



# Dynamic Pipeline Route Assessment

## Enhanced Value through Applied Analysis

### Least Cost Path Analysis

Least Cost Path (LCP) analysis has a high level of applicability to the pipeline routing process. Documented cases of applying LCP have proven cost savings of 5% up to 30% on overall pipeline construction costs.

### Constraint Based Routing

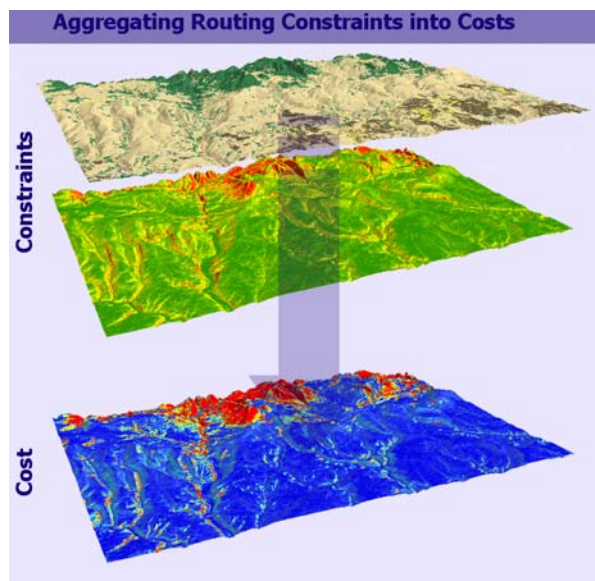
The most common approach for applying LCP to pipeline routing is based on rationalizing routing constraints into a ranking system. Ranking systems used are most often relative ranking systems and result in capture of construction costs as a series of effort and avoidance maps. These effort and avoidance maps are developed from the experience of pipeline routing subject matter experts for such items as geotechnical hazards, environmental impact, terrain constraints, socioeconomic concerns, construction logistics, and regulatory and risk issues.

Another ranking system approach in use is one that moves away from relative ranking towards true dollar value costs. A relative ranking system may place the values of 1 through to 10 on the effort to construct a pipeline given a particular land classification. The true dollar value cost approach, on the other hand, is to assign a dollar value per mile (or per unit length) to each type of land classification. So a relative ranking may say that the effort is "3" for pipeline construction in moderately rolling agricultural land whereas a true dollar cost may be reported as \$1.2MM/mile.

In either case, the cumulative "efforts" or dollar costs of coincident concerns must be accounted for through rule-based aggregation.

### Terrain and Constraint Based Routing

When using a purely Constraint based routing approach the slope is calculated prior and ranked prior to applying the LCP analysis. Slope values derived in the pre-calculation are somewhat deceiving since they represent general slope of the terrain and not the slope with respect to the pipeline.



Why is this relevant? The relevance comes into routing because it is slope along the pipeline alignment (longitudinal slope) that is of most concern to the pipeline planning team and not the general slope. The amount of terrain undulation along the pipeline is a measure of several costs throughout the pipeline lifecycle; costs that are evidenced in terms of "cut and fill" operations, constructability, the type of equipment usable in clearing and construction, potential geotechnical issues, pipeline hydraulics, or site remediation.

The migration from constraint based to Terrain and Constraint based routing is relatively simple, especially for those pipeline teams having already invested in establishing relative ranking or true dollar cost maps. The main difference is removing pre-calculated slope from the mix and placing into a multi-dimensional LCP algorithm for evaluation at run-time.

Above and beyond the ability to dynamically calculate and evaluate slope, use of a multi-dimensional LCP algorithm provides additional benefits such as:

- Ability to constrain route based on bending radius;



- Assign different costs for uphill and downhill slopes;
- Direct incorporation of terrain effects on labor and equipment effectiveness;
- Improved material estimates since length of pipeline route measured in three dimensional space;
- Evaluation of pipeline hydraulics within a GIS, and;
- Inclusion of proximity related issues, for instance, class location, accessibility, and construction logistics.

to the routing question. However, it also means that the approach is less rigid in its evaluation of the routes, especially with respect to slope. The Terrain and Constraint approach results show a much more highly concentrated solution, that is, less variation or “noise” in the modeling results.

Alignments from both of these approaches coincide in many places. However, within the area of interest windows there is a lateral deviation between the two alignments of nearly 6 miles.

## Comparison Case Study

A case study was setup for a 24” greenfield oil pipeline between known start and end points spaced approximately 140 miles (straight line distance). The area of interest has wide variety of construction costs and a constantly changing mix of rugged and relatively flat terrain.

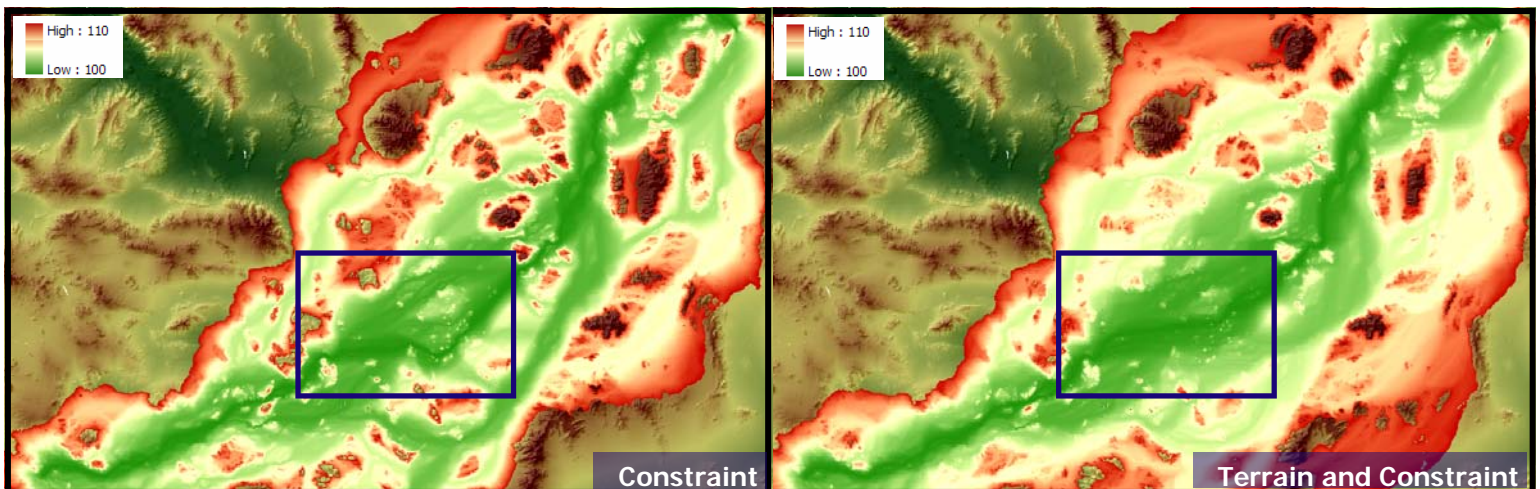
The purpose of this case study was to compare the results of applying Constraint based and Terrain and Constraint based LCP approaches to the same question *“Where is the best path for a pipeline alignment given the relative costs of construction and the desire to construct in areas having slopes less than twenty degrees?”*

The results of the two LCP approaches are shown below. The Constraint approach shows more deep green which indicates that the approach is providing many more “solutions”

## Comparison of Approaches

In this particular case study, the same questions asked of both methodologies resulted in two mildly yet significantly distinct alignments. The Constraint approach produced a pipeline 155 miles in length whereas the Terrain and Constraint approach produced a pipeline that was 150 miles in length. A 5 mile decrease in length or, in other words, approximately 3.2% savings in material and construction costs!

The results show that dynamically accounting for terrain variations during a least cost path analysis produces a tighter set of routing options and this has translated into improved cost savings. Using a Terrain and Constraint approach better mimics engineering requirements while accounting for established relative costs.



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