — Spatial Data Mapping, Management, Modeling and More



***Beyond Mapping* book**

<*Click here*> *for a printer-friendly version of this topic (.pdf).*

(*Back to the Table of Contents*)

Technobabble

(GIS World, February/January 1991)

(*return to top of Topic*)

…is that seemingly endless drone masking what would otherwise be a clear understanding of technology

If you have been following the Beyond Mapping series some strange things have been suggested--map-ematics, effective distance, map derivative, weighted windows, optimal path density, and net weighted visual exposure density surface. "You can't do that to a map; that's disgusting; are you sure it's legal?", may have been but a few of your comments. Technobabble. Just a bunch of technobabble.

Professor Hough of San Francisco State University's Communication Arts Department sums it up-- "GIS is not just warm, woolen socks." He explains that it is a change in mapping (and communications for that matter), like the cocoon to the caterpillar and butterfly. Ugly, but effective. To those on the outside, the cocoon just sits there. To those on the inside, there is total upheaval and complete restructuring. Such is the metamorphose brought on by the digital map.

Well, maybe, maybe not. Most of the practical applications of GIS involve automating current manual procedures. Correct that-- most involve investing in a database which, hopefully, will eventually automate the current manual procedures. A lot of work, to do what we have been doing for years. The perceived benefit, once GIS is on-line, is that we can do it faster, more detailed and colorful. The butterfly is obviously superior to the worm. But more importantly, it is radically different. The understanding of the differences and developing new procedures is The “behind the scene” revolution of GIS in the 1990's. It's not business as usual.

Consider the familiar map overlay operation. Suppose you are interested in locating your company's forest management parcels containing both Douglas fir trees and Cohasset soil. In the 1960's, your cartographic solution was to overlay both maps on a light-table and sketch. The result was a single map depicting the intersection. Good spatial characterization. However, if acreage estimates were required, hours of planimeter or dot grid work were required.

Your statistical procedure more likely involved searching a data base. Data such as acreage, timber and soil types for each management parcel was written on a card. Holes were punched along the edges to summarize the information. A geographic search simply involved passing a long needle through the appropriate edge position. When lifted, the parcels meeting that condition fell out of the stack. Repeat with the 'sieved' subset, and the cards containing both conditions fell out-- Douglas fir and Cohasset soil. Add up the acreage. Good statistical characterization.

A couple of problems persisted-- the procedures were tedious and disjoint. You could spend hours drafting and calculating for even a simple query over a small area. So what, the procedures are as comfortable as a pair of warm, woolen socks. Some folks even argue that the time involved is peanuts in comparison to the hours of creating, caressing and cursing an automated data base. Valid argument. Each of us knows our most efficient mode.

But the problem of the two manual systems being disjoint is critical. It is not just a matter of time. It's the nature of the information derived-- an answer to a specific question, a dead end. It doesn't become part of the data base. It cannot be easily shared with others and their subsequent analyzes incorporated. Your drafting and calculating, for all you know, may be repeated the following week by a colleague down the hall.

In large part, the capacity of the computer to store and share information is what tipped the scales from index cards to data base management. At least in the beginning, it certainly wasn't efficiency and ease of use. The transition was (is?) painful for most of us. Now the 'Information Age' is being heralded as the modern equivalent of the Industrial Age. Not merely a progression of technology, as much as a radical departure.

It's like the automobile. At first, it was just an engine affixed to a wagon. Aspirations for the new fanged thing were to do the work of a team of horses. Nothing more; nothing less. But as the car evolved, new demands for speed and capacity continuously redefined the 'automated wagon.' Entirely new concepts, such as aerodynamics, four-wheel drive and catalytic converters, have become commonplace. Nostalgia aside, isn't the car a vast improvement on the wagon? Although different, it's not that complicated to learn to drive a car over a driving a team of horses. You get there a lot quicker. And can do more.

The transition from the horse to horsepower, however, required both personal and social investments.

GIS is placing similar demands. Your challenge is to understand the differences between traditional map processing and apply these new procedures in creative ways. But that's not enough. It's like the 80 mph Bugatti. Awesome, but it's useless unless there are 80 mph roads. A washboard, wagon trail not only limits your potential, but is down-right dangerous.

That's where we are with GIS. The equivalent of supersonic (or supernatural, your choice) procedures for map analysis are in place. Most folks opt to keep things down to earth and apply GIS in traditional ways. Those that choose the high road soon find that the base data is as rocky as a wagon trail. Our historical concepts of mapped data are rooted in the map as a generalized image for human viewing. But GIS considers maps as rather large sets of numbers poised for quantitative analysis. Creation of an image is just one of the things you can do. Statistical and mathematical analytics comprise a multitude of other things.

GIS, from this perspective, is the blend of cartographic and numerical processing that was missing in the 1960's. The concept that it is a 'cash register' in which transactions on the landscape are recorded is one manifestation of the link. Tremendously useful, but challenges neither the basic procedures nor the basic data form. The ensuing articles in Beyond Mapping will do both. Even something as intuitively obvious as overlaying a couple of maps will be contorted into whether it is a 'point-by-point', 'region-wide', or 'map-wide' operation. Concern for both spatial and thematic 'error propagation' is also a must. Technobabble. TECHNOBABBLE! ...but it's interesting. Sort of like those electronic woolen socks with a nine volt battery you slip into your ski boots.

What's Needed to Go Beyond Mapping

(GIS World, April/March 1991)

(***return to top of Topic***)

... "to boldly go where no man has gone before" (StarTrek), I had better pack a toothbrush

GIS is a workhorse. It manages our spatial data. It provides timely updates to our data bases. Creates colorful and valuable map products. In short, it is rapidly becoming an integral part of our record keeping and report generation... 'Useful.' However, to some, it is an ill-tempered race horse, moving at breakneck speed. Expensive and cantankerous at best. The domain of the overly-indulgent rich... 'Frivolous.' To others, it is a Pegasus, whose wings soar us to new heights. A radical departure from traditional mapping. With entirely new concepts... 'Dreams.'

In reality, it is all three. The digital nature of GIS maps provides the skeleton for each perspective. Once you have a computer-compatible map, only your imagination limits its use. Well, that and your software vendor. Like horses, GIS software comes in a wide variety of sizes, shapes and colors. A Clydesdale just won't make it at a fox hunt with the queen. Nor is a thoroughbred suited for the plow. In selecting your 'best-fitted beast', its functionality in large part that determines its appropriate use. The overlaying and geographic searches of the mapping and data management functions of a GIS are relatively familiar to most current and aspiring users. But what is needed for GIS modeling (map analysis)? What takes a GIS beyond mapping?

Below is a checklist of the analytic capabilities that go beyond the basic GIS procedures. It is designed to spur discussion among users and vendors, as well as provide a structure for both past and forthcoming

Beyond Mapping articles.

'If I wanted it all, I would want...'

MATHEMATICAL OPERATORS

- ***Basic Math*** -- the most frequently used buttons on your pocket calculator. Add, subtract, multiply, divide, average, etc.
- ***Advanced Math*** -- the rest of the buttons. Such as the trigonometry functions, powers, roots, etc.
- ***'Macro' Command Language*** -- the ability to branch, loop, and test within a sequence of map processing commands.

SPATIAL STATISTICS

- ***Descriptive Statistics*** -- describe a single map variable or set of map features. For example, a standard normal variable (SNV) map identifies statistically 'unusual' areas and is computed by—

  *SNV= ((Xobs - Xmean)/Xstdev) * 100*

  where Xobs is the observed value at a particular location; Xmean is the map wide average of the variable; and Xstdev is the standard deviation of the variable. Another example is the calculation of the average for one mapped variable (e.g., slope) for a set of map features (e.g., timber harvesting parcels). A basic set of statistical procedures include the frequency counts, average, standard deviation, coefficient of variation, minimum, maximum, mode, median, diversity, deviation and proportion similar.
- ***Comparative Statistics*** -- compare two or more map variables or sets of map features. For example, a simple t-test can be used to compare the similarity (coincidence) between two maps. A basic set of statistical procedures include simple and frequency weighted crosstabs, Chi-squared, t, F, and Scheffe tests.
- ***Predictive Statistics*** -- establish relationships among map variables. For example, a simple linear regression can be developed for predicting one map variable from a set of other map variables. A basic set of statistical operators include clustering and simple linear, multiple, and curvilinear regressions.

DISTANCE MEASUREMENT

- ***Simple Distance*** -- calculates the shortest straight line between two points (Pythagorean Theorem).
- Buffer -- identifies all locations within a specified distance of a point, line or areal feature, such as all locations within 100 feet of a stream.
- ***Narrowness*** -- determines 'constrictions' as the shortest cord connecting opposing edges of an areal feature, such as a forest opening.
- ***Simple Proximity*** -- identifies the shortest, straight line distance from a point, line or areal feature to all other locations in a mapped area. Similar to a series of 'buffers' of equal steps emanating from a feature like ripples in a pond.
- ***Weighted Proximity*** (Movement) -- identifies the shortest, but not necessarily straight line distance from a point, line or areal feature to all other locations in a mapped area. Distance is measured as a function of absolute and relative barriers affecting movement (friction). Similar to a 'travel-time' map in network analysis, yet movement is allowed over a continuous surface.

NEIGHBORHOOD CHARACTERIZATION

- ***Surface Configuration*** -- characterizes a continuous surface's form. A basic set includes slope, aspect and profile. An advanced set includes an array of engineering techniques such as grade, curvature and cut/fill.
- ***Roving Window Summary*** -- summarizes values within a specified vicinity around each location, such as the total number of houses within an eighth of a mile creating a housing density surface. A basic set of summary operators include total, average, standard deviation, coefficient of variation, maximum, minimum, mode, median, and diversity. Statistics comparing the center of window to its neighbors includes deviation and proportion similar.
- ***Interpolation*** -- computes an expected value for each map location (continuous surface) based on a set of point samples. A basic set includes weighted nearest neighbor and Kriging techniques.

VISUAL EXPOSURE

- ***Inter-visibility*** -- identifies if two points are visually connected.
- ***Viewshed Delineation*** -- identifies all locations that are visually connected to a point, line or areal feature.
- ***Exposure Density*** -- determines how often each location is visually connected to a line or areal feature.
- ***Weighted Exposure Density*** -- calculates a weighted visual exposure value for each map location by considering the relative 'visual importance' of each viewing point, line or areal feature. For example, an area visually connected to a major highway will have a higher exposure value than another area connected the same number of times to a lightly travelled road.

OPTIMAL PATHS

- ***Simple Paths*** -- determines the 'best' route from one location to another along a set of lines (Network Analysis) or over a continuous surface. In the case of a terrain surface, it identifies water flow. In the case of a travel-time surface, it identifies the quickest path.
- ***Path Density*** -- counts the number of paths passing though each element of a network or continuous surface that optimally connects a set starting and finishing points. In the case of a terrain surface, it identifies confluence (channeling) of water flows. In the case of a travel-time surface, it identifies traffic confluence (heavily-used corridors), be it cars, hikers or elk.
- ***Weighted Path Density*** -- similar to normal path density, except each path is weighted by the volume of flow along the path.

SHAPE CHARACTERIZATION

- ***Convexity Index*** -- a measure of the boundary 'regularity' of an areal feature based on the ratio of its perimeter to its area.
- ***Fractal Geometry*** -- quantifies the 'complexity' of a feature's shape as an exponential relationship of its perimeter, area and fractal dimension.
- ***Spatial Integrity*** -- a measure of the 'intactness' of areal features relating holes and fragments of features forming the map mosaic, such as clear cuts in a forested landscape.
- ***Contiguity*** -- assesses the 'pattern' among groups of features, such as whether the clear cuts are clumped together or evenly distributed in the landscape.
- ***Inter-Feature Distance*** -- computes the average distance within a set of map features, such as individual parcels of endangered species habitat.

Whew! So that's all there is to it. At first glance, the advanced analysis 'grab-bag' may seem a bit overwhelming. It appears less of a workhorse, than a whole pack team, all pulling in different directions.

But that's because it’s unfamiliar; not that's it all that tough. The majority of the concepts have been in your 'visceral' (if not your conscious state) for a long time. Heaven knows they have been in textbooks for years. They're waiting for you to apply them in innovative ways that take you beyond mapping. Just ask your software vendor.

Who Says You Can’t Teach an Old Dog New Tricks?

(GIS World, May 1991)

(return to top of Topic)

...but then again, it's about as tough to teach a new dog a new trick.

Now that I am older with several years under (and over) my belt, I am enamored with new tricks-- the GIS bag of tricks. I am an old forester who has evolved from cyber-phobiac to a cyber-philliac. Nothing is more fun than wrestling with a new perspective on the old venerable field of Forestry. I just can't pass up the chance to comment on this issue's theme of 'GIS in Natural Resources.' Before the word came down from GIS World strategists, I had planned an article on some little-used (esoteric?) analytical procedure like error propagation modeling or shape characterization using fractal geometry and other assorted techy stuff.

All that is going to have to wait. Let's talk about the real world-- the deep woods. The world of dirt and slopes and trees and fish. How about a new perspective on the old problem of timber harvesting and fish romance? You know, create an map that says "if you run your skidder over here, it will likely kill the spawning whoopee over there." (Note-- a skidder is a tractor-like thing that drags trees around in the woods... for any utility company CIO reader still around after last issue's theme).

Let's consider this harvest-stopping loggerhead between the fish and the forester. It's simple-- leave a 100' buffer around class two streams. That ought to save the sexy salmon... or will it? My bet is about the time you get your harvest plan drafted and hung on the wall, the local angling association will ask, "What would happen if, just to be on the safe side, you considered a 200' buffer?" A valid question. A real concern.

Worse yet, if you don't address it, chances are you will be asked the same question by the judge at an injunction hearing. But you already wore out a box of crayons (let alone your patience) drafting the 100' buffer plan. You don't have time to respond to every 'little' concern.

Like those dark moments in an old western before the cavalry arrives, not all is lost. GIS will save you. Just edit the 100 to 200 in your GIS model and rerun it. It will take you moments, and your silicon subordinate (computer) just minutes, to respond. Just as you thought, not much change in the plan. Why wouldn't the fisherman and judge believe you? You know these things. You’re an old hand when it comes to knowing what bears (and fish and owls) do in the woods. GIS is just another hoop they make you jump through. A waste of time. A waste of money. But it does cover your... ah, decisions.

You're a crafty old fox who knows what GIS is, and isn't. Old woods wisdom put's this new fanged technology in its place... a faster drafter. It's not a new trick, just an accelerated old trick. The old dog is happy with that. But more importantly, are the fish happy? Is your company's bottom line happy? My guess is that your old perspective on map analysis isn't helping either. I bet you're killing fish and loosing revenue at the same time... with your concept of a GIS you're just doing it faster.

We're not talking just trees and fish here, there is dirt in between. What you need is a realistic Sediment Loading Potential (SLP) model as outlined in figure 1. Let's apply some common sense. The farther away from the stream you keep the skidder, the less the sediment should cloud salmon romance. That's why the fisherman wanted to increase the buffer. But are all buffer-feet the same? Not by a long shot. If there are steep slopes of sparsely covered vegetation between your skidder and the fish, you had better be a lot farther away than couple of hundred feet. But, if gentle, vegetated terrain separates them, you could harvest well within a hundred feet of the stream. Your old trick, whether tediously or rapidly applied, killed the fish and robbed the logger. It's just not that simple and straight forward... 100 or 200 feet, your choice.

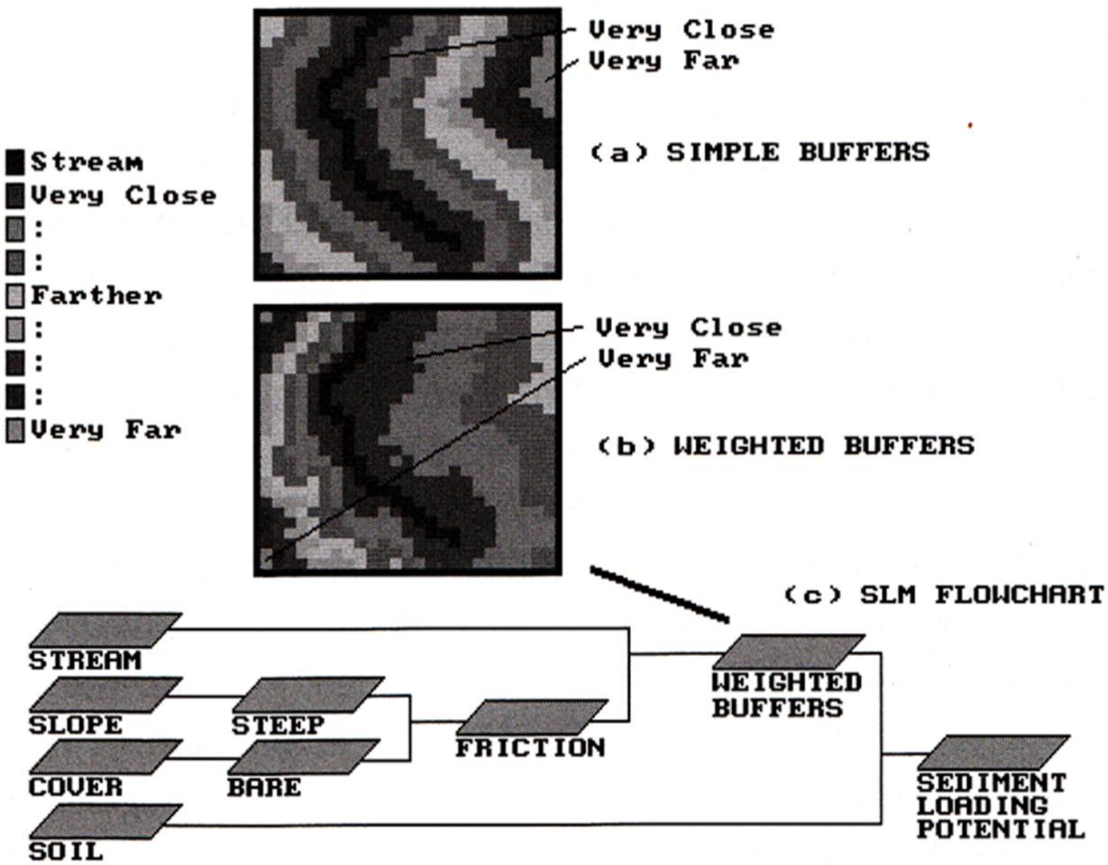


Figure 1. The top figure (a) shows a series of 100 foot buffers around a stream. Figure (b) shows a series of 'effective buffers' considering the slope and cover conditions of intervening terrain. The flowchart (c) depicts the Sediment Loading Model that identifies hazardous areas.

You need a new trick, like 'effective distance measurement.' This topic was driven into the ground several issues ago, but it's definitely applicable here (GW Vol. 2-5 through Vol. 3-2, Beyond Mapping column). We need a 'rubber ruler' that stretches in highly erodible places and shrinks in stable ones. The accompanying figure shows this effect. The map at the top calculates sediment loading potential as simply the inverse of the distance squared. You can do this with a ruler. But you would be hard pressed to create the more realistic map at the bottom which considers both intervening slope and cover conditions in assessing effective sediment loading distance.

GIS is more than just a faster mapper. It's more than a replacement for your old oak file cabinets. It's a technology providing new tools for resource management planning... spatial statistics, effective distance, optimal paths, visual exposure, to name but a few. But as impressive this new toolbox is, it is not the true revolution brought on by GIS. The real impact of GIS is the way we do business. It provides the means for the US Forest Service's "New Perspective" on forestry-- a capability for consensus building and conflict resolution.

All GIS models, whether simple or complex, have three characteristics. They are flexible, succinct, and dynamic. Once a model has been developed, it encourages the addition of new considerations and parameter weights. It almost shouts, "You want to try it a different way?" When is the last time your draftsperson demonstrated such flexibility? And in an agreeable manner to boot.

Computers, by nature, are stupid. They can do lot of things, but they don't know what to do. Each step has to be 'made perfectly clear.' This can be frustrating, but valuable in the long run. The GIS model becomes a clear statement of the analysis procedure. It succinctly summarizes the voluminous appendices of most reports. Note the flowchart at the bottom of the figure 1. It shows that the effective distance from streams is a function of the intervening slope and cover conditions. It takes sediment loading a step further, by considering the soil conditions... SLP= fn(slope, cover, soils). Or in other words, if you run your skidder on unstable soils you are likely to disturb the dirt. If this disturbance is effectively close to the stream, you got a problem. If it is effectively far away (even though it may be 'ruler' close), the sediment loading potential is low. This is common sense-- expressed in five simple sentences to the computer. The model encapsulates and demonstrates your rational thinking. Now the judge and angler can 'see' what you're talking about.

Finally, GIS models are dynamic. They allow you to try different scenarios-- different perspectives. Suppose your model for harvest planning considers visual exposure, as well as slope and proximity to roads. The best parcels to log are those that are gently sloped, with good access and minimal visual exposure. What if I suggest that visual exposure is ten times more important than the engineering considerations? What parcels, if any, are no longer appropriate for harvesting? In philosophical space we might violently disagree. Every square foot appears to be contested. But do we disagree in geographic space? Where do we disagree? Which parcels are involved? Spatial answers, not ideological statements, are needed. You run the model with your perspective, and I will run it with mine. Subtract the two 'solution' maps and we will see where and how we disagree. That's information for conflict resolution. That's dialogue for consensus building. That's the GIS revolution.

So what's new in the natural resource management?. The seemingly un-natural technology of GIS-- that's what is new. To the old forester, it at first appears to cramp his or her management style. Like the flower in the 'Little Shop of Horrors' it just keeps growing as it shouts "Feed Me, Feed Me, FEED ME!"... Digitize, Digitize, DIGITIZE! But it's not just a new layer of record-keeping. It's more than mapping and spatial data management. It's a new toolbox allowing you to plan in more realistic manner. In fact, it's a whole new perspective on the resource decision-making environment. I bet you can learn a new trick or two.

Frankly My Dear, I Don't Give a Damn

(Rhett to Scarlet, in Gone with the Wind)

(GIS World, June 1991)

(return to top of Topic)

The last section introduced the idea that GIS is more than what 'meets the eye' …more than a computer mapping system. More than a spatial data base management system. Even more than an analytic toolbox. These capabilities are its parts-- but the whole, in this case, is much more than the sum of its parts. GIS, in the final analysis, is a communication device.

Like Rhett, you may not give a damn. All this new technology is more trouble than it is worth-- just like Scarlet. But there is still that spark that attracts you. Maybe, just maybe, there is something to all this GIS infatuation. You have heard bits and pieces of its proclaimed capabilities. How it is going to change the way you do things. But it certainly is a strange beast, not unlike a Platypus. There are bits and pieces of disciplines that are familiar, like computers and drafting and statistics; but when assembled in its strange way, it is hard to understand how it keeps afloat. That's GIS-- a strange, but compelling beast.

As a technology, I can take it or leave it. It is interesting, but often seems academic, or even esoteric. It's just technology for technology sake, isn't it? Or does it really improve decision-making? Or just improve the vendor's bottom line? A real question. A real concern... for 'real' folks.

Consider our current policy formation and decision-making environments. Professor Vlachos, a natural resources futurist at Colorado State University, identifies three inputs to this process-- the Science, Social and Legal components of society (see figure 1). Loosely paraphrased, he states that a delicate balance of all three is necessary to reach an effective decision. For example (my example, his are much better, but his lively delivery is required), assume the populace of a developing country is suffering from a dietary deficiency in animal protein. Also, assume the country has vast areas of natural grasslands. Common sense (and voluminous tables of research from the beef council) point to the easy technical solution of cattle production.

That's it-- an obvious, and technically supportable solution. But wait a moment. There are indigenous cultural and religious taboos against killing cows. And the legal concept of private property is non-existent. Nor is there a precedent for land ownership and fencing. In short, the plan receives high technical marks and appears acceptable from that single perspective. But, viewed differently, it fails the social and legal tests. A decision bust.

In a less obvious fashion, the necessary balance among the three decision sectors is what is upsetting our current decision- making. A technical solution often meets social acceptance in a loggerhead. The result is an injunction and the legal sector is called upon to make the management decision. Black robes and a litany of conflicting testimony replaces effective science and social inputs.

Facing the real prospect of litigation, we resort to a state of 'analysis paralysis.' We constantly search for one more decimal point accuracy to the technically 'perfect' solution. "If we could just get more data, the answer would be obvious." Don't manage the woods, inventory them. It's like placing a sign at park headquarters-- 'closed for inventory.'

But maybe your data and analysis is good enough. Not perfect, but good enough to make a decision. The problem could be the decision environment. What is lacking, is a capability to clearly communicate rational thinking and different perspectives. The accompanying figure summarizes these thoughts. An inability to communicate causes the Social and Scientific inputs to turn toward the Legal sector to solve their perceived differences-- litigation. If I am not part of the analysis process, chances are I don't fully understand, or trust it. Another hundred pages of appendices, or even more colorful maps, won't help. See you in court.

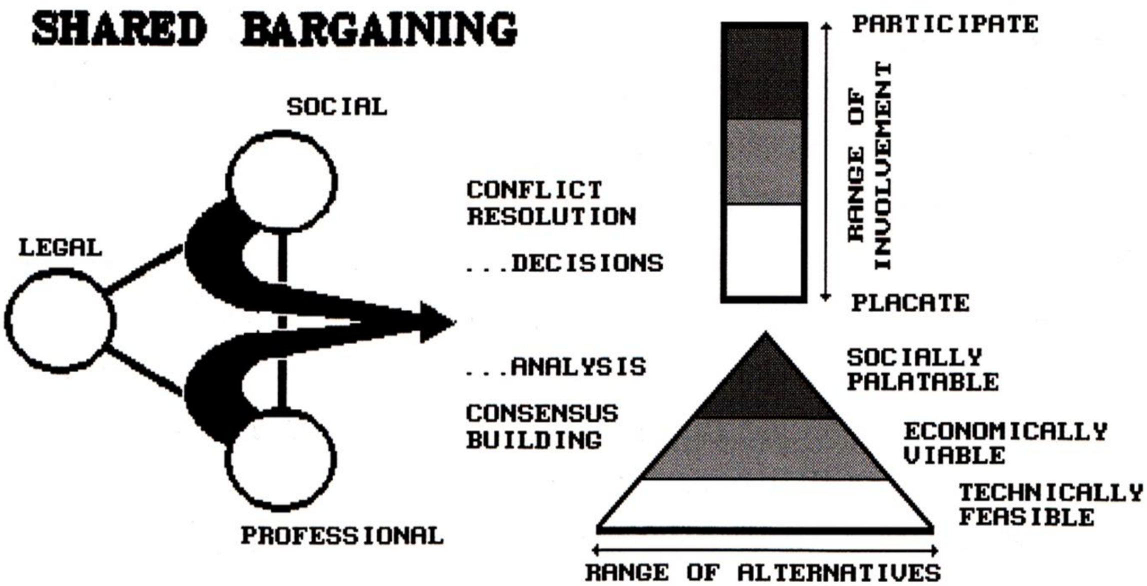


Figure 1. The considerations in effective decision-making require dialogue and participatory involvement, as well as technical and economic scrutiny.

However, effective communication causes the inputs to turn away from the Legal sector in search of an acceptable decision. The right side of the figure addresses the working environment. Most geographic-related decisions have a relatively broad range of technically feasible options. As the pyramid depicts, there is a smaller set of options that are economically viable. We have developed elaborate procedures for assessing management options that are both feasible and viable-- the technical solution.

Yet, in reality, there is an even smaller set of options are socially acceptable. It is this final 'sieve' of management alternatives that often confounds our decision-making. It uses elusive measures such as human values, attitudes, beliefs, judgement, trust and understanding. Not the usual quantitative stuff used in computer algorithms and decision-making models. So, what does all this have to do with GIS? In a GIS, maps are numbers aren't they? GIS is a technology, isn't it? Well yes... and no.

The step from feasible and viable options, to acceptable ones is not so much science and economics, than it is communication. And effective communication implies involvement. The range of involvement (upper right portion of figure 1) extends from placation to actual participation. Public hearings are often more placation than participation. At an initial hearing, concerned parties are asked for their input, but for practical reasons, they are excluded from the analysis process. At a final hearing they are expected to approve the results of analysis they do not understand. "Trust us. Everything is there. Just choose alternative A or B."

Participatory decision-making has two main thrusts-- consensus building and conflict resolution. *Consensus building* involves technologically-driven communication and occurs during the alternative formation phase of the decision-making process. It involves the GIS specialist's translation of the various considerations raised by a decision team into a spatial model. Once completed, the model is run under a wide variety of conditions and the differences in outcome are noted. From this perspective, any single map solution isn't important. It is how maps change as different scenarios are tried that becomes information to make a decision. "What if avoidance of visual exposure is more important than avoidance of steep slopes in siting the new road? Where does the proposed route change, if at all?" In nearly twenty years of GIS consulting, I have consistently found that seemingly divergent philosophical views most often result in only slightly different map views. This realization often leads to group consensus.

If it doesn't, *conflict resolution* is necessary. This socially driven communication occurs during the decision formulation phase. It involves the creation of a 'conflicts map' that compares the outcomes from two or more competing uses. Each management parcel (vector polygon or raster cell) is assigned a code describing the conflict over the location. "This location is ideal for preservation, recreation and development. What should we do?" Make a decision, that's what you need to do. This process most often involves human rationalizing, or 'tradeoffs.' "Look here, I will let you develop this parcel if you agree to assign that one to preservation." The dialogue is far from a mathematical optimization, but often closer to an effective decision. It uses the GIS to focus discussion away from broad ideological positions, to the specific project area and its unique distribution of possible uses.

GIS is a mapping tool, a spatial data base management technology and a analytic revolution. But what may be its most important attribute is its ability to communicate. It isn't just a better technical answer, it is a more comprehensible one. It fosters discussion that often leads to understanding, and ultimately effective decisions. Think of it. All Rhett and Scarlet needed was a bit more constructive discussion, and they could have lived happily ever after in a small duplex outside Atlanta.

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(Return to top of Topic)

(Back to the Table of Contents)