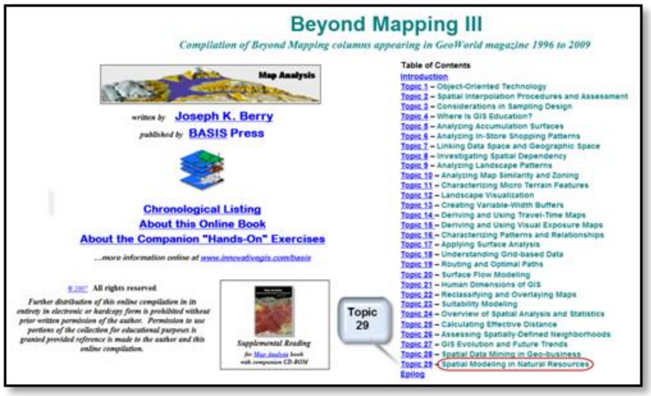
E911 for the Backcountry

(GeoWorld, July 2010)



www.innovativegis.com/basis/MapAnalysis/

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.

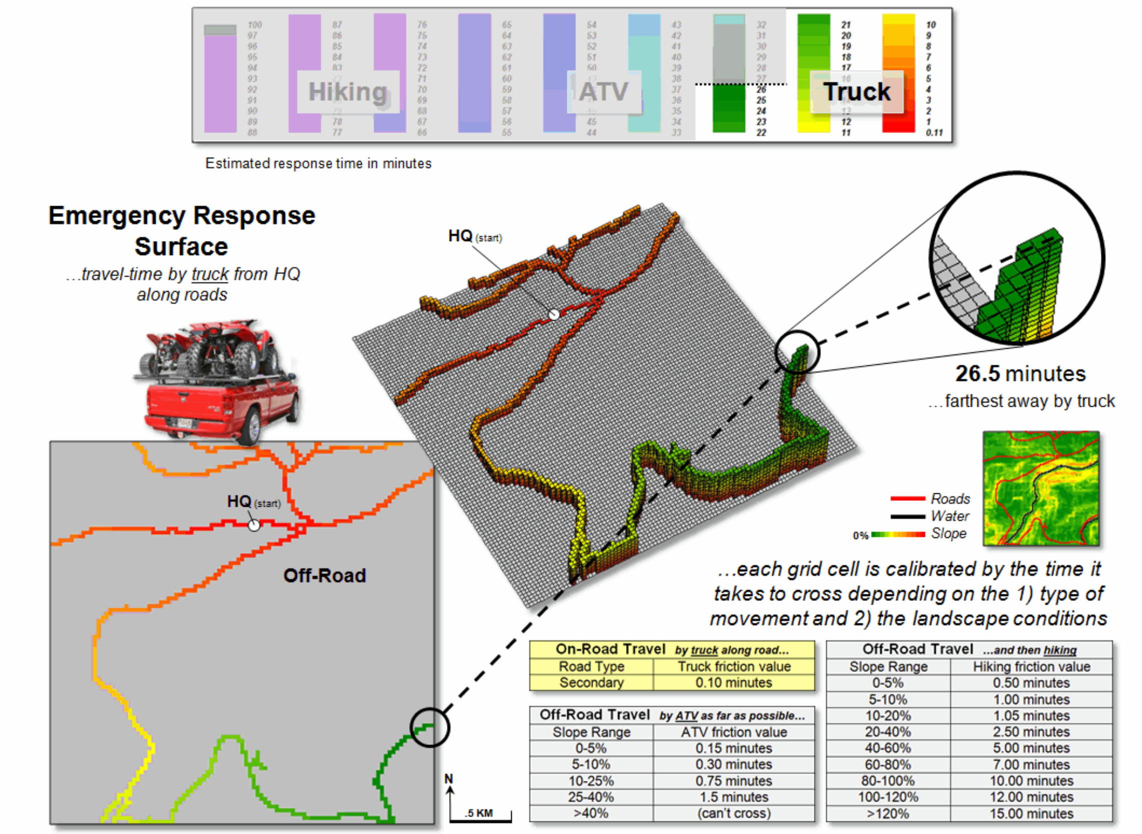


Figure 1. On-road emergency response travel-time.

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 start "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.

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.

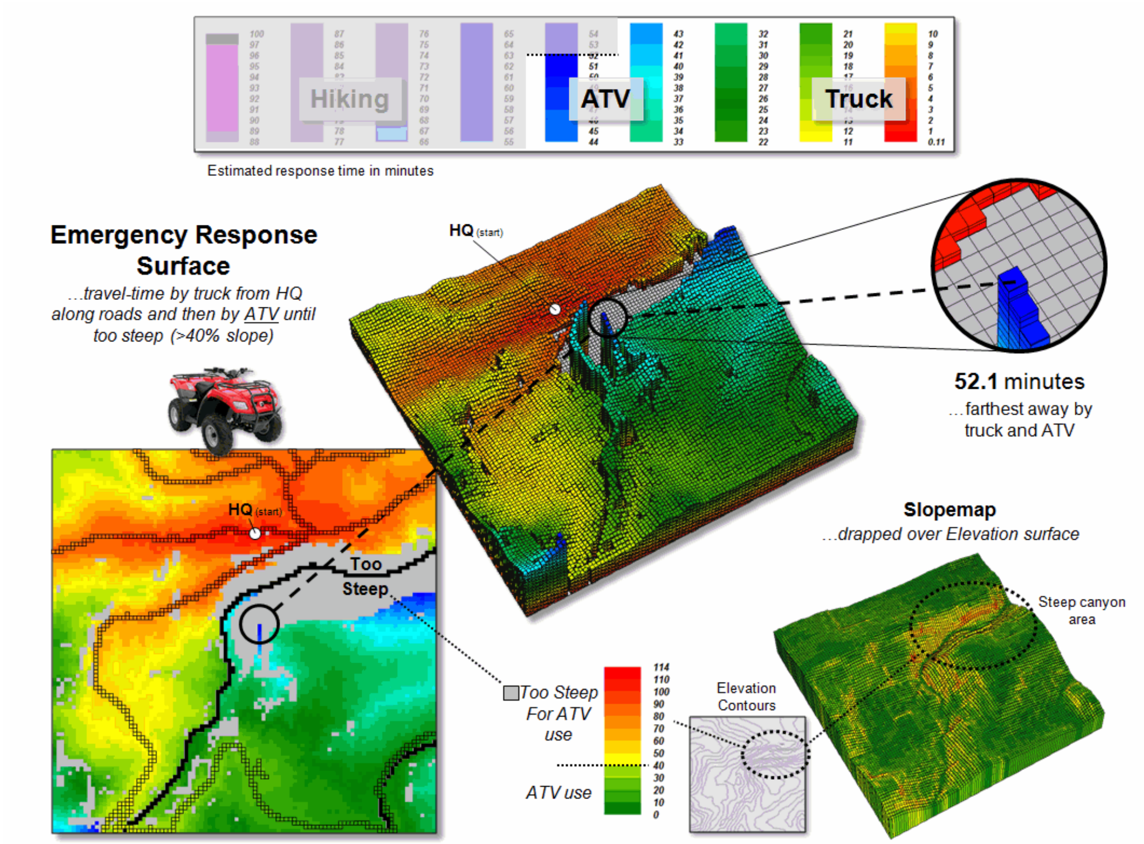


Figure 2. On-road plus off-road travel-time using ATV under operable terrain conditions.

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.

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.

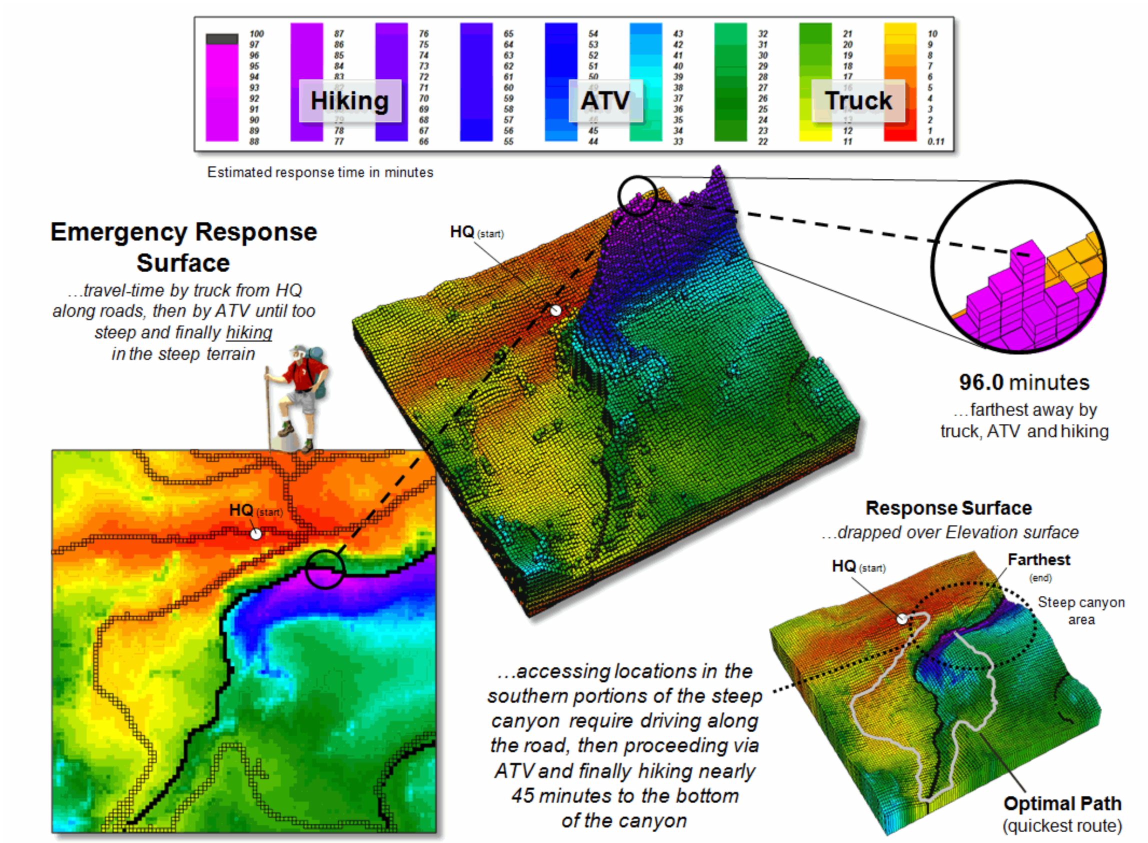


Figure 3. On-road plus off-road travel-time by ATV and then hiking under extreme terrain conditions.

(GeoWorld, July 2010 excerpt)

Figure 4 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 4). 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.

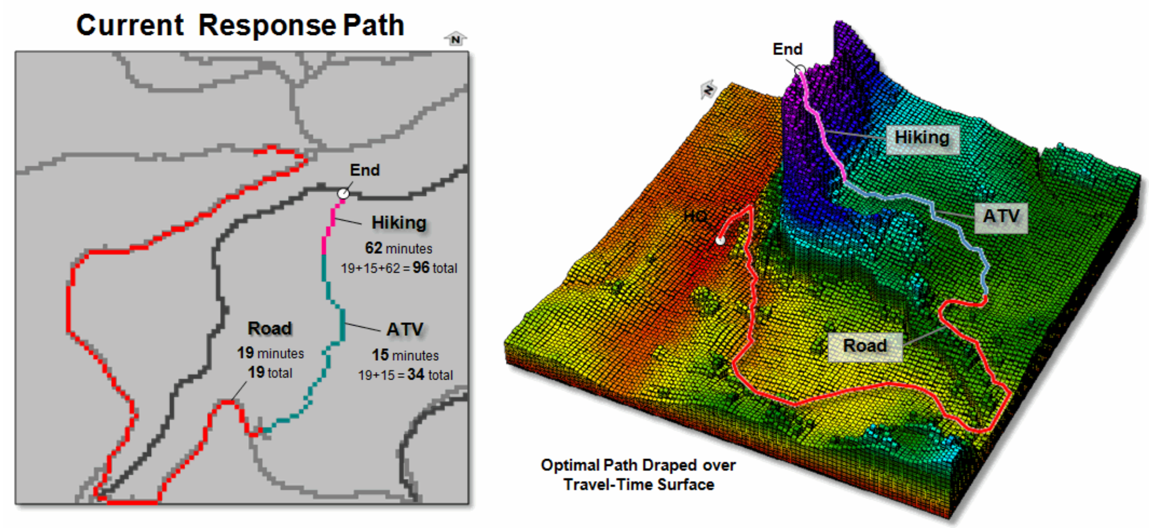


Figure 4. The optimal path is identified as the steepest downhill route over a travel-time surface. (see Author's Note 2)

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 Notes: 1) *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. 2) See www.innovativegis.com/basis/MapAnalysis/Topic14/Topic14.htm#Hiking_time for a more detailed discussion on deriving off-road travel-time surfaces and establishing optimal paths. 3) For background information in applying "effective distance" in natural resources, see www.innovativegis.com/basis/MapAnalysis/Topic29/Topic29.htm. 4) See www.innovativegis.com/basis/MapAnalysis/Topic25/Topic25.htm for detailed discussion of the "splash" algorithm for calculating effective distance.*