A Versatile Route Selection Process

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Member

Abstract

Effective early planning is a key step in successful implementation of pipeline projects. Planning activities are often used to support permitting, financing, stakeholder acceptance, design and construction. One of the most important planning aspects of a pipeline project is the selection of an implementable pipeline route. Many resources are available to help evaluate the various factors influencing pipeline route selection. In this paper, a versatile route selection procedure is presented that provides an analysis tool to help organize and evaluate the many influencing factors and resources available to the planning team. The procedure is adaptable to projects ranging from simple to highly complex. It allows for either a specific cost-based analysis or a less specific relative cost approach and is adaptable for calibration to historic site-specific cost data, if applicable. The procedure also provides a method to incorporate the cost analysis with non-cost issues. Route analysis by a quantitative scoring system or by more subjective evaluations are accommodated. Methodologies for stakeholder's to influence the character and results of evaluations are presented. The route selection process has been used successfully on a variety of both sanitary sewer and water system pipelines through the western United States.

Background

The planning of engineering projects is often a complex balance of the project's technical needs with those of other factors influencing the work. Pipeline projects can be among the most complex during the planning stage since their long linear influence zones often result in some type of interaction with a significant number of external factors. Because of this complexity, effective early planning is often a key step in successful implementation of pipeline projects. One of the most important planning aspects for these projects is the selection of the pipeline route. The pipeline route will typically influence all the various factors affecting the implementation of the project.

Many resources are available to help identify and evaluate the pipeline route selection issues. *Pipeline Route Selection for Rural and Cross-Country Pipelines* (ASCE Manuals and Reports on Engineering Practice No. 46, 1998) is a comprehensive publication that describes a wide variety of factors influencing the selection of pipeline routes. Although the title of the ASCE manual implies it may not be applicable to urban installations, experience shows that many of the issues discussed in the manual are directly applicable in the urban environment. Also, many engineers and planners throughout the world have developed their own methods and analysis tools for route selection. Local agencies have long recognized the nature of pipeline projects and many have developed guidelines, or in some cases, laws and regulations governing their implementation. Some cities, for example, have adopted ordinances that do not allow open cutting of newly paved arterial streets for a prescribed time period without special permission. Many state transportation

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departments require pipeline crossings of state highways to be constructed using only tunneling or bore and jack techniques.

In addition to their usefulness in planning of projects, pipeline route studies are often a necessary step in the implementation of these types of projects. Environmental documentation and related permitting efforts often require that a full analysis of alternative routes be conducted prior to applying for permits or certifying environmental documents. Land acquisition by condemnation can also be difficult if the sponsoring agency cannot demonstrate that alternative routes are not in the best interests of the public. Accordingly, it is often critical that the pipeline route selection process be adaptable to specific project conditions, be easily understood, and be capable of supporting the decisions made by the sponsoring agency.

In this paper, a route selection process intended to allow the systematic evaluation of all these issues is described. The process has been designed to allow the project team to select the apparent best route relative to the full scope of interests influencing implementation of a pipeline project. The process is intended to be compatible with, and complementary to, other route selection resources available to the project team. Although a variety of pipeline route selection issues are specifically described in this paper, the route selection process described herein has been designed to be suitably versatile such that it may be adapted to whatever set of factors and decision making procedures are important to the individual project.

Basic Planning Elements

Individual pipeline projects are typically a component of a larger-scale project or system. The basic planning elements of these larger-scale projects will normally have some influence on the characteristics of the pipeline project. Typically the following basic planning elements are included in both the pipeline component of larger-scale projects or those of more pure pipeline projects:

- **Identification of Need**—This element includes the basic determination that a pipeline is required to accomplish some type of conveyance function. This element is typically part of a master plan or facility plan type of activity.
- **Estimating Demands or Flowrates**—This element is a key step in establishing the scope of the project and is also typically part of a master plan or facility plan type of activity.
- **Hydraulic Analyses**—This element will usually begin during the master plan or facility plan stage and continually influence the characteristics of the project until it is finalized during project design. It is an important planning element prior to the pipeline route study since it is often used to establish a planning level estimate of the pipe size and other key characteristics (i.e. the scope of a route study for a 72-inch pipeline is often significantly more involved than that for a 24-inch pipeline).
- **Identify System Configuration Requirements**—This element begins along with the hydraulic analyses and is used to conceptualize the actual facility. It typically includes reconnaissance level layout of the facility in the actual project area and the identification of appurtenant features, such as valve vaults. Site limitations due to factors such as topography and physical obstructions are usually identified. This

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planning element is the stage where alternative pipeline systems (including routes) are initially developed.

- **Route Analysis and Selection**—This element builds on the alternatives identified during the configuration identification stage. The end product is the apparent best route that will be pursued for final implementation.

- **Preliminary Design and Implementation**—This element is typically the last step in the planning process. The apparent best route would be evaluated and expanded to provide more precise detail and the project would typically move into the stage of acquiring and finalizing the necessary permissions to design and construct the system.

An expanded description of the full planning process for a pipeline project is beyond the scope of this paper. As such, this paper will focus on a more detailed development of only the **Identification of System Configuration Requirements** and the **Route Analysis and Selection** elements of the planning process described above. The author also acknowledges that many agencies have a specific planning process that would likely include different steps to implement a project than those listed above. However, it is expected that the planning elements listed above would normally be included in all planning processes in some fashion and in approximately the same order. Therefore, the route selection process described in the remainder of this paper should be adaptable into the various planning steps used by most agencies.

Identification of System Configuration Requirements

Establishing the configuration requirements for a pipeline system generally involves the conceptual layout of that system which, in turn, must be developed in consideration of the system's intended function. The following are the key system features generally considered in developing conceptual pipeline system layouts:

- **Source Connections and Pressure**—The supply source for the pipeline must be identified. The characteristics of that source (i.e. location, pressure, size, etc.) must also be considered for compatibility with the pipeline system. Typically this criteria dictates the beginning point and hydraulic supply characteristics of the system. Conversely, the pipeline system can often be used to establish the criteria for this feature if it is not existing.

- **Termination Connections and Pressure**—The end point for the pipeline system must be well understood. The location, flow, and delivery pressure requirements often dictate many aspects of the overall system configuration. As with source connections, the pipeline system may also have an influence on this feature.

- **Intermediate Delivery/Connection Points**—Intermediate deliveries may influence system routes, pipesizes, and hydraulic performance requirements.

- **Occurrence of Pump Stations and Reservoirs**—These features often have predetermined sites and hydraulic characteristics that can limit pipeline system features.

- **Appurtenant Features**—These include line valves, pressure control stations, drains, air release assemblies, and a variety of other features. Depending on the system

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performance needs and site constraints, these features must be considered in the conceptual layout of the pipeline system.

Given an understanding of the system configuration requirements for the pipeline, the project team would develop conceptual layouts of the pipeline system. Other factors such as topography and obvious pipeline route corridors will also influence the selection of the conceptual system configuration. At this stage of project development, the project team will also use a variety of other resources to develop the conceptual layouts. These resources typically include topographic maps, aerial photography, property maps, planning documents, roadway/utility plans, and actual site reconnaissance. A comprehensive assessment of these issues results in the development of the conceptual system layout. Figure 1 presents a simplified example of a conceptual pipeline system configuration and layout.

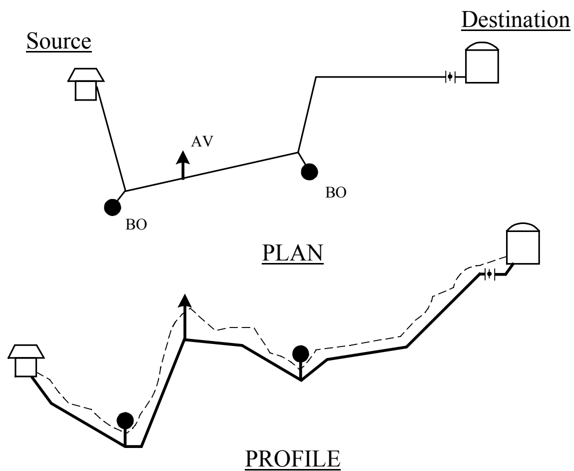

Figure 1. Conceptual System Configuration and Layout (Simplified)

At this stage of project development, the project team would have a good understanding of the project area and system criteria. This is the appropriate stage of the work to develop alternative conceptual layouts. The identification of these alternatives for pipeline projects is most often driven by the use of alternative pipeline routes. Figure 2 illustrates how pipeline route alternatives would impact the conceptual system configuration of Figure 1. This conceptual layout, including alternatives, would become the basis for further analysis of the system.

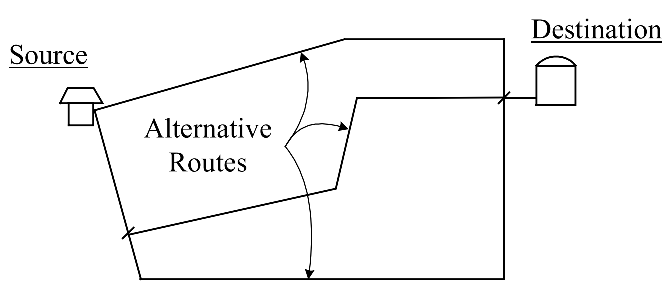

Figure 2. Conceptual System Configuration With Route Alternatives

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Route Analysis and Selection

Once the pipeline system configuration and route alternatives have been developed, route analysis can be conducted and ultimately an apparent best route can be selected. Note that the level of detail used to conduct a pipeline route analysis is not the same for all projects. Some situations require only a cursory evaluation of pipeline route factors. These situations would typically include short/direct pipelines, pipelines in unimproved open country settings, those being installed in existing rights-of-way, those with little or no environmental impacts, and those that are otherwise unencumbered by public opposition or other implementation issues. Conversely, other situations with more complex project features and implementation issues require more detailed evaluations.

In this section, a route analysis and selection methodology will be described that is adaptable to either very cursory or very complex analyses. This methodology includes the following four principal steps that will be developed in more detail:

- Divide Route Alternative into Manageable "Route Segments"
- Conduct Non-Cost and Cost Analyses
- Summarize and Compare Cost and Non-Cost Characteristics
- Select an Apparent Best Route

Route Segments

The development of pipeline route alternatives often involves the use of portions of the route that are common between two or more alternatives. This partial commonality between alternatives can sometimes create difficulty in comparing the relative characteristics of the overall routes that share these common segments. Additionally, the consideration of the common segments of the route can also result in extra descriptive effort and cost estimates to fully present or document the route analyses. In order to help simplify the analysis and comparison of several overall combined routes, the alternative routes should be divided into segments. Generally route segments are selected by identifying the least number of segments that will allow all of the alternative routes to be described by a unique combination of these individual segments. Sometimes, additional segments are added to allow more attention to be paid to significant characteristics of some portion of an overall route (i.e. contaminated areas are often segmented separately). Figure 3 illustrates the optimal segmentation of the alternative routes previously identified in Figure 2. Route segments are shown by the letters A through E.

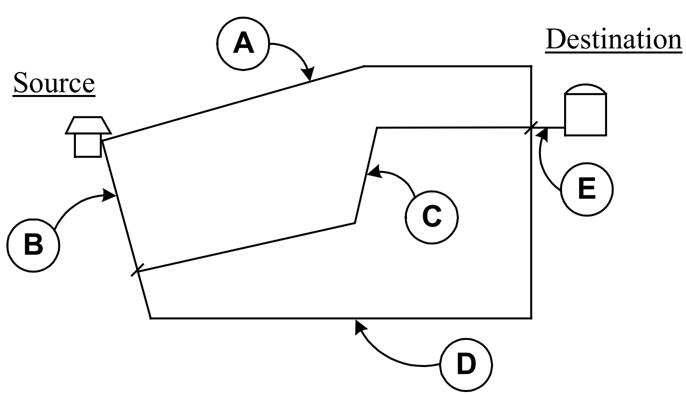

Figure 3: Route Segments for Alternative Routes

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Using the route segments shown in Figure 3, the three overall, or combined, route alternatives can be described using the segments as follows:

Alternative 1—AE
Alternative 2—BCE
Alternative 3—BDE

Non-Cost and Cost Analysis

Non-Cost Analysis. Non-cost analysis involves the evaluation of each route segment and overall combined route according to a specific set of analysis categories. These categories can be developed from a variety of sources. Resources described above, such as ASCE Manual 46 and local agency regulations, can be used. Selection of these categories is also an opportunity for project stakeholders to provide input into the route analysis. Homeowners groups, operations staff, regulators, and other stakeholders often have unique issues that require analysis in this portion of the overall route study.

It is beyond the scope of this paper to provide a comprehensive discussion of all of the various categories that can be considered in the non-cost analysis. Each project team will need to consider the various resources and influencing factors required to select the categories to be used in their individual analyses. In spite of this limitation, the following is a partial listing of general categories often used for non-cost analysis of pipeline routes:

- Constructibility
- Community Disruption
- Existing Utility Conflicts
- Permits/Implementation Issues
- Traffic/Transportion
- Right-of-Way/Land Use
- Environmental Concerns
- Existing System Compatibility

Using the selected categories and key factors applicable within each category, the project team would conduct an analysis of each route segment relative to each category. The analyses may be presented as a written document, a listing of advantages and disadvantages, or a variety of other forms depending on the project scope and complexity. This analysis can also be reviewed with project stakeholders to help ensure that various opinions are reflected in the analyses. Often, workshops are held with representatives of all or some of the stakeholders.

Once the analyses are complete, each segment is given a rating for each category. These ratings can be either a subjective rating, such as “more favorable”, “neutral”, and “less favorable”, or a quantitative numerical score, such as 5 points for very good or only 1 point for relatively negative characteristics. The use of subjective versus quantitative scoring is a project-specific decision. Many agencies prefer the numerically precise comparison offered by the quantitative score while others prefer the relative nature of the subjective scoring. Subjective scoring is generally preferred because it avoids problems sometimes associated with assigning the numerical value and is sometimes more easily accepted by regulators and stakeholder groups. Also, the quantitative method forces a numerical average to be assigned for even highly significant negative characteristics. However, both systems are used extensively in actual practice and both will be fully described in this paper.

Using the non-cost categories listed above and the route segments of Figure 3, Table 1A presents an example of non-cost scoring by the quantitative numerical value method, and Table 1B

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presents an example of non-cost scoring by the subjective method. Note that all ratings are imaginary and are only presented for use in illustrating the route analysis methodology.

Table 1A. Quantitative Non-Cost Route Segment Ratings

Non-cost Category	Route Segment				
	A	B	C	D	E
Constructibility	2	4	4	4	4
Traffic/Transportation	2	4	3	4	5
Community Disruption	2	4	3	4	5
Environmental Concerns	4	4	3	2	3
Right-of-Way/Land Use	3	3	2	2	5
Existing Utility Conflicts	2	3	3	4	2
Permitting/Implementation Issues	3	4	3	3	4
System Compatibility	4	4	4	3	5
Legend: 5=Excellent Characteristics; 1=Poor Characteristics					

Table 1B. Subjective Route Segment Non-Cost Ratings

Non-cost Category	Route Segment				
	A	B	C	D	E
Constructibility	○	●	●	●	●
Traffic/Transportation	○	●	⊙	●	●
Community Disruption	○	●	⊙	●	●
Environmental Concerns	●	●	⊙	○	⊙
Right-of-Way/Land Use	⊙	⊙	○	○	●
Existing Utility Conflicts	○	⊙	⊙	●	○
Permitting/Implementation Issues	⊙	●	⊙	⊙	●
System Compatibility	●	●	●	⊙	●
Legend: More Favorable Characteristic =	●				
Neutral Characteristics =	⊙				
Less Favorable Characteristics =	○				

Once non-cost ratings have been assigned to the route segments, the ratings can be combined for the overall, or combined route alternatives. Combining the ratings for the quantitative numerical method can be done using simple averaging or more complex weighted methods. Averaging does not allow for consideration of the relative importance of the analysis category or the relative length or importance of the segment. For instance, simple averaging would allow an equal influence on the overall score from a low score for a very short segment as would be provided by a high score for a very long segment. In a similar way, simple averaging also dilutes the influence of analysis categories that may be more or less significant relative to one another. The effects of averaging on combining the non-cost ratings can be offset by implementing a weighting system to both the segments themselves and to the rating categories.

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Table 2A illustrates the combining of the route segment ratings from Table 1A. In Table 2A, segment ratings are combined using both a category weighting and a segment weighting based strictly on length. Other methods of segment weighting can also be accommodated within this system. Weighting factors summing to 100% were assigned to each of the analysis categories. The dual weighted score of Table 2A illustrates the effect of algebraically combining the segment length weighting and the analysis category weighting factors. The selection of the weighting factors is an important function that may involve a combination of the project team, project stakeholders, and sponsoring agency staff. This type of involvement in the non-cost analyses generally has a high value to the participants.

As one might expect, combining the ratings for the subjective scoring method is more of a judgement decision. However, involvement of a combination of the project team, project stakeholders, and sponsoring agency staff in rating workshops or other methods of participation is still a key option for this type of rating system. Table 2B illustrates an imaginary combination of the subjective ratings for the individual route segment ratings shown in Table 1B.

Note that one advantage of the quantitative numerical method of combining route segment ratings is the ability to conduct a sensitivity analysis on the results. The category weighting factors can be manipulated up and down in several combinations (always summing to 100%) to assess the sensitivity of the results versus the relative importance of individual categories. The magnitude of the changes in combined ratings due to variations in the weighting factors gives the project team a better appreciation of the validity of the computed results.

Table 2A. Quantitative Combine Route Non-Cost Ratings

Non-cost Category	Category Weighting Factor	Alternative 1			Alternative 2				Alternative 3			
		A	E	Length Weighted Average	B	C	E	Length Weighted Average	B	D	E	Length Weighted Average
Constructibility	20%	2	4	2.1	4	4	4	4.0	4	4	4	4.0
Traffic/Transportation	10%	2	5	2.2	4	3	5	3.3	4	4	5	4.0
Community Disruption	10%	2	5	2.2	4	3	5	3.3	4	4	5	4.0
Environmental Concerns	20%	4	3	3.9	4	3	3	3.2	4	2	3	2.4
Right-of-Way/Land Use	5%	3	5	3.1	3	2	5	2.4	3	2	5	2.3
Existing Utility	5%	2	2	2.0	3	3	2	2.9	3	4	2	3.7
Permitting/Impl Issues	20%	3	4	3.1	4	3	4	3.3	4	3	4	3.2
System Compatibility	10%	4	5	4.1	4	4	5	4.1	4	3	5	3.3
Dual Weighted Non-cost Score				2.93				3.43				3.36
Overall Non-cost Rank				3				1				2

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Table 2B. Subjective Combined Route Non-Cost Ratings											
	Alternative 1			Alternative 2				Alternative 3			
Non-cost Category	A	E	Average Route Rating	B	C	E	Average Route Rating	B	D	E	Average Route Rating
Constructibility	○	●	○	●	●	●	●	●	●	●	●
Traffic/Transportation	○	●	○	●	⊙	●	●	●	●	●	●
Community Disruption	○	●	○	●	⊙	●	●	●	●	●	●
Environmental Concerns	●	⊙	●	●	⊙	⊙	⊙	●	○	⊙	⊙
Right-of-Way/Land Use	⊙	●	⊙	⊙	○	●	⊙	⊙	○	●	⊙
Existing Utility Conflicts	○	○	○	⊙	⊙	○	⊙	⊙	●	○	⊙
Permiting/Impl Issues	⊙	●	⊙	●	⊙	●	●	●	⊙	●	●
System Compatibility	●	●	●	●	●	●	●	●	⊙	●	●
Overall Non-cost Rating	⊙			●				●			
Legend: More Favorable Characteristics = ● Neutral Characteristics = ⊙ Less Favorable Characteristics = ○											

Cost Analysis. Cost analysis of alternative pipeline routes is almost always a key consideration to the sponsoring agency in the selection of the apparent best route. Given the importance of the cost analysis, it is a key goal to be able to provide meaningful cost data without the need for a detailed cost assessment of the specific features of each alternative route. This section presents a simple cost analysis method that satisfies the goal of providing meaningful cost data without detailed route-specific cost estimating.

The cost analysis method described in this section is considered equivalent to order-of-magnitude cost estimate accuracy. If properly prepared, the cost analysis described herein should provide costs within an accuracy range from about 30 percent above to about 30 percent below the actual costs for the pipeline constructed along the alternative route. This level of cost estimating is typical for route studies and should provide a suitable basis for proper route selection.

The cost analysis is conducted by the use of various cost factors for different development conditions influencing the cost of pipeline construction in a given area. These cost factors are established on a relative basis such that they are proportional to a cost factor set at 1.0 for the base development case. These cost factors are referred to as difficulty factors in this paper. A difficulty factor of 1.0 for the base case is assumed to be equivalent to pipeline construction with about 3 to 6 foot depth of cover in normally excavatable soils on a paved street in an urban setting. Existing utilities, traffic, and work space are also assumed to be consistent with conditions encountered in wider feeder streets in modern residential subdivision settings.

The use of these proportional cost factors is based on the application of "cultural modifiers", or difficulty factors, developed as part of the US EPA sanitary sewer system needs assessment work in 1970's. The EPA work suggested the following four basic difficulty factors:

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Open Country	—	0.74
Low Urban	—	1.00
Medium Urban	—	1.19
High Urban	—	1.32

The applicability of the open country case is fairly self-explanatory. The low urban category is characteristic of the base case described above. The medium urban factor is characteristic of fairly congested urban business areas and is typically applied to arterial streets and modern commercial areas serving residential areas. The high urban case is typical for dense urban congested areas typical of town centers, downtown areas, and congested commercial areas.

The basic factors from the US EPA work have proven fairly dependable on several projects where this cost analysis method has been employed. However, project-specific factors should also be developed for situations not readily covered by the four basic factors. Project-specific factors can be developed or reviewed for accuracy on individual projects by estimating the cost of a unit length of the low urban base case (factor = 1.0) and comparing that cost to that for a unit length of the project-specific condition developed using the same cost basis. Project specific factors should be developed on a case-by-case basis.

Experience with this system has revealed the following project-specific difficulty factors that have proven fairly repeatable from project to project:

Forested Land	—	1.15
Gravel Roads	—	0.90
Tunneled Crossings	—	3 to 5

Pipeline projects often encounter cost categories unrelated to the surface development characteristics. These conditions may be common to portions of routes characterized by several of the difficulty factors described above. Experience has shown the following supplemental factors may be applied as project-specific cost factors:

Groundwater Control	—	1.30
Rock Excavation	—	1.40

These factors should be applied as a separate multiplier after applying the difficulty factor for the surface development condition. It may be argued that this method of accounting for supplemental costs would tend to show a higher cost for dealing with these conditions in an urban setting than would be expected in an open country case. While this condition should be reviewed on a case-by-case basis, project experience has shown that the additional complications posed by the more developed situations actually will increase the cost for these supplemental activities in a manner proportionate to the applicable factor.

Another supplemental factor sometimes developed on a project-specific basis for more comprehensive route studies is a depth of cover factor. This factor can help assess the impacts of route alternatives that involve deeper excavations and is typically applicable to gravity flow pipeline projects.

In order to develop a cost estimate for the alternative routes, the project team would assign difficulty factors and applicable supplemental factors to each route segment or applicable portion thereof. By multiplying the difficulty factor by the length of the segment characterized by this

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factor, each route segment can be described using an equivalent length. The equivalent length for each segment included in an overall route alternative would be added together to provide a total equivalent length for the alternative. Finally, this total equivalent length is multiplied by the unit cost for the low urban base case and the basis for a cost estimate is created. Using this approach, an actual cost estimate is only required for a unit length of the low urban case plus any project-specific factors, as described above.

Note that appurtenant structures would also need to be accounted for to develop a complete cost estimate. A unit cost for each type of appurtenant structure can be developed and incorporated into the estimate. The conceptual system configuration developed earlier can be used to quantify these project features. Applicable contingencies and other indirect costs would also be required to provide a complete cost estimate.

The cost analysis described in this section also has the flexibility to be conducted on a comparative basis and therefore eliminate the need to provide actual dollar values. Often, specific cost values are not properly understood at the preliminary analysis level at which most route studies are conducted. Also, actual cost information can be controversial and add unnecessary complications to relative cost comparisons. Less complex route studies would be prime candidates for these comparative type cost assessments. Conversely, cost information can be useful when the cost of the routes are ultimately compared with the non-cost analysis information. Sometimes the actual cost difference between routes can influence decisions regarding the significance of non-cost issues.

A comparative cost assessment without actual dollar values can be developed by applying the difficulty factors as described above to develop the total equivalent length of the combined alternative. This total equivalent length will usually provide enough information to compare the relative costs between alternative routes. This relative cost comparison assumes that the difference in the cost of appurtenant structures is not significant between alternatives. Often, a numerical accounting of the number and type of appurtenant structures is sufficient to demonstrate their relative influence on the comparative cost information.

Table 3 shows the application of difficulty factors to the route segments illustrated in Figure 3. These factors were selected at random and are only intended to help illustrate the use of the equivalent length concepts. This information will also be used in the next section to illustrate comparison of cost and non-cost analysis.

Table 4 summarizes the equivalent length for the overall combined route alternative examples used in this paper. Table 4 also shows actual lengths for comparison. For this paper, no dollar value estimates are used, only the equivalent length comparative method is illustrated.

As complete cost data or final equivalent lengths are established, the project team would assign an overall cost rating to each alternative. This information is ultimately used as part of the comparison of routes described in the next section. The cost rating for the quantitative method can be assigned in a variety of ways. Some studies have used a simple rank, assigning the value of 1 to the most costly and so on. The ranking method does not account for the relative differences between the alternative costs. For instance, an alternative with a cost more than, but very close to, another alternative may be unfairly penalized relative to that other alternative by use of its lower ranking.

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Table 3. Application of Difficulty Factors and Equivalent Length to Route Segments

Route Segment		Actual Length (ft)	Category	Difficulty Factor	Equivalent Length
A		3700	Medium Urban	1.19	4403
		500	Low Urban	1.00	500
	Total	**4200**			**4903**
B		400	Medium Urban	1.19	476
		700	Low Urban	1.00	700
	Total	**1100**			**1176**
C		2600	Gravel	0.90	2340
		1300	Open Country	0.74	962
	Total	**3900**			**3302**
D		500	Low Urban	1.00	500
		200	Gravel	0.90	180
		4500	Open Country	0.74	3330
	Total	**5200**			**4010**
E		300	Low Urban	1.19	357
	Total	**300**			**357**

Table 4. Total Equivalent Length Summary

Alternative	Route Segments	Equivalent Length	Actual Length	Total Equivalent Length	Total Actual Length
1	A	4903	4200		
	E	357	300	5260	4500
2	B	1176	1100		
	C	3302	3900		
	E	357	300	4835	5300
3	B	1176	1100		
	D	4010	5200		
	E	357	300	5543	6600

A better method to assign overall cost scores is to develop a simple relative cost algorithm. The relative cost algorithm is developed by dividing the cost range into equal segments. The range to be divided into equal segments is defined on the low end by multiplying the lowest difficulty factor used in the analysis to the average total actual length of the combined alternatives. The upper end of the range is determined by multiplying the highest difficulty factor used in the analyses by this same average actual length. The resulting range is divided into equal portions with each portion assigned a numerical value beginning at 1 for the highest portion of the overall range. The number of portions should be equal to the range of non-cost scoring. In the case described in this paper, non-cost ratings range from 1 to 5, therefore 5 portions would be used; 1 being the highest cost and 5 being the lowest. Experience has shown that this relative cost algorithm will typically yield a fair distribution of cost scores relative to the difference between alternatives.

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Subjective ratings are not usually assigned for cost. The final subjective summary and comparison of routes usually just use the actual cost data.

Cost scoring should be considered an academic exercise and is typically not the subject of workshops and significant involvement by stakeholder groups. Cost information is generally less subjective than non-cost analyses and should be treated more factually.

Comparison of Characteristics and Apparent Best Route Selection

Once cost and non-cost analyses have been completed, these characteristics can be summarized and compared for each alternative route. As in the case of the non-cost analyses, these summaries and comparisons can be quantitative or subjective.

For the quantitative comparison, weighting factors for the cost and non-cost ratings must be applied to arrive at a resultant overall rating. As with the non-cost ratings, involvement of the project team, project stakeholders, and the sponsoring agencies staff is often used to select these weighting factors. Also, since this step is simply the final combination of two values (cost and non-cost scores) per alternative route, a sensitivity analysis can easily be conducted to determine the relative impact on the final combined score that results from varying the weighting factors.

Table 5 illustrates an overall summary of cost and non-cost information for the alternative route examples used in this paper. Actual cost information (equivalent length) is also shown in Table 5 to illustrate that this data might also be used in a combined subjective/quantitative comparison of the information.

Table 5. Quantitative Scoring Summary with Length Data

Alternative Route	Actual Length	Equivalent Length	Cost Score	Non-cost Score	Overall Score
1	4500	5260	4	2.93	3.5
2	5300	4835	4	3.43	3.7
3	6600	5543	2	3.36	2.7
		Weighting Factor:	50%	50%	

Table 6 shows subjective summary data for the overall alternative routes. Actual cost information (equivalent length) is also shown in Table 6 to illustrate that cost data is typically used directly for the subjective comparison of the information. The final result of a subjective analysis is often a ranking of alternatives.

Table 6. Subjective Scoring Summary with Length Data

Alternative Route	Actual Length	Equivalent Length	Non-cost Rating	Overall Rating	Overall Rank
1	4500	5260	⊙	⊙	2
2	5300	4835	●	●	1
3	6600	5543	●	⊙	3

Legend: More Favorable Characteristics = ●
Neutral Characteristics = ⊙
Less Favorable Characteristics = ○

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Once all of the information has been summarized and compared, the apparent best route can be selected. Again, considerable value is placed on the ability of involving a combination of the project team, the project stakeholders, and the sponsoring agency's staff in this final step in the process. Once the apparent best route has been established, work related to preliminary design and other actual implementation activities may commence.

Summary of Versatility Features

The route selection process described in this document has several features that provide a wide degree of versatility to the project team. In this section, these features are summarized so the project team can consider these issues while developing their own approach to the route selection process.

Accommodates Variable Complexity: The route selection process can be applied to very simple and very complex analyses. The various tools described for the cost and non-cost analyses can be structured to include more or less information. Also, the level and types of analysis required to arrive at the cost and non-cost ratings is completely within the control of the project team.

Provides Flexible Participation: The various steps in the process allow people of different viewpoints or interests to participate in the project. Their participation may be included at the earliest stages of the analyses or only at the final summary and comparison stage. The process may be conducted solely by the project team or expanded to include a wide variety of stakeholders.

Compatible With Variable Levels of Cost Estimating: The use of project-specific difficulty factors and supplemental factors influences the level of cost estimating required to provide a meaningful result. Depending on the complexity of the work and the sensitivity of the cost data to the route selection, additional difficulty factors and/or more detailed cost estimates can be used to add more cost precision to the analysis of route segment costs.

Cost Estimates Can Be Calibrated: The cost analysis methods described in this document can be calibrated to actual project cost data as part of a cost verification process. Once difficulty factors are identified for a specific project, it is often a useful exercise to apply the cost analysis methods to another local project with known site conditions and costs. This way, the application of the factors and the determination of the base cost value for the low urban (base case) difficulty factor can be adjusted to help provide more accurate and locally adjusted cost results. Once the analysis yields costs consistent with the known actual cost data, these factors and cost values can be applied to the new project with more confidence.

Results Subject to Sensitivity Analysis: A useful tool directly applicable to the quantitative analysis method is the ability to vary the weighting factors and observe the relative impact on the resulting preferred route. This sensitivity testing can be a powerful tool in convincing project stakeholders of the validity of the results. Since the presentation of information for the subjective analyses is fairly simple, a sensitivity analysis can also be applied to that method of data analysis. Sensitivity analyses for the subjective method are typically conducted by workshop discussions or documented in some type of written discussion regarding the impact of extreme interpretations of project issues.

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