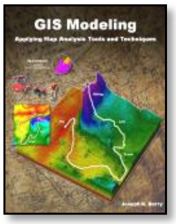
Beyond Mapping IV

Topic 8 – GIS Modeling in Natural Resources



GIS Modeling book

Harvesting an Understanding of GIS Modeling — *describes a prototype model for assessing off-road access to forest areas*

Extending Forest Harvesting's Reach — *discusses a multiplicative weighting method for model extension*

E911 for the Backcountry — *describes development of an on- and off-road travel-time surface for emergency response*

Extending Emergency Response Beyond the Lines — *discusses basic model processing and modifications for additional considerations*

Comparing Emergency Response Alternatives — *describes comparison procedures and route evaluation techniques*

GIS's Supporting Role in the Future of Natural Resources — *discusses the influence of human dimensions in natural resources and GIS technology's role*

Further Reading — *five additional sections*

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

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Harvesting an Understanding of GIS Modeling

(GeoWorld, April 2010)

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Vast regions of the Rocky Mountains are under attack by mountain pine beetles and a blanket of brown is covering many of the hillsides. Dead and dying trees stretch to the horizon. In five years there will be just sticks poking up and within twenty years the forest floor will look like a game of "pick-up sticks" with a new forest poking through.

It's an ecological cycle, but it is both aggravated by and aggravating to many of us who live and play in the shadows of the mountains. Is there something we can do to contain the spread and hasten the regenerative cycle? One suggestion is to remove the dead wood to speed forest health and convert it to useful products to boot.

This appears attractive but just knowing there are giga-tons of beetle-gnawed biomass awaiting "wood utilization" solutions isn't a fully actionable answer. What products are viable? Where and how much harvesting is appropriate?

These two basic questions captured the attention of combined graduate project teams at the University of Denver. A "capstone MBA" team focused on the business case while a "GIS modeling" team focused on the geographic considerations. Their joint experience in identifying, describing and evaluating potential solutions provided an opportunity to get their heads around a complex issue requiring integration of spatial and non-spatial analysis, both at a macro state-wide level and a micro local level. The experience also provides a springboard for a short Beyond Mapping series on GIS modeling (scar tissue and all).

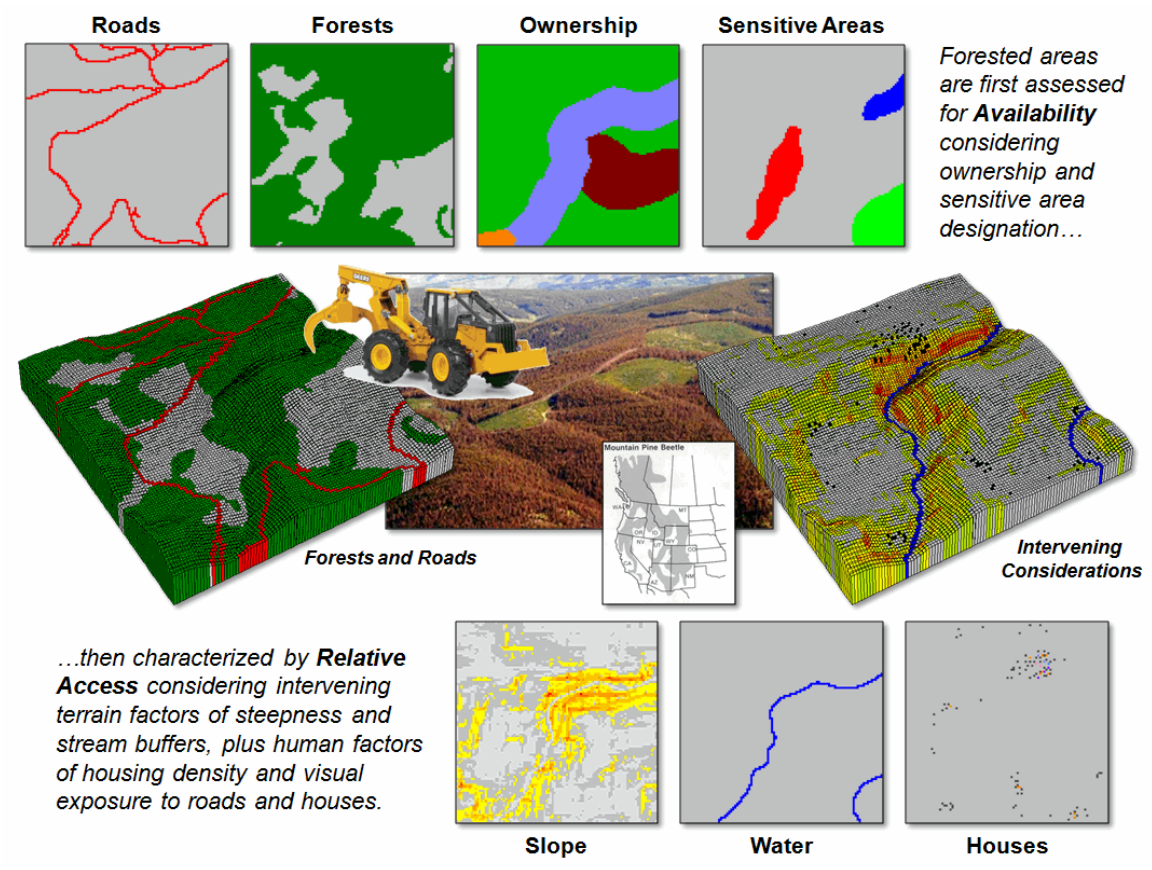
Our outside collaborators (a non-profit organization and a large energy company) narrowed the investigation to biomass for augmentation of base-load electric energy generation—first lesson, *always heed the client's interests*. This assumption narrows the macro considerations as haul distances from a plant are critical. Considering mountainous travel, buffering to a simple geographic distance is insufficient and travel-time zones were recommended—second lesson, *clients love the on-road travel-time concept*.

The concept of modeling off-road access, on the other hand, is a bit harder to appreciate. It was decided that a micro level "proof-of-concept prototype model" for assessing forest access would be developed. Figure 1 depicts the map variables and basic approach taken for a hypothetical demonstration area—third lesson, *never use real data for a prototype model if you want clients to concentrate on model logic*.

The first phase of the basic model determines ***Availability*** of lands for harvesting activity. Legal concerns, such as ownership, stream buffers and sensitive areas must be identified and unavailable lands removed from further consideration. In addition, physical conditions can become "absolute barriers," such as steep slopes beyond the operating range of equipment. A second phase characterizes the relative ***Access*** of available lands by considering intervening conditions as "relative barriers," such as increasing slope in operable areas increases costs of harvesting.

It is important not to "over-drive" the purpose of a Prototype Model as a mechanism for demonstrating a viable approach and stimulating discussion—fourth lesson, *"keep it simple stupid (KISS)" to lock a client's focus on model approach and logic*. Anticipated refinements should be reserved for a "Further Considerations" section in the presentation describing the prototype model.

If model refinement accompanies prototype development, there isn't a need for a prototype. But that is the bane of a "waterfall approach" to GIS modeling. You can easily drown by jumping off the edge at the onset; whereas calmly walking into the pool with your client engages and involves them, as well as bounds a manageable first cut of the approach and logic … baby steps with a client, not a top-down GIS'er solution out of the box. Fifth lesson—*there is a sweet spot along a client's perception of a model from a Black box of confusion to Pandora's box of terror*.



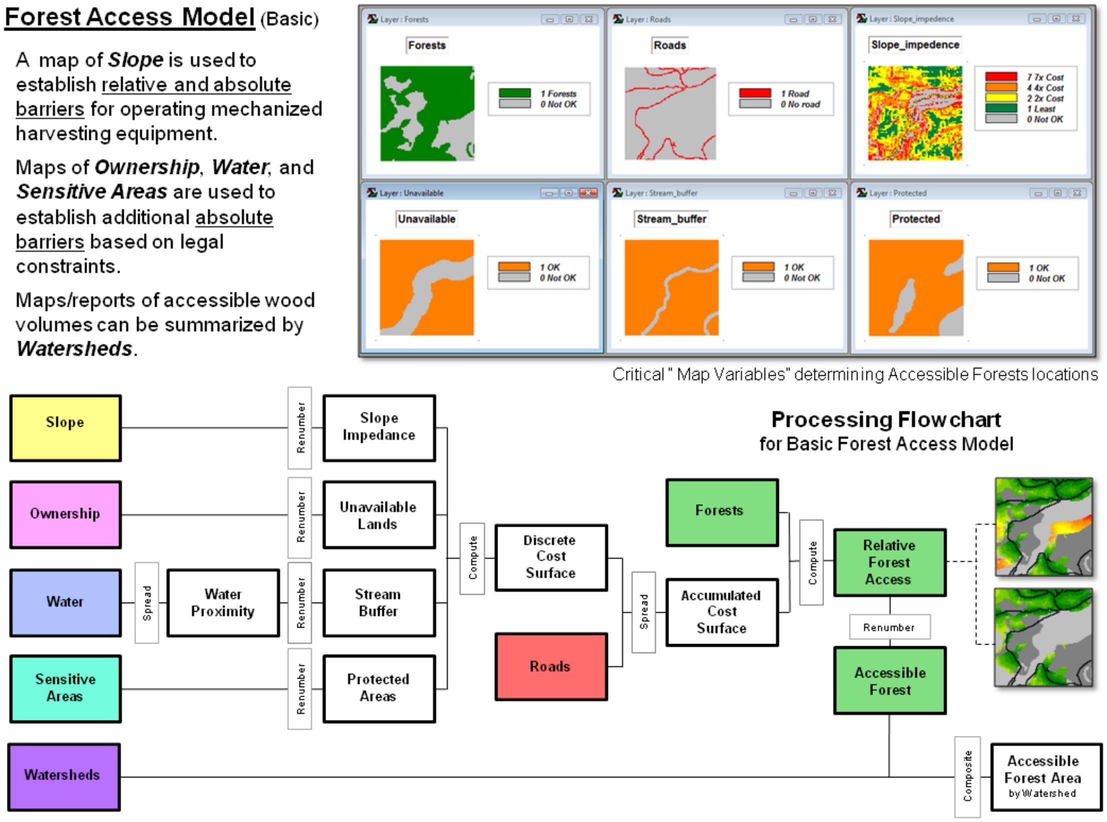
*Forested areas are first assessed for **Availability** considering ownership and sensitive area designation…*

*…then characterized by **Relative Access** considering intervening terrain factors of steepness and stream buffers, plus human factors of housing density and visual exposure to roads and houses.*

Figure 1. Relative harvesting access is determined by availability of forest lands as modified by intervening conditions.

Figure 2 contains a flowchart of model logic for the basic Availability/Access prototype model. Only four base maps and ten commands are involved in a demonstrative first cut. A Slope map is used to derive slope impedance where ranges of steepness are assigned 1 (most preferred)= 0-10%, 2= 10-20%, 4= 20-30% 7 (seven times less preferred)= 30-40% and 0 (unavailable)= >40%.

The other maps of Ownership, Water and Sensitive Areas are used to derive binary maps where 1= available and 0= unavailable lands. The final step calculates the acreage of accessible forests within each watershed.



Forest Access Model (Basic)

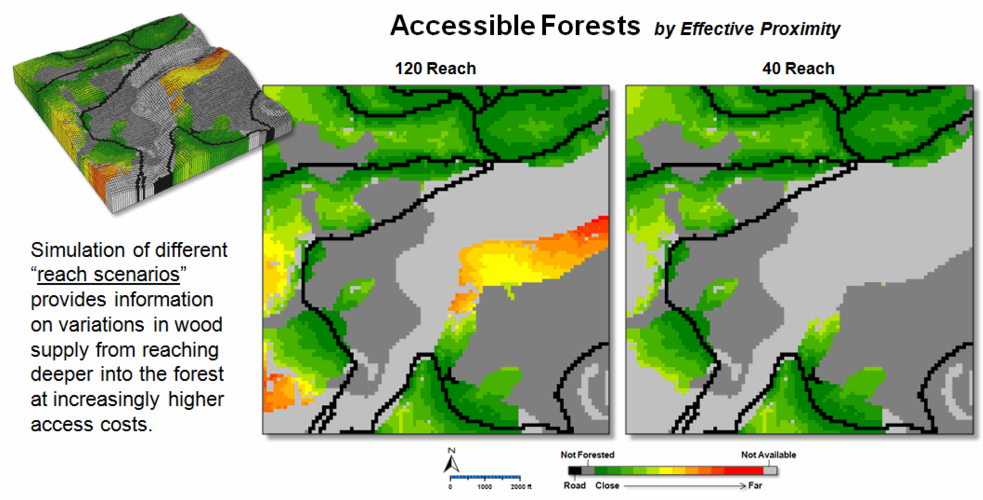
A map of ***Slope*** is used to establish relative and absolute barriers for operating mechanized harvesting equipment.

Maps of ***Ownership***, ***Water***, and ***Sensitive Areas*** are used to establish additional absolute barriers based on legal constraints.

Maps/reports of accessible wood volumes can be summarized by ***Watersheds***.

Critical "Map Variables" determining Accessible Forests locations

Figure 2. Flowchart of the basic model involves four base maps and ten processing commands.



Simulation of different "reach scenarios" provides information on variations in wood supply from reaching deeper into the forest at increasingly higher access costs.

Figure 3. Different effective "reaches" into the accessible forested areas can be generated to

simulate varying budget sensitivities.

The four calibrated maps are multiplied for a Discrete Cost Surface that contains a zero for unavailable lands (any 0 in the map stack sends that location to 0) and the relative "friction values" based on terrain steepness are preserved for available areas (1 * 1* 1 * friction value retains that value). In turn, this map is used to generate the relative access map using a "Least Cost" approach that will be discussed in next month's column that "lifts the hood" on technical considerations (see Author's note).

Figure 3 provides an early peek at some of the output generated by the basic Forest Access model. The left inset shows the relative access values for all of the available forested areas with warmer tones indicating a long harvesting reach into the woods; light grey, unavailable and dark grey, non-forested. A user can conjure up different "reach" scenarios defining accessible forests as a means to understand the spatial relationships from grabbing just the "low hanging economic fruit (…err, I mean wood)" that is easily accessed (right inset), to increasingly aggressive plunges deeper into the woods at increasingly higher access costs.

Also, consideration of human concerns, such as housing density and visual exposure, might affect a practical assessment of the access reach. Finally, locating suitable staging areas (termed "Landings") for wood collection and the delineation of the forest areas they serve (termed "Timbersheds") provide even more fodder for next couple of columns.

Author's Note: *For more discussion on effective distance and connectivity, see Beyond Mapping Compilation Series, book III, Topic 4, "Calculating Effective Distance" and book IV, Topic 2, "Extending Effective Distance Procedures" posted at* www.innovativegis.com.

Extending Forest Harvesting's Reach

(GeoWorld, May 2010)

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The previous section described a basic spatial model for determining relative harvesting availability and accessibility of beetle-killed forests for harvesting. The prototype model was developed by "capstone MBA" and "GIS modeling" graduate teams at the University of Denver. A non-profit organization and a large energy company served as outside collaborators and narrowed the focus to the extraction of biomass for base-load electrical energy generation.

State-wide analysis involving on-road travel was proposed for assessing hauling distances of wood chips to power plants where the resource would be further refined and mixed with coal. Adjusting for mountainous travel along the road network, some beetle-kill areas simply are too far from a plant for consideration.

Local level analysis involving off-road harvesting is considerably more complex. In summary, this processing determines the relative accessibility from the landings into the forest considering a variety of terrain, ownership and environmental considerations. Adjusting for off-road access, some beetle-kill areas are unavailable or effectively too far from roads for harvesting.

The Basic Access Model outlined in the top portion of figure 1 demonstrates the types of factors that can be considered in assessing off-road access. The processing first identifies *absolute barriers* to harvesting based on ownership, environmentally sensitive areas, water buffers and terrain that is too steep for equipment to operate. These factors are represented as binary map layers with 1= available and 0= unavailable for harvesting activity.

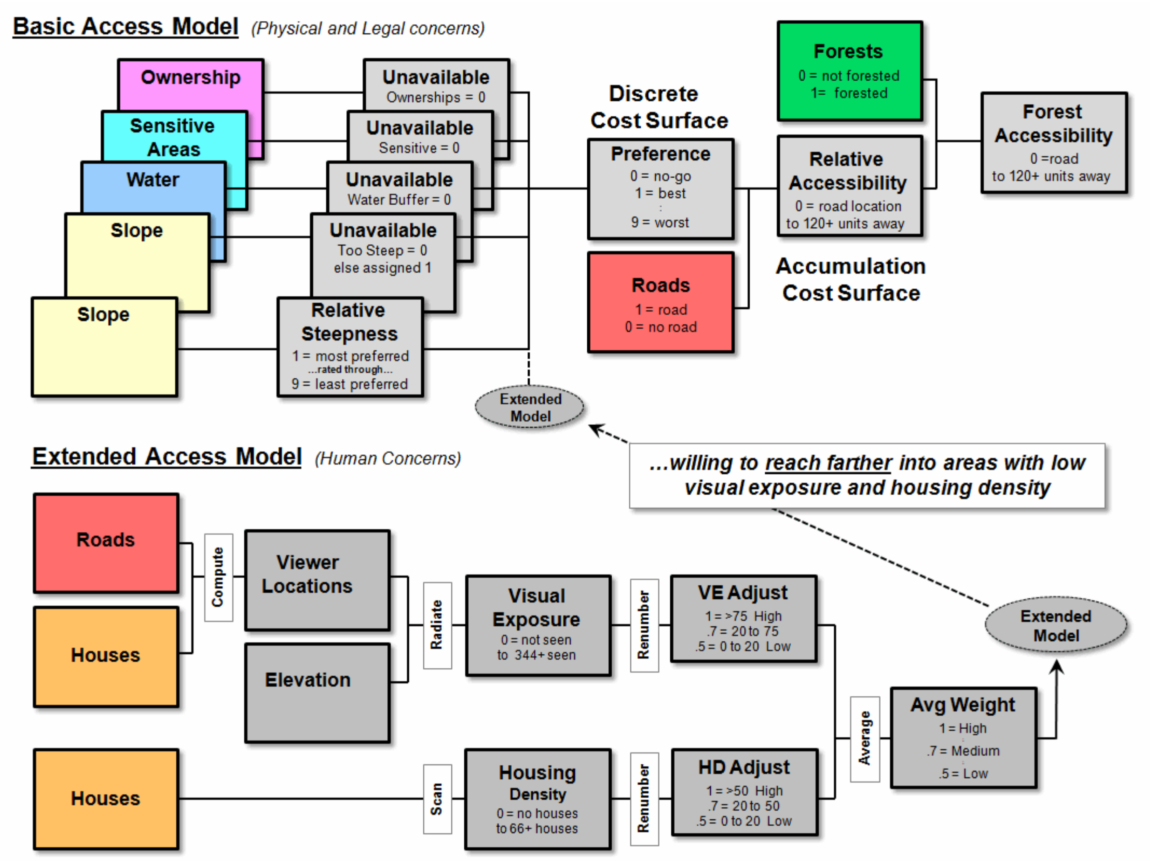


Figure 1. The Extended Access Model develops a multiplicative weighting factor based on housing density and visual exposure of potential harvesting areas.

Relative barriers to forest access are rated from 1= most preferred to 9= least preferred. In the prototype model, slopes within the harvesting equipment operating range are used to demonstrate relative barriers with increasingly steeper slopes becoming less and less desirable. Multiplying the stack of map layers identifying absolute and relative barriers results in an overall preference surface for harvesting with values from 0 (no-go), to 1 (best) through 9 (worst). The final step uses grid-based *effective distance* techniques to determine the relative accessibility of available forested areas from roads (see author's note).

As an extension to the basic model, human concerns for minimizing visual exposure and housing density are outlined in the lower portion of figure 1. The procedure first derives a visual exposure density surface identifying the number of times each location is seen from houses and roads and then calibrates the exposure from .5 (low exposure) through 1.0 (high exposure). Similarly, a housing density surface identifying the number of houses within a half mile radius was calibrated from .5 (low density) to 1.0 (high density). The two adjusted maps are averaged for an overall weighting factor for each map location.

When the multiplicative weight is applied to the preference map stack, it improves (lowers) preference ratings in areas with low visual exposure and housing density, while retaining the basic ratings in areas of high visual exposure and housing density. The effect on the model is to favor reaching farther into available forested areas in locations that are less contentious.

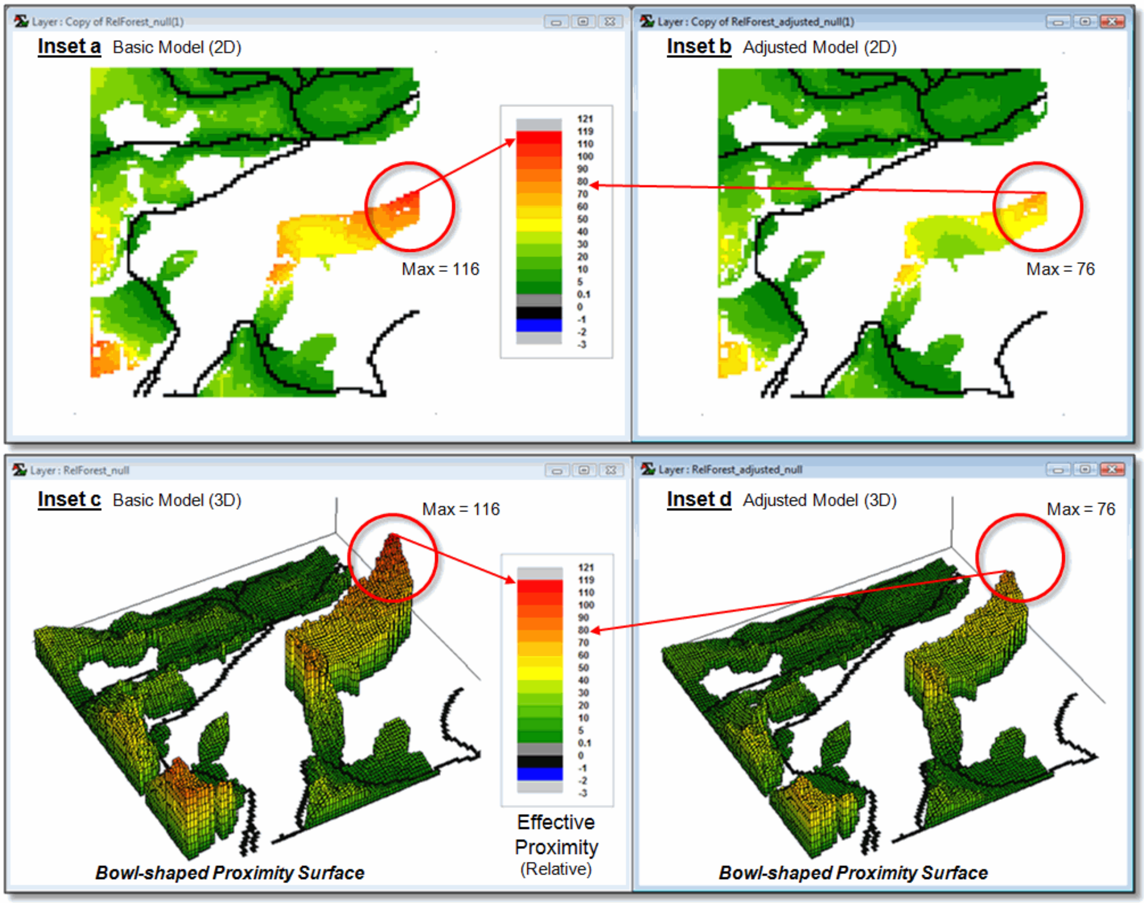
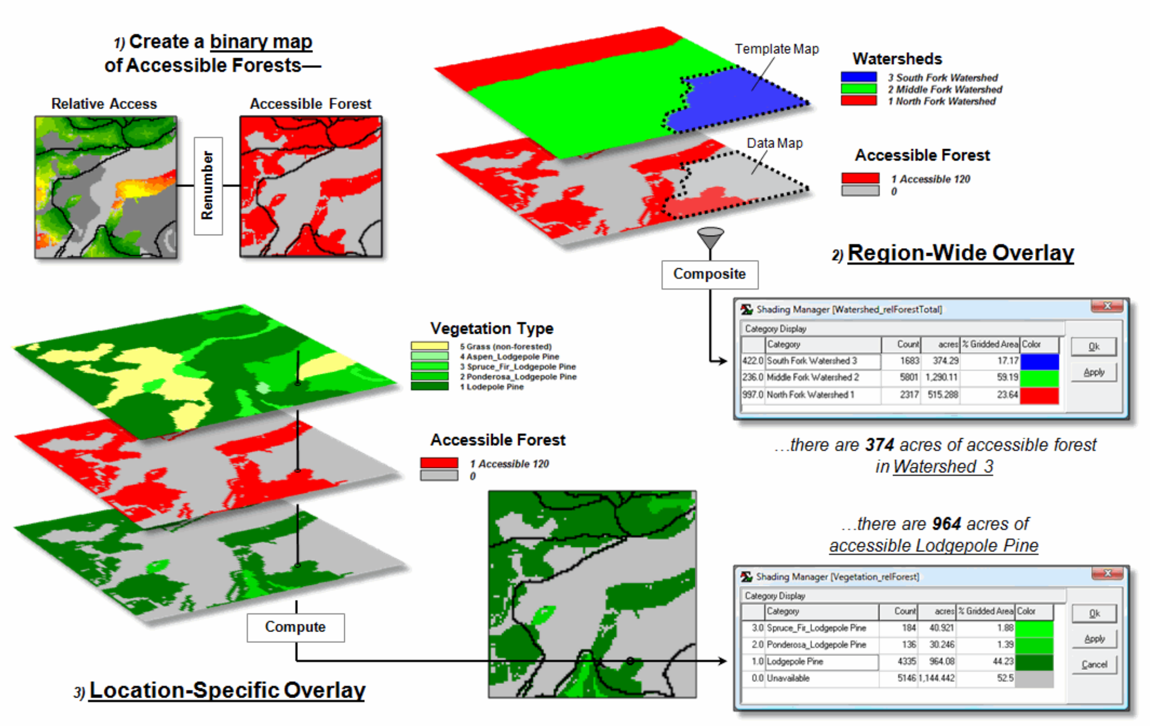


Figure 2. Comparison of Basic and Extended model results.

Figure 2 compares the results with the left side of the figure tracking the results of Basic Model and the right side tracking the results of the Extended Model that favors harvesting in areas of low human impact. The effective distance to the farthest available forest location is reduced by a third from 116 to 76. The 3D plots on the bottom of the figure (insets c and d) depict the results as bowl-shaped accumulation surfaces with the lowest value of 0 "cells away" from the road in the lower center portion of the project area. Note the considerable easing (lower values; flattening of the surface) of the relative proximity at the circled remote location.

Figure 3 illustrates a couple of techniques for summarizing related map information using a binary map of accessible forest areas. A region-wide (zonal) overlay operation can be used to "count" the total number of acres of accessible forest in each of the three watersheds (e.g., 374 aces of accessible forest in Watershed 3). Also, by simply multiplying the binary map times the vegetation map identifies the vegetation type and area for all of the accessible forest locations (e.g., 964 acres of accessible Lodgepole pine).



Shading Manager [Watershed_relForestTotal]

	Category	Count	acres	% Gridded Area	Color
422.0	South Fork Watershed 3	1683	374.29	17.17	🟦
236.0	Middle Fork Watershed 2	5801	1,290.11	59.19	🟩
997.0	North Fork Watershed 1	2317	515.288	23.64	🟥

Shading Manager [Vegetation_relForest]

	Category	Count	acres	% Gridded Area	Color
3.0	Spruce_Fir_Lodgepole Pine	184	40.921	1.88	🟩
2.0	Ponderosa_Lodgepole Pine	136	30.246	1.39	🟩
1.0	Lodgepole Pine	4335	964.08	44.23	🟩
0.0	Unavailable	5146	1,144.442	52.5	▨

Figure 3. D. Summarizing accessible forest areas by watersheds and vegetation type.

The ability to repackage all beetle-kill areas into those meeting harvesting availability and access requirements is critical. Just knowing that there are giga-tons of biomass out there isn't sufficient until they are mapped within a comprehensive decision-making context. Additional extensions include procedures for determining the best set of staging areas, termed "landings," and the characterization of the potential wood chip supply within each of their corresponding "timbersheds" (see Author's Notes).

The next three sections consider on- and off-road travel for backcountry emergency response. The basic approach using effective distance is similar to harvesting access except the identification and response time for the optimal route (minimum travel-time) by truck, ATV and hiking between two locations is the goal.

Author's Note: *For a discussion on identifying and characterizing "Timbersheds" see Further Online Reading section 1, "A Twelve-step Program for Recovery from Flaky Forest Formulations" at the end of this topic.*

E911 for the Backcountry

(GeoWorld, July 2010)

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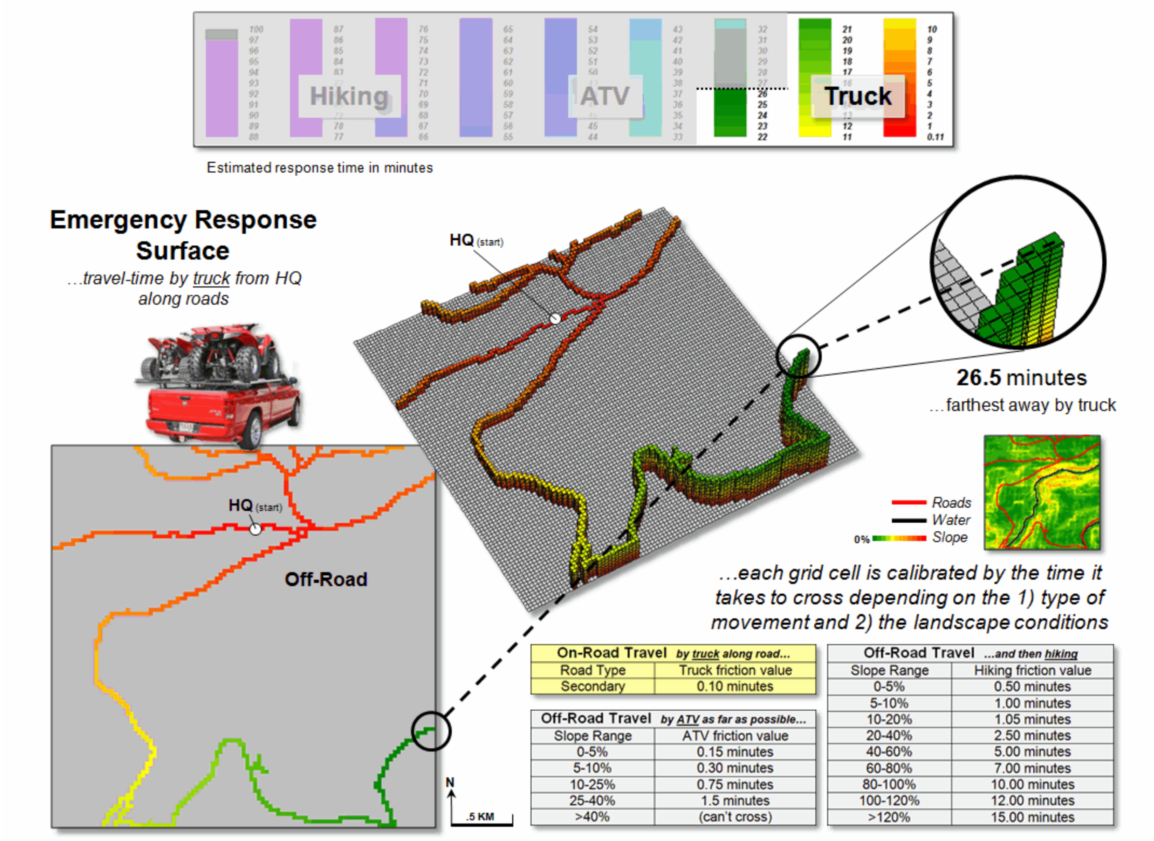
One of the most important applications of geotechnology has been Enhanced 911 (E911) location technology that enables emergency services to receive the geographic position of a mobile phone. The geographic position is automatically geo-coded to a street address and routing software is used to identify an optimal path for emergency response. But what happens if the call that "I've fallen and can't get up" comes from a backcountry location miles from a road? The closest road location "as the crow flies" is rarely the quickest route in mountainous terrain.

A continuous space solution is a bit more complex than traditional network analysis as the relative and absolute barriers for emergency response are scattered about the landscape. In addition, the intervening conditions affect modes of travel differently. For example, an emergency response vehicle can move rapidly along the backcountry roads, and then all terrain vehicles (ATV) can be employed off the roads. But ATVs cannot operate under extremely steep and rugged conditions where hiking becomes necessary.

The left side of figure 1 illustrates the on-road portion of a travel-time (TT) surface from headquarters along secondary backcountry roads. The grid-based solution uses friction values for each grid cell in a manner analogous to road segment vectors in network analysis. The difference being that each grid cell is calibrated for the time it takes to cross it (0.10 minute in this simplified example).

The result is an estimate of the travel-time to reach any road location. Note that the on-road surface forms a rollercoaster shape with the lowest point at the headquarters (TT = 0 minutes away) and progressively increases to the farthest away location (TT = 26.5 minutes). If there are two or more headquarters, there would be multiple “bottoms” and the surface would form ridges at the equidistance locations in terms of travel-time—each road location assigned a value indicating time to reach it from the closest headquarters.



…each grid cell is calibrated by the time it takes to cross depending on the 1) type of movement and 2) the landscape conditions

On-Road Travel *by truck along road…*	
Road Type	Truck friction value
Secondary	0.10 minutes

Off-Road Travel *by ATV as far as possible…*	
Slope Range	ATV friction value
0-5%	0.15 minutes
5-10%	0.30 minutes
10-25%	0.75 minutes
25-40%	1.5 minutes
>40%	(can't cross)

Off-Road Travel *…and then hiking*	
Slope Range	Hiking friction value
0-5%	0.50 minutes
5-10%	1.00 minutes
10-20%	1.05 minutes
20-40%	2.50 minutes
40-60%	5.00 minutes
60-80%	7.00 minutes
80-100%	10.00 minutes
100-120%	12.00 minutes
>120%	15.00 minutes

Figure 1. On-road emergency response travel-time.

The lower-right portion of figure 1 shows the calibrations for on-road travel by truck and off-road travel by ATV and hiking as a function of terrain steepness and recognition of rivers as absolute barriers to surface travel. The programming trick at this point is to use the accumulated on-road travel-time for each road location as the starting TT for continued movement off-road. For example, the off-road locations around the farthest away road location starts “counting” at 26.5, thereby carrying forward the on-road travel time to get to off-road locations. As the algorithm proceeds it notes the on- and off-road travel-time to each ATV accessible location and retains the minimum time (shortest TT).

Figure 2 identifies the shortest combined on- and off-road travel-times. Note that the emergency response solution forms a bowl-like surface with the headquarters as the lowest point and the road proximities forming “valleys” of quick access. The sides of the valleys indicate ATV off-road travel with steeper rises for areas of steeper terrain slopes (slower movement; higher TT accumulation). The farthest away location accessible by truck and then ATV is 52.1 minutes.

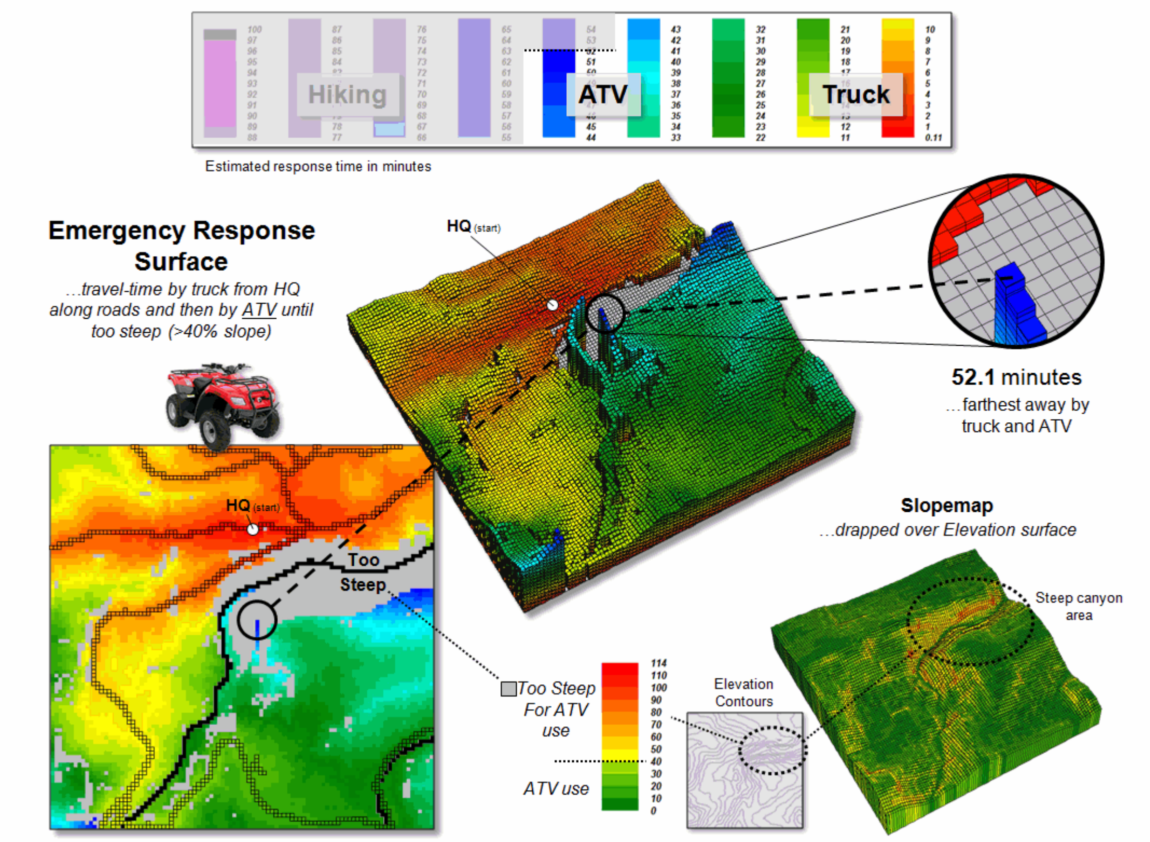


Figure 2. On-road plus off-road travel-time using ATV under operable terrain conditions.

The grey areas in the figure indicate locations that are too steep for ATV travel, particularly apparent in the steep canyon area (lower left insert with warmer tones of Slope draped over the Elevation surface). The sharp “escarpment-like” feature in the center of the response surface is caused by the absolute barrier effect of the river—shorter/easier easier access from roads west of the river.

Figure 3 completes the emergency response surface by accounting for hiking time from where the wave front of the accumulated travel-time by truck and ATV stopped. Note the very steep rise in the surface (blue tones) resulting from the slow movement in the rugged and steep slopes of the canyon area. The farthest away location accessible by truck, then ATV and hiking is estimated at 96.0 minutes.

The lower-left insert shows the emergency response values draped over the Elevation surface.

Note that the least accessible areas occur on the southern side of the steep canyon. The optimal (quickest) path from headquarters to the farthest location is indicated—that is within the assumptions and calibration of the model.

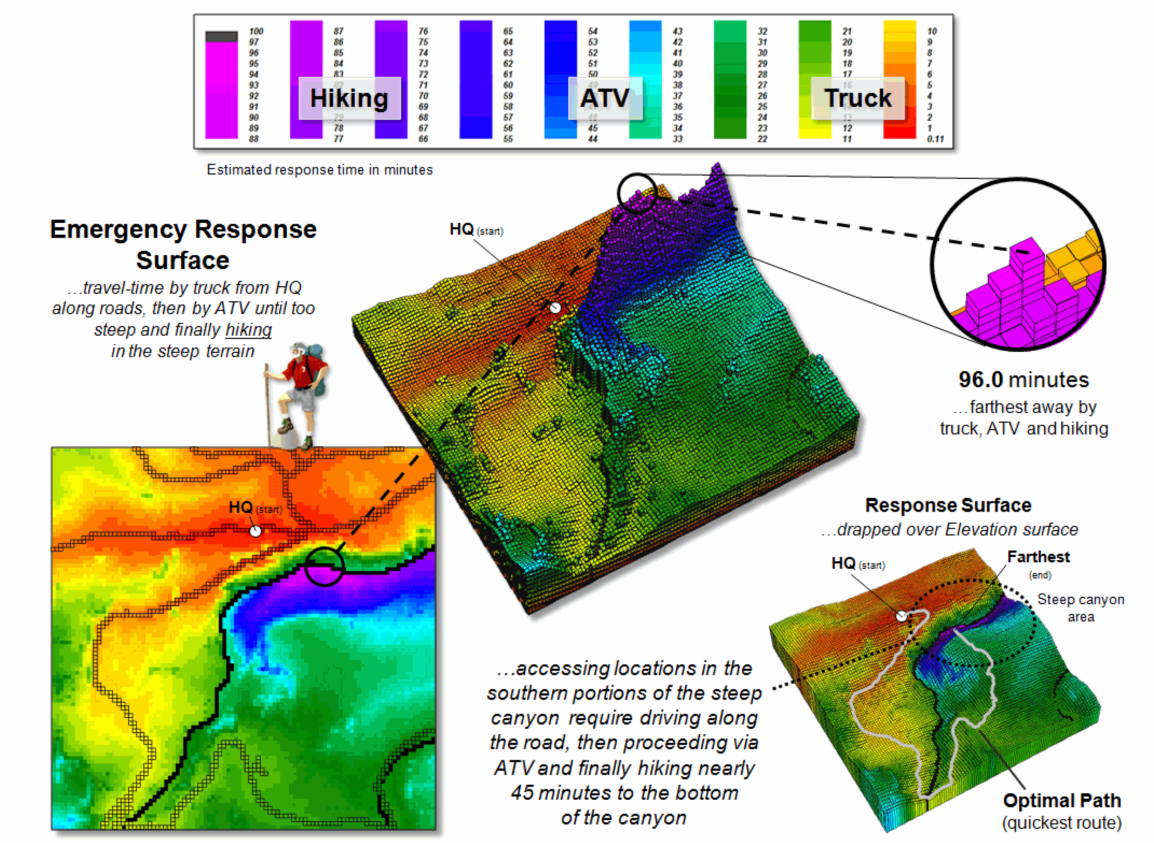


Figure 3. On-road plus off-road travel-time by ATV and then hiking under extreme terrain conditions.

The bottom line of all this discussion is that GIS modeling can extend emergency response planning "beyond the lines" of a fixed road network—an important spatial reasoning point for GIS'ers and non-GIS'ing resource managers alike.

Author's Note: *See www.innovativegis.com/basis/MapAnalysis/Topic29/EmergencyResponse.htm for an animated slide set illustrating the incremental propagation of the travel-time wave front considering on- and off-road travel and materials for a "hands-on" exercise in deriving continuous space emergency response surfaces.*

Extending Emergency Response

Beyond the Lines

(GeoWorld, August 2010)

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The previous section described a basic GIS model for backcountry emergency response considering both on- and off-road travel. The process used grid-based map analysis techniques that consider the spatial arrangement of absolute barriers (not passable) and relative barriers (passable with varying ease) that impede emergency response throughout continuous geographic space.

While the processing approach is conceptually similar to Network Analysis, movement is not constrained to a linear network of roads represented as a series of irregular line segments but can consider travel throughout geographic space represented as a set of uniform grid cells. The model assumes that the response team first travels by truck along existing roads, then off-loads their all-terrain vehicles (ATV) for travel away from the roads until open water or steep slopes are encountered. From there the team must proceed on foot. The result of the model is a travel-time map surface with an estimated minimum response time assigned to each map location in a project area.

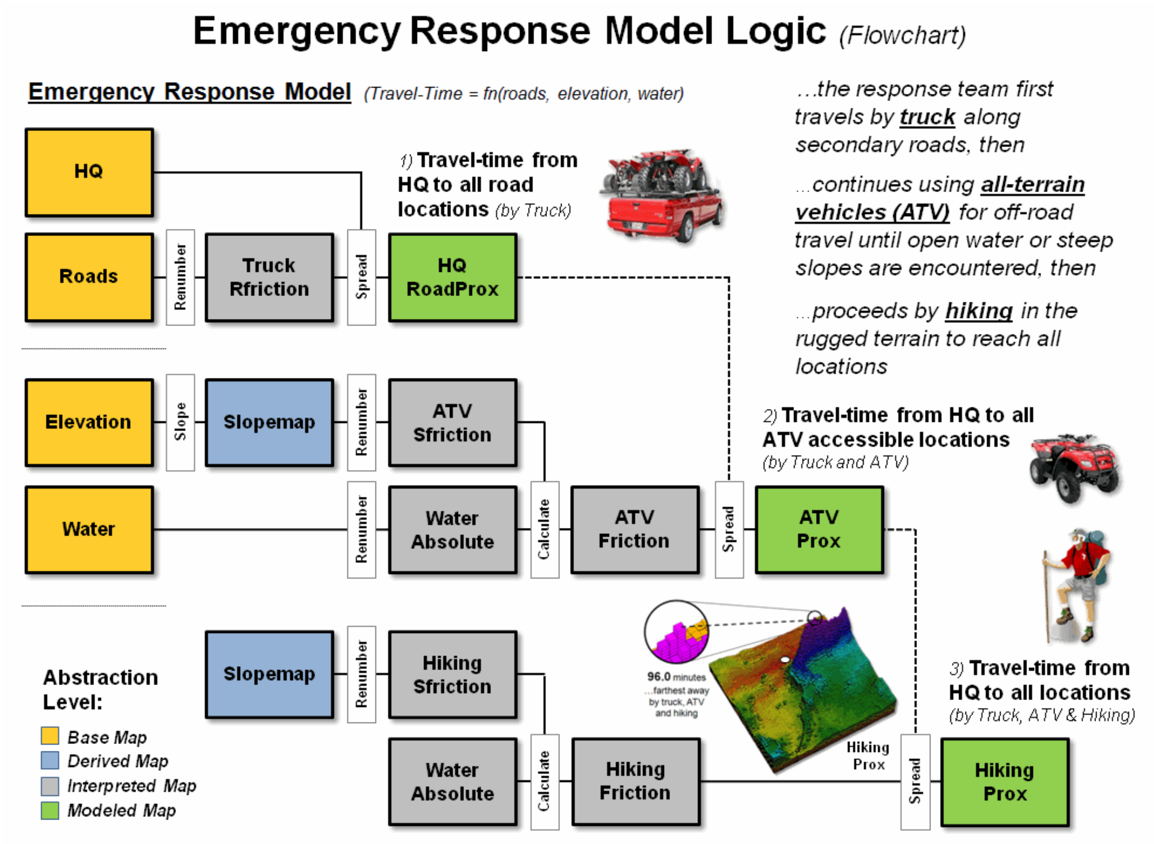

Figure 1. Flowchart of map analysis processing to establish emergency response time to any location within a project area.

Last section's discussion described the key conceptual considerations and results of the three stages of backcountry emergency response model—truck, ATV and hiking movement. The most notable points were that movement proceeds as ever increasing waves emanating from a staring location that are guided by absolute/relative barriers and results in a continuous travel-time map (bowl-like 3D surface).

Figure 1 outlines the processing as a flowchart. Boxes represent map layers and lines represent analysis tools (MapCalc commands are indicated). The flowchart is organized with columns characterizing "analysis levels" proceeding from Base maps (existing data), to Derived maps, to Interpreted maps, to Modeled map solutions. The progression reflects a gradient of abstraction from "fact-based" (physical) characterization of the landscape involving Base and Derived maps, through increasingly more "judgment-based" (conceptual) characterizations involving Interpreted and Modeled maps expressing spatial relationships within the context of a problem.

The row groupings represent "criteria considerations" used in solving a spatial problem. In this case, the processing first considers truck travel along the roads then extends the movement off-road by ATV travel and finally hiking into the areas that are inaccessible by ATV. The off-road movement is guided by open water (absolute barrier for both ATV and hiking) and terrain steepness (relative barrier for both ATV and hiking and absolute barrier for ATV in very steep slopes).

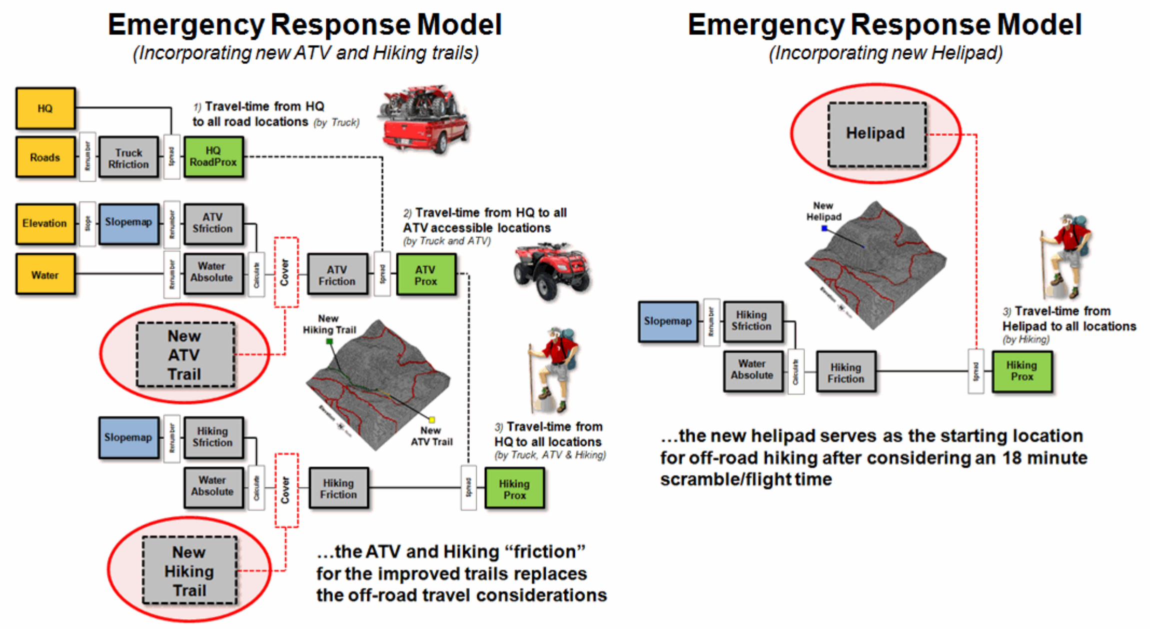

Figure 2. Extended response models for new trails (left) and helipad (right).

Figure 2 identifies modifications to the model considering construction of new ATV and hiking trails and a helipad. The left side of the figure updates the ATV and hiking "friction" maps with lower travel-time values for the trails over the unimproved off-road travel impedances. The hiking trail includes a foot bridge at the head of the canyon that crosses the river. The revised friction values (ATV trail = 0.15 minutes; hiking trail = 0.5 minutes) directly replace the old values using a single command and the model is re-executed.

In the case of the new helipad (right side of the figure) the hiking submodel is used but with a new starting location that assumes an 18 minute scramble/flight time to reach the location.

The bottom portion of figure 3 shows the three emergency response surfaces. Visual inspection shows considerable differences in the estimated response time for the area east of the river.

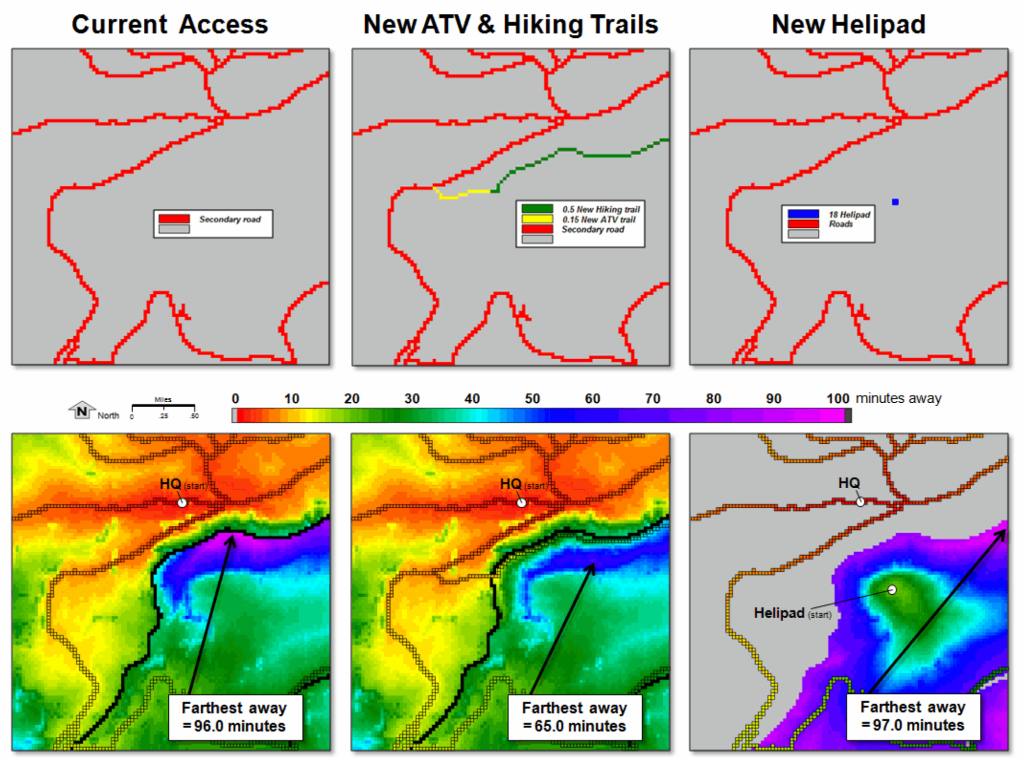

Figure 3. Emergency response surfaces for the current situation, additional trails and helipad.

Current access requires truck travel across the bridge over the river in the extreme SW portion of the project area. Construction of the new trails provides quick ATV access to the foot bridge then easy hiking on the improved trail along the eastern edge of the river for faster response times on the east side of the canyon (light blue). Construction of the new helipad greatly improves response time for the upper portions of the east side of the canyon.

The next section’s discussion focuses on quantifying the changes in response time and developing routing solutions that indicate the type of travel (truck, ATV, hiking, helicopter) for segments along the optimal path to any location.

Comparing Emergency Response Alternatives

(GeoWorld, September 2010)

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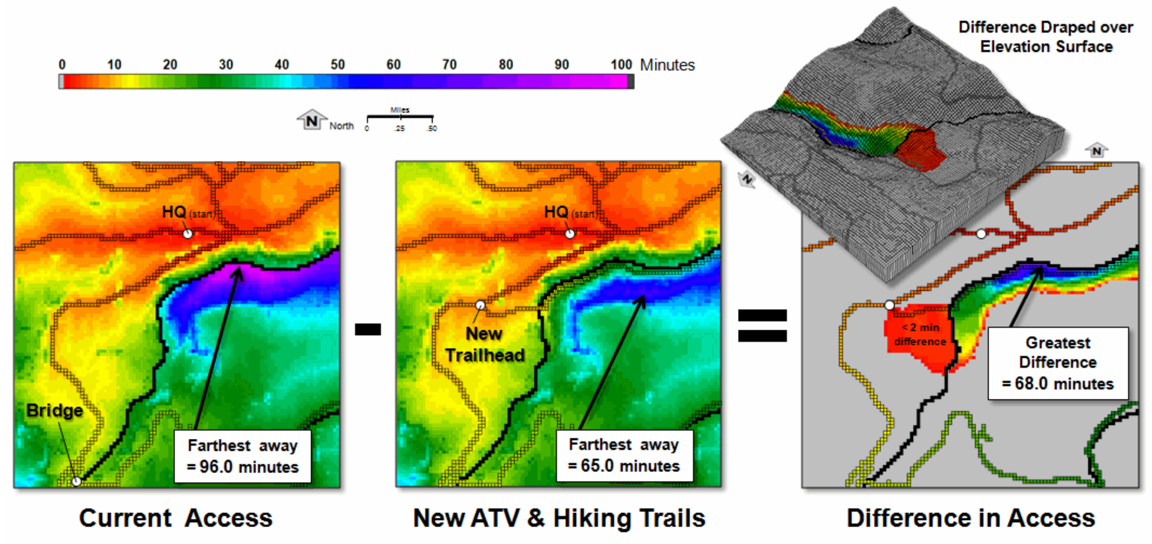
The last couple of sections described a simplified backcountry emergency response model considering both on- and off-road travel and then extended the discussion by simulating two alternative planning scenarios—the introduction of a new ATV/Hiking trail and a Helipad. The conceptual framework, procedures and considerations in developing the alternative scenarios were the focus. This section’s focus is on comparison procedures and route evaluation techniques.



Current Access

New ATV & Hiking Trails

Difference in Access

Figure 1. Subtracting two travel-time surfaces determines the relative advantage at every location in a project area.

The left side of figure 1 depicts the minimum expected travel-time from headquarters to all locations within a project area under current conditions. The river in the center (black) acts as an absolute barrier that forces all travel to the southeastern portion across a bridge in the extreme southwest. This makes the farthest away location more than an hour and a half from the headquarters, although it is less than half a mile away “as the crow flies.”

The inset in the center of the figure locates a proposed new ATV/Hiking trail. The first segment of from the road to the river enables ATV travel. A light suspension bridge crosses the river to provide hiking access to an improved trail along the southern side of the canyon.

While the trail is justified primarily for increasing recreation potential within the canyon, it has considerable impact on emergency response in the canyon. Note the introduction of the green and light blue tones along the river that indicate response times of about half an hour as compared to more than an hour and a half (purple) currently required.

The right side of figure 1 shows the difference in travel-time under current conditions and the proposed new trail. This is accomplished by simply subtracting the two maps—where 0 = unchanged response times (light grey), values = difference in the response times (red through blue tones). The red area between the road and the suspension bridge notes that ATV access is slightly improved (less than 2 minutes difference) with the introduction of the new trail. The greens and blues show considerable improvement in response time with a maximum difference of 68.0 minutes.

Draping the result over the elevation surface shows that the south side of the canyon bottom is best serviced via the new trail. The more important, non-intuitive information is the dividing line of best access approach (red line) halfway up the southern side of the canyon. Locations nearer the top of the canyon are best accessed via the current truck/ATV/Hiking utilizing the southern bridge.

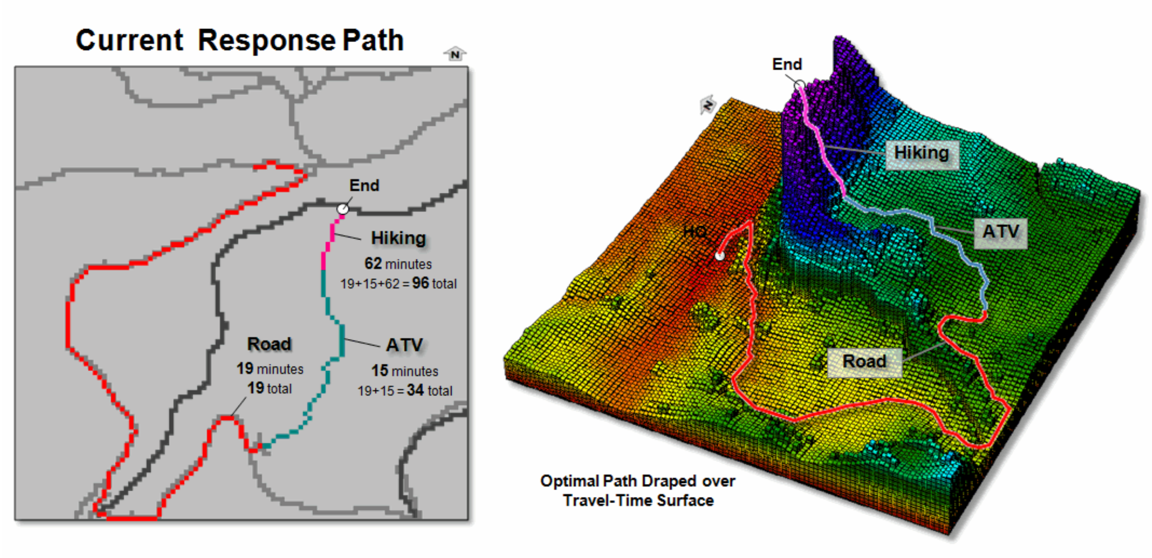

Current Response Path

Figure 2. The optimal path is identified as the steepest downhill route over a travel-time surface.
(see Author's Note)

Figure 2 extends the analysis to characterize the optimal path for the most remote location under current conditions. The first segment (red) routes the truck along the road for approximately 19 minutes to an old logging landing. The ATV's are unloaded and precede off-road (cyan) toward the northeast for an additional 15 minutes (19 + 15= 34 minutes total). Note the route's "bend" to the east to avoid the sharply increased travel-time in the rugged terrain along the west canyon rim as depicted in the travel-time surface.

Once the southern side of the canyon becomes too steep for the ATVs, the rescue team hikes the final segment of 62 minutes (violet) for an estimated total elapsed time of 96 minutes (19 + 15 + 62 = 96). A digitized routing file can be uploaded to a handheld GPS unit to assist off-road navigation and real-time coordinates can be sent back to headquarters for monitoring the team's progress—much like commonplace network navigation/tracking systems in cars and trucks, except on- and off-road movement is considered.

The backbone of the backcountry emergency response model is the derivation of the travel-time surface (right side of figure 2). It is "calculated once and used many" as any location can be entered and the steepest downhill path over the surface identifies the best response route from headquarters—including Truck, ATV and Hiking segments with their estimated lapsed times and progressive coordinates.

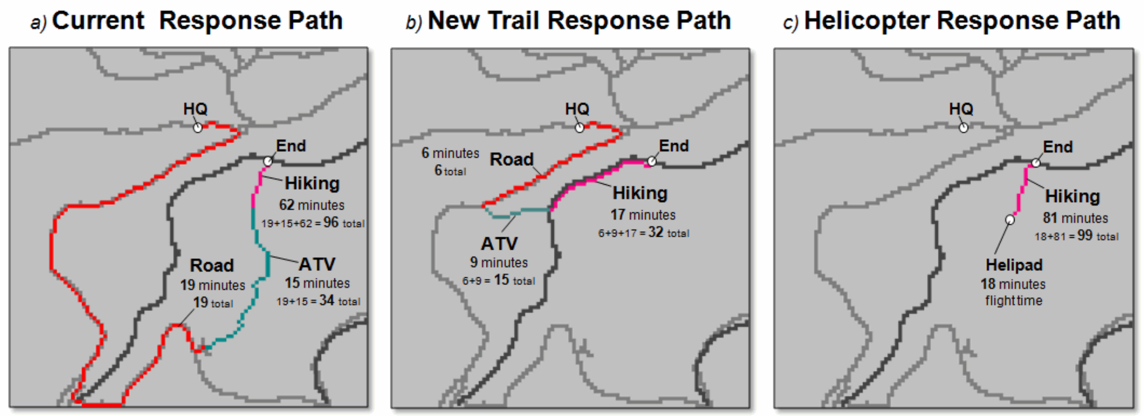


Figure 3. Comparison of emergency response routes to a remote location under alternative scenarios.

In addition, alternate scenarios can be modeled for different conditions, such as seasons, or proposed projects. For example, figure 3 shows three response routes to the same remote location—considering a) current conditions, b) new trail and c) new helipad. In this case, the response is much quicker for the new trail route versus either the current or helipad alternatives.

It is important to note that the validity of any spatial model is dependent on the quality of the underlying data layers and the robustness of the model—garbage in (as well as garbled throughput) is garbage out. In this case, the model only considers one absolute barrier to movement (water) and one relative barrier (slope) making it far too simplistic for operational use. While it is useful for introducing the concept, but considerable interaction between domain experts and GIS specialists is needed to advance the idea into a full-fledged application …any takers out there?

Author's Note: *See Beyond Mapping Compilation Series, book III, Further Reading section 6, "Derive and Use Hiking-Time Maps for Off-Road Travel" posted at* www.innovativegis.com *for a more detailed discussion on deriving off-road travel-time surfaces and establishing optimal paths.*

GIS's Supporting Role in the Future of Natural Resources

(GeoWorld, December 2010)

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My completely charming wife recently made a thought-provoking presentation entitled "Human Dimensions: From Backstage to Front and Center" for a seminar series on Decades of Change in Ecological Research at Colorado State University. In the talk she made reference that in 1970s individual disciplinary scientists controlled the podium of discussion, and social science, its issues and human dimensions, were primarily back stage in natural resource research, planning and management (left side of figure 1).

In the 1980s, the podium became a "team table" with a diversity of disciplines collaboratively engaged in science-based discussion for assessing management options. The discussion around the table was expanded to include social science's theories and understandings of human values, attitudes and behaviors.

During the 1990s, the team table expanded further to a room full of "banquet tables" containing a broad diversity of interests promoting direct and active engagement of scientists, managers, stakeholders and representative publics in the conversation. The interaction was space/time bound to scheduled meetings, representative input, organized discussion and manual flip chart documentation.

What dramatically changed over the years is the role of human dimensions in addressing natural resource issues from its early "back stage" position to a "front and center" involvement and increasingly active voice.

Today and into the future, *Social Acceptability* has fully joined *Ecosystem Sustainability* and *Economic Viability* as a critical third filter needed for successful decision-making (figure 2). Like a three-legged stool, removal of any of the legs results in an unstable condition and the likelihood of failed decisions.

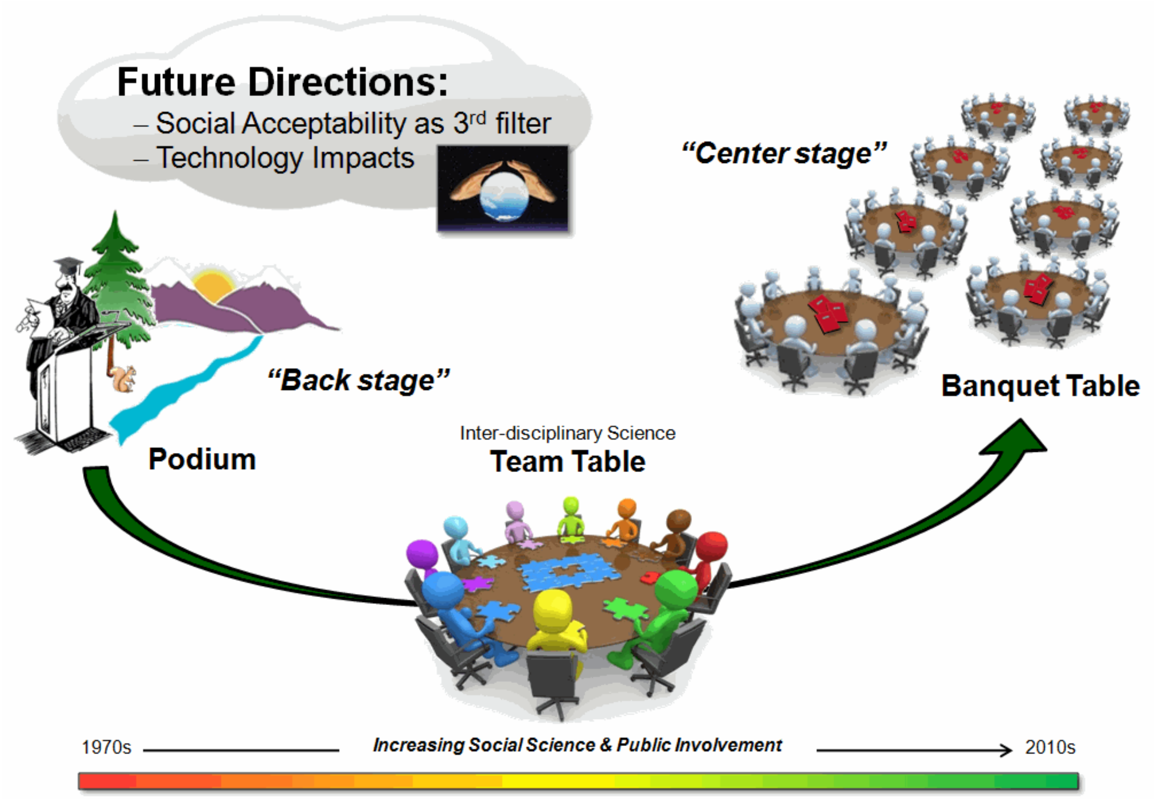

Figure 1. Social science and human dimensions in natural resources have moved from back stage to front and center.

Joining social acceptability as a significant factor impacting the future of natural resources is the changing capabilities and roles of technology— with geotechnology poised to play a key supporting role. Spatially-enabled *Social Networking* concepts, such as "community collaborative mapping," "participatory GIS," "user generated content" and the "spatial tweet" will be the shared futures of social science, natural resources and geotechnology.

To a large extent, GIS technology had a fairly slow start in natural resources as practical application got mired in the forest mensuration and mapping units within most NR organizations— data first, utility later. While innovative research projects demonstrated new ways of doing business with spatial data, the data-centric perspective of the specialists (mapping and geo-query) dominated the analysis-centric needs of the managers, policy and decision makers (spatial reasoning and modeling).

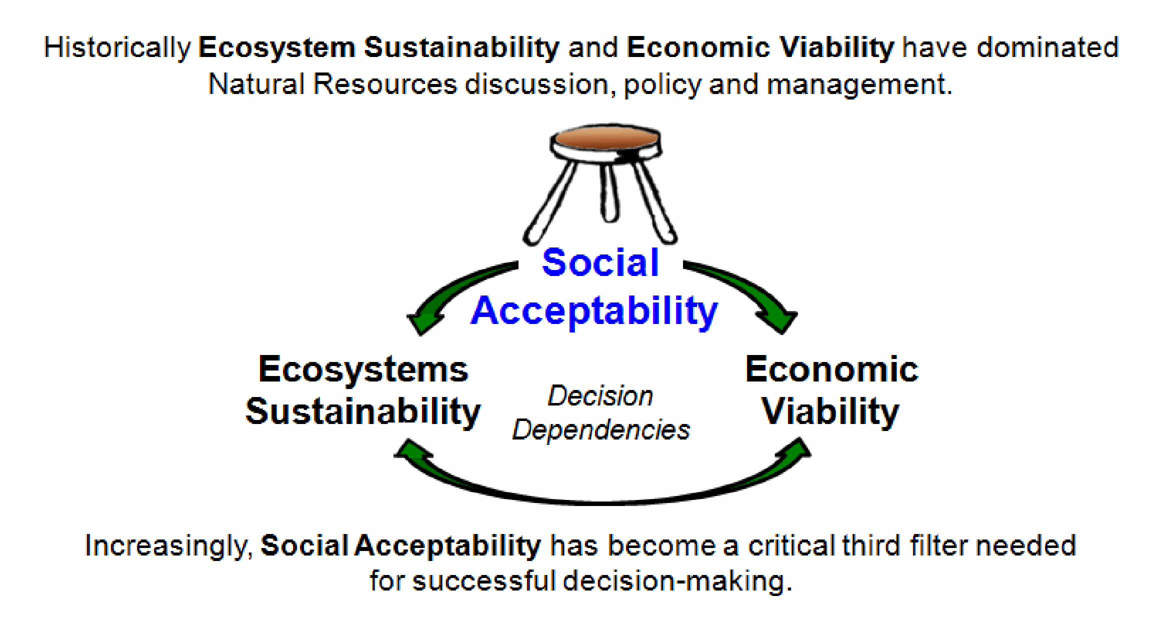

Figure 2. Social acceptability of plans and policy has become an important third filter in natural resources management.

But with the growing voice of human dimensions in natural resources there appears to be a plot twist in the works. Maps are being viewed less and less as static wall hangings depicting "*where is what*" and more as dynamic spatial expressions of "*why, so what and what if…*" within the context of alternative management and policy options.

That brings us to one of the hottest new things in computing… "crowdsourcing." In case some of you (most?) might not be aware of this new field, a thumbnail sketch with a bit of discussion seems in order (figure 3). *Crowdsourcing* is a term that mashes the words "crowd" and "outsourcing" to describe *the act of taking tasks traditionally performed by a team of in-house or outsourced specialists, and outsourcing the tasks to the community through an 'open call' to a large group of people (the crowd) asking for their input (Wikipedia).*

For example, the public may be invited to carry out a design task (also known as "community-based design" and "distributed participatory design"), or help capture, systematize or analyze large amounts of data (citizen science) by *leveraging mass collaboration enabled by the Internet*.

Many cities now provide a smart phone "app" for citizens to take a picture of a pothole and send the geo-tagged photo to the streets department. In a similar manner, park users could report hiking trail locations in need of repair, rate their of trail experience or even send pictures of areas they believe are unusually beautiful or ugly. Crowdsourcing simply provides a modern mechanism for completing a survey in digital form while in route or when they get back to the parking lot and civilized connectivity.

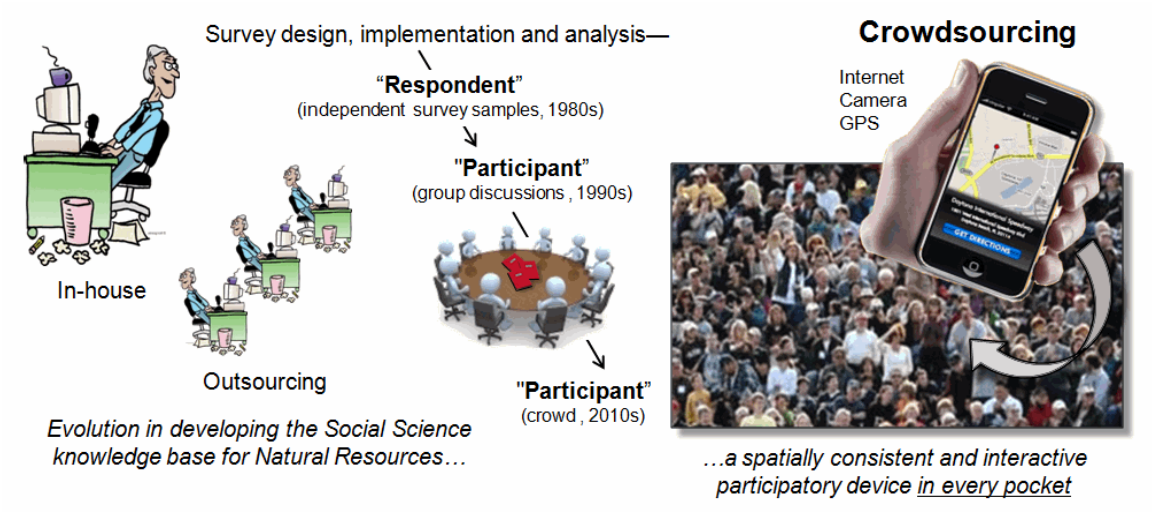

Figure 3. Crowdsourcing solicits mass collaboration via the Internet in formulating socially acceptable policy and plans.

However for natural resource professionals and GIS'ers, crowdsourcing can go well beyond data collection by extending the "social science tools" for consensus building and conflict resolution used in calibrating and weighting spatial models. For example, a model for routing an electric transmission line that considers engineering, environmental and development factors can be executed under a variety of scenarios reflecting different influences of the criteria map layers as interpreted by different stakeholder groups (see Author's Note). The result is infusion of the collective interpretation and judgment required for effective cognitive mapping—participatory input.

Currently, the calibrating and weighting a spatial model usually involves a small set of representatives sitting around a table and hashing out a presumed collective opinion of a larger group's understanding, interpretations and relative weightings. Crowdsourcing suggests one can hang a routing or other spatial model out on a website, invite folks to participate, have some GUI's that let them interactively set the model's calibrations and weights, and then execute their scenario. They could repeat as often as they like, and once satisfied with a solution they would submit the model parameters. Sort of a virtual public hearing but with more refined interaction and less stale doughnuts and lukewarm coffee left on the tables.

To complete the playhouse metaphor, mapping and geo-query will set the stage, while spatial reasoning and modeling plays out the production with the active participation of an extended audience of scientists, managers, stakeholders and publics—sort of a natural resources experimental theater in the round. This ought to be fun with human dimensions front and center in the limelight and geotechnology handling the stage management.

Author's Note: *For a discussion of procedures in participatory GIS see Beyond Mapping Compilation Series book III, Topic 8 section 3 "A Recipe for Calibrating and Weighting GIS Model Criteria" posted at* www.innovativegis.com. .

Further Online Reading: *(Chronological listing posted at* ***www.innovativegis.com/basis/BeyondMappingSeries/****)*

A Twelve-step Program for Recovery from Flaky Forest Formulations — *describes a spatial model for identifying Landings and Timbersheds (June 2010)*

Bringing Travel and Terrain Directions into Line — *describes comparison procedures and route evaluation techniques (December 2012)*

Optimal Path Density is not all that Dense (Conceptually) — *uses Optimal Path Density Analysis to identify "corridors of common access" (January 2013)*

Assessing Wildfire Response (Part 1): *Oneth by Land, Twoeth by Air* — *discusses a spatial model for determining effective helicopter landing zones (August 2011)*

Assessing Wildfire Response (Part 2): *Jumping Right into It* — *describes map analysis procedures for determining initial response time for alternative attack modes (September 2011)*

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