

GIS Analysis Tools in Submarine Cable Planning

While the advantages of Geographic Information Systems (GIS) for storing and displaying spatial data are widely recognised, the analytic capabilities are less well known outside the GIS community. Extensions to core GIS software make possible new information, insights and better understanding of spatial relationships.

GIS analysis functions can identify locations that meet a set of criteria, reclassify data to a common class-scale, weight datasets and combine these to analyse suitability or adherence to a given set of rules. GIS provides the framework for solving complicated problems. The output can be displayed on a map, where relationships are apparent and solutions can be devised. We have used analytic functions available in the ESRI ArcGIS extension Spatial Analyst to define a cable route through complex seafloor in the deep ocean (Figure 1). At Fugro Seafloor Surveys, Inc. (FSSI) desktop studies are produced for potential cable routes through the world's oceans, increasing awareness of the challenges inherent in finding the safest and least expensive route for an undersea cable. Distinct requirements for cable installation differ for deep and shallow water. The model described first is for a cable placed in deep water (>1,500 metres); subsequently, necessary modifications are addressed for a cable laid in shallow water, where it is often buried for protection.

Deep-water Model

Cable installers typically plan cable routes to avoid hard seafloor and steep slopes and they attempt to position a cable two to three times water-depth from hazards, obstructions or repeaters of adjacent cables (Table 1). Using GIS spatial analyses tools we can find the shortest possible route that meets these installation criteria. To address cable-route planning restrictions we utilise types of data collected prior to and during a route survey. In our model we use survey data collected by an FSSI Sys09 towed sonar that collects co-registered swath bathymetry and imagery data. We include information on the location of adjacent cables, pipelines, wrecks, obstructions, maritime boundaries, fishing areas, and the location and nature of any other non-geologic feature - in other words, features that impact upon installation, safety and maintenance of the cable. We then assign numerical values to describe our set of rules defining favourable areas for cable installation (Table 2). Again, the route must be the shortest suitable distance for cost efficiency and safety.

Defining Cable Route

During route survey precise bathymetry data is acquired and used to calculate a gradient map (Table 1, Figure 2) and seabed imagery (such as grayscale pixel values 0-255) that indicate the reflectivity (or hardness) of the seafloor. So far, we have two easily quantified components of the model (Figure 2). We also maintain and constantly augment a database of the positions of wrecks, obstructions and repeaters relative to any route. Using this information, new datasets are derived to calculate spatial areas of influence of these features as a function of water depth (1 times water depth, etc.) (Figure 3).

Our study area crosses a dramatic seafloor feature, a mid-ocean spreading centre (Figure 1). New seafloor is created at spreading centres, resulting in freshly solidified, unsedimented, rocky seafloor and steep bordering ridges. Addition of the Global Maritime Wrecks Database (from General Dynamics) reveals that the wrecks of two World War II U-boats lie in the axis of the spreading centre. There are a few repeaters and adjacent cables that the route must cross but we observe no other obstructions nearby (Figure 1). It is desirable to keep the route as close as possible to the centre of the swath of acquired data. This retains data surrounding the route for maintenance and algorithms employed in shortest-route programs will preferentially move a route to data edges when high-risk areas cross the entire swath. Using this array of information, we formulate a numerical definition describing where we wish to lay the cable. Data types are reclassified to a common class-scale and levels of importance, or weights, are assigned to the various factors to define a surface that considers all of the criteria and their importance. Reclassification is carried out on a scale of 1 to 5 (1 being most desirable) to reduce all components to a common scale (Table 2). An average depth of 3,500 metres is assumed for purposes of reclassifying the distance to wrecks and repeaters as a function of water depth.

These factors and their levels of importance are combined in the Raster Calculator function in Spatial Analyst. For a cable laid in deep water, and not buried, slopes are less important, so they are given 25% significance (Table 3). Protected cable can mitigate hard seafloor, so a level of 20% importance is assigned to this factor. In the deep ocean it is difficult to retrieve a cable if it fails, and surrounding repeaters and wrecks make this task more hazardous. However, cable faults are rare, so distance to repeaters is given a value of 20%. A 25% weight is assigned for distance to wrecks. In addition to making cable retrieval difficult, it is undesirable to lay the cable across a wreck, where spans or abrasion can occur. A 10% weight is assigned to the swath centre to bias the route to remain in the centre of the swath.

The resulting surface shows by increasing shades of red where it is safest (lightest) to least desirable (darkest) to position the cable (Figure 4). This is termed "risk surface" as it shows risks due to seafloor conditions throughout the area. A starting and end-point is assigned for the chosen route. A cost-weighted function is used with directionality to create risk-distance and risk-direction surfaces for calculating the safest, shortest route meeting our criteria (Figure 4). The route accounts for both weights assigned to various risk factors and distance from start to end points, as well as cumulative distance along the best route. The route drawn by the analytical process is very rough (Figure 4) but a reformatted version of the risk surface and route can be imported into cable planning software, such as MakaiPlan, for refinement, adding cable types, repeaters, calculating distance along the route, etc.

Changes for Shallow Water

To apply this method to a buried cable laid in shallow water, the weights are reassigned (Table 4). Steep slopes are very hazardous to cable ploughs and are assigned a high level of importance. Ploughing through rock requires specialised (and expensive) equipment, so

seafloor hardness also receives a higher weight.

Shortcomings of Method

As usual, there are some inherent shortcomings. For example, unless the survey equipment directly images a wreck the position cannot be assumed accurate. Given that the U-boats sank over sixty years ago and positioning then relied on celestial navigation, we assume that the accuracy of the locations is questionable. This holds true for any obstacle not directly imaged by survey equipment. In addition, the amplitude response of side-scan sonar instruments cannot differentiate the strong sonar return of a hard seafloor from that of a scarp facing the towfish. This factor may be addressed in further iterations of the model.

Other Risk Additions

Engineers planning a cable route consider many more factors than those addressed in our model. Although difficult to quantify, other considerations include:

- changes in bearing to limit number of alter course points
- very hard or very soft sediments presenting risk to plough during burial and burial assessment survey results, such as shear strength of the sediments
- varying distance over which shortest route calculated to account for turning radius
- most likely direction of slope failure in steep areas subject to seismic activity
- removing slope component from side-scan sonar data to reduce sonar response to more accurate measure of seafloor hardness
- minimising paths through territorial seas or marine reserves to minimise host country fees.

Conclusion

Geographic Information System software is a much more valuable tool to the submarine cable industry than merely as a database and map-making platform. GIS spatial modelling functions offer means to gain new insights into survey data that can aid cable route planners by defining areas of seafloor to avoid.

Acknowledgements

The authors thank Deborah Bartlett and Sylvia Emerson of Global Marine Systems for kindly granting permission to use survey data for this analysis. In addition, we acknowledge Lisa Morrow of Tyco Telecommunications, and Sasha Oâ€™Bow-Hove of Alcatel Submarine Systems for their comments on the analysis parameters and other generous input.

<https://www.hydro-international.com/content/article/gis-analysis-tools-in-submarine-cable-planning>
