The Ability of a Land Ferry System to Alleviate the Increasing Costs of Maintaining the I-80 Transportation Corridor: An Economic Assessment

Final Report

Prepared for the Performance Analysis Division
Nevada Department of Transportation

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EXECUTIVE SUMMARY

This report presents an economic assessment of the ability of a Land Ferry system to alleviate the increasing costs of maintaining the I-80 transportation corridor in Nevada. The project starts at Fernley, Nevada and ends at Wells, Nevada for a length of approximately 320 miles. The project scope includes creating a new alignment close to the existing I-80 highway and the Union Pacific Railroad (UPR) in order to run a Land Ferry system that will help reduce truck traffic along the I-80 Transportation Corridor.

Approximately 10% to 40% of the current volume in this commercial segment of I-80 is truck traffic. The alignment has proven to be vital in the decision-making process, since rail installation is very costly. To minimize the cost of the Land Ferry system, it is important to provide an alignment that uses the most effective route while limiting tunneling, excavation, and fills, since these will increase construction costs substantially.

Power generation for the locomotives is another aspect that needs to be addressed carefully. The University of Nevada, Las Vegas (UNLV) has looked into four different possible sources of energy, including solar, wind, geothermal, and several forms of diesel. The most economical choice for power generation was determined to be wind energy.

The Land Ferry system would not take business away from the existing businesses along the I-80 corridor. However, it may affect truck drivers, depending on how they are paid and taxed. On the other hand, using a Regional Input-Output Modelling System (RIMS II) model, it was estimated that the project would create over 45,788 jobs during the three-year construction period. Furthermore, the operation of the Land Ferry would create 318 permanent jobs.

This report provides a benefit-cost analysis of the Land Ferry project. Using a 40-year analysis period, both user and non-user benefits were quantified and compared to capital costs. The benefits and costs considered in this analysis include savings in travel time saving, reductions of accidents, savings in vehicle operating costs, reductions in vehicle emissions, project capital costs, and project operation and maintenance costs. Results from this analysis are summarized in Table 1.

TABLE 1 Overall Benefits and Costs of the Land Ferry Project

Costs	$4.36B	**Net Present Value**	$3.23B
Benefits	$7.59B	**Benefit/Cost Ratio**	1.7

As expected for this type of project, most of the benefits are in savings in travel time ($356.4M), savings in vehicle operating costs ($1000.4M), reduction of accidents ($674.7M), and pavement maintenance ($511.2M). These benefits are a consequence of the shift of trucks from I-80 to the Land Ferry, which leads to an improvement in pavement roughness. Rough pavements cause speed reductions, increase fuel consumption, and increase vehicle maintenance costs. The overall benefit-cost ratio (1.7) implies a cost-effective project.

INTRODUCTION

The I-80 transportation corridor experiences heavy freight traffic on both highways and railroads. Heavy truck traffic on highways results in high maintenance costs, which are not sustainable considering the current revenue streams. Moreover, heavy trucks consume a large amount of fuel, resulting in significant carbon dioxide (CO_2) emissions. In addition, long driving distances result in safety concerns arising from drivers falling asleep and long response time for accidents. Taking into consideration that the number of trucks will continue to increase, it is very important to start addressing issues regarding maintenance, reliability, safety, and emissions. Alternatives to address these issues include:

1. Highway maintenance as is done currently (status quo option)
2. Add more lanes
3. Add more sidings to the existing railroads
4. De-market Amtrak service
5. Build additional rail systems and tracks
6. Build rail system capable of carrying heavy trucks, a Land Ferry

The difference between the last two alternatives is the capacity and the related infrastructure needed to load and unload trucks instead of a container on the rail carriage. The Land Ferry alternative will support the transport of complete tractor-trailer rigs, with or without the driver. This alternative can offer the convenience of door-to-door service of trucks combined with cost savings associated with the long-haul economics of rail. This can be accomplished by utilizing a loading system to roll heavy trucks onto a flat bed. That is, loading and unloading of all the trucks and vehicles can be accomplished simultaneously. A simulation of the proposed concept can be watched through this link: http://www.youtube.com/watch?v=6rviGklJEMI. A potential layout of the system is illustrated through this link: http://www.youtube.com/watch?v=4w4O9k6VJWI.

The Land Ferry system represents a new multimodal alternative that partially removes trucks from the highway while maintaining the same flexibility currently provided by using trucks. That is, cargo can still be picked up and delivered by trucks while the highway journey can be totally or partially replaced by rail. Around the world, various countries use these multimodal locomotive systems to alleviate many of the concerns raised above. One such system is located in India and it is known as the Roll-on Roll-off (RORO) system. Studies conducted on most comparable route – approximately 400 miles long – showed that when the RORO system operated at full capacity (40 trucks), the total fuel savings were around 10 liters of fuel per kilometer, or 1,407 gallons of fuel per trip *(1)*.

To evaluate the potential of a Land Ferry system, several factors must be considered. As a case study, the I-80 corridor on northern Nevada was chosen to conduct a feasibility analysis. This corridor currently deals with heavy truck traffic and associated high maintenance cost. In addition, the corridor provides various opportunities to utilize removable energies to power the system. In this study, the location of the alignment, the costs for right-of-way and land acquisition, the environmental costs, construction costs, maintenance costs, and user costs all were taken into consideration. In addition, economic impacts of the proposed Land Ferry system were estimated.

The area of interest for this research is the 320 miles stretch of the I-80 corridor connecting Fernley and Wells, in northern Nevada. The location for the origin and destination were suggested by the Nevada Department of Transportation (NDOT) based on their experience and knowledge of the corridor. All the Geographic Information Systems (GIS) data and raster datasets collected for location purposes were clipped and extracted, using a rectangular polygon for the region of interest. Other data used in this research was obtained from the National Map of the Unites States Geological Survey *(2)*. The proposed Land Ferry system in northern Nevada would run parallel to a Union Pacific Railroad (UPR) line with freight and Amtrak service. The existing railroad is currently operating close to capacity due to the maintenance requirements of the existing track and bridges, limitations during flooding, at-grade crossings, and the need to share tracks between freight and passenger transport.

This document is organized as follows.

- Section 1 discusses the background associated with the project.
- Section 2 discusses the proposed alignment for the Land Ferry system.
- The construction costs are provided in Section 3.
- Section 4 describes the automated loading mechanism for sliding vehicles onto and off the platforms.
- Power generation by means of various sources is discussed in Section 5.
- The economic impacts of the Land Ferry system are summarized in Section 6.
- Section 7 summarizes the benefit-cost analysis for the Land Ferry facility that would be located along I-80 in Nevada.

SECTION 1: BACKGROUND

The large amount of trucks utilizing the corridor for freight transport has led to a multitude of glaring issues for Nevada and the rest of the country. The nation has put forth an effort to alleviate the dependence on fossil fuels by promoting the green energy industry; however, logistics companies may find it difficult to utilize such methods due to various constraints. A transportation option that would drastically reduce emissions, promote fuel savings, reduce vehicle maintenance costs, and improve roadway and driver safety very likely would appeal to major logistic operations.

Carbon dioxide emissions are a great cause for concern as they have a large negative impact on the environment; specifically, carbon dioxide is a natural greenhouse gas, and therefore promotes global warming. Further, carbon dioxide contributes to acid rain, which can severely damage plant life. Moreover, I-80 can be a dangerous roadway, given the high amount of long-haul trucking and harsh weather conditions. Experts believe that alleviating the truck traffic will increase roadway safety, and therefore reduce roadway casualties/injuries.

Currently, I-80 runs through numerous towns as it travels across the northern portion of Nevada. However, many of these towns do not warrant the construction of a new train station for the Land Ferry, and the cost of constructing each station is estimated to be significant. In addition, more stations than deemed necessary must not be built in order to lessen the already large financial burden that would accompany the construction of new Land Ferry stations.

In order to determine the best location for the Land Ferry stations, the selection process was based on U.S. census data as well as traffic data collected by the NDOT. The location of the mines scattered throughout northern Nevada was a factor as well. Many of the small towns connected by I-80 primarily rely on these mines as a major source of jobs and income. Because of this, these mines create a large portion of the overall economy for these small towns. In order to attract business from the mines to use the Land Ferry for transportation of goods, either to or from the mines, placing stations close to the mines would be beneficial. However, the final determination of the number and location of stations will be provided by NDOT.

The following objectives will be discussed in the following subsections:

1. A cost-effective alignment
2. Construction costs based on the proposed alignment
3. Development of standards to determine the locomotives necessary for this project
4. Analysis of loading systems to be used to transfer trucks to the Land Ferry
5. Analysis of current traffic trends and the effects of instituting the Land Ferry system
6. Analysis of the economic impact of specified regions, based on construction and operation of the Land Ferry
7. Evaluation of alternatives for power generation by means of solar, geothermal, wind and diesel fuel.
8. A 40-year benefit-cost analysis

SECTION 2: ALIGNMENT

Currently, existing railroad tracks run parallel to the I-80 corridor. However, unlike the interstate, which falls under NDOT's jurisdiction, the Union Pacific Railroad owns and operates the railroad lines. Currently, these railroad lines are either operating under a capacity at a level of service of 'C' or higher *(3)*. As a result, it will be difficult to use the existing railroad lines for the proposed Land Ferry.

The existing UPR alignment parallels I-80 except for three distinct sections, at which the railroad lines divert towards the south in order to serve small towns that are not sit along I-80. These sections also serve to avoid some of the mountainous area typical of the State of Nevada.

A large number of alternative alignments could be proposed to join the two ends (origin and destination), as shown in Figure 1. In this context, it was very difficult to make the right decision in selecting and screening the most promising alignment that later on would prove to be a route that saves time and money *(4)*. In the past, expert judgment was used to establish a preliminary alignment for a new road/railway track. Such a labor-intensive process could be eliminated by utilizing computer-based applications, such as GIS. The selection of an economical alignment using GIS needed both spatial and temporal data, such as land cover, topography, and flood maps.

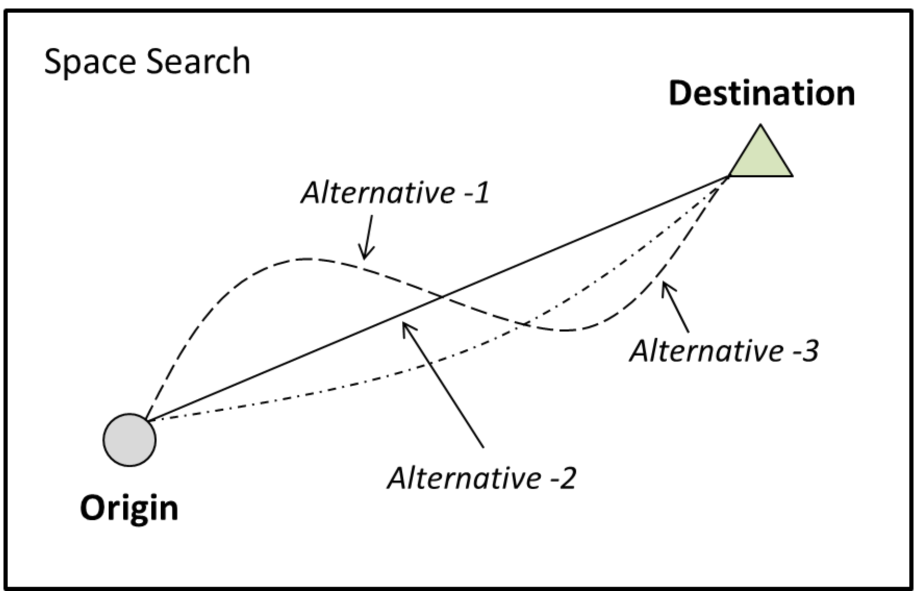


FIGURE 1 Alternative alignments joining the origin and destination.

A new alignment could be designed and constructed if UPR does not allow the use of its railroad lines for the Land Ferry. In this case, one alternative for this new design would be to parallel the existing I-80 as best as possible, similar to the UPR line. This would allow the Land Ferry to serve the interior cities along the I-80. The second alternative would be to create a new alignment that takes a more direct route across the state. If both of these alternatives are considered, it would mean a much higher price and a longer period for the project to construct a new line that spans hundreds of miles. These new line would almost guarantee the need for tunneling, involving increased costs associated with this due to the mountainous terrain.

The natural terrain will play a large role during the design and construction of the proposed railroad line. The maximum grade that a railroad line can have is 1.5%, which means that the alignment will have to circumvent the existing mountains as best as possible *(5)*. Small grade changes could be handled by the cut-and-fill method. This would be the most preferred method, compared to the alternative of tunneling. Due to the large costs associated with tunneling, this option should be avoided unless deemed unavoidable in order to keep project costs at a minimum.

The creation of a new alignment – either in conjunction with the existing alignment or the construction of a completely new alignment – includes the political aspect of acquiring the land necessary in order to construct the project. The U.S. government, particularly the Bureau of Land Management (BLM) owns most of the land in northern Nevada around the I-80. In order to build a new railroad, this land needs to be acquired by whoever owns and operates the railroad. Besides securing the necessary land to construct and operate the Land Ferry, special considerations must be given, if deemed necessary, to cross any existing roads. Cooperation with all concerned jurisdictions will be necessary for the successful execution of the project.

For the proposed alignment, six new stations are recommended by NDOT. This includes five full stations and one half station. Building six stations allows trucks to serve the interior towns of northern Nevada while being close enough to many of the mines in hopes of attracting some of the transportation to and from the mines as well.

Project Study Area

The area of interest for this project is the I-80 corridor in Nevada. Fernley and Wells are considered the two ends – origin and destination, respectively – for which the optimal alignment will be proposed, as shown in Figure 2. The study area includes a 311-mile stretch of the I-80 corridor. In addition, the UPR runs though both ends of the study area.

A part of this project, a methodology was developed to find the optimal alignment for the Land Ferry project, and a sensitivity analysis was performed. The proposed alignment optimizes the existing railroad alignment, based on the following factors.

- Topography, using Digital Elevation Maps (DEM)
- Land cover, such as water bodies, wetlands, farmland, developed area, and forests
- Flood zones
- Landslides
- Earthworks, including cut-and-fill volumes

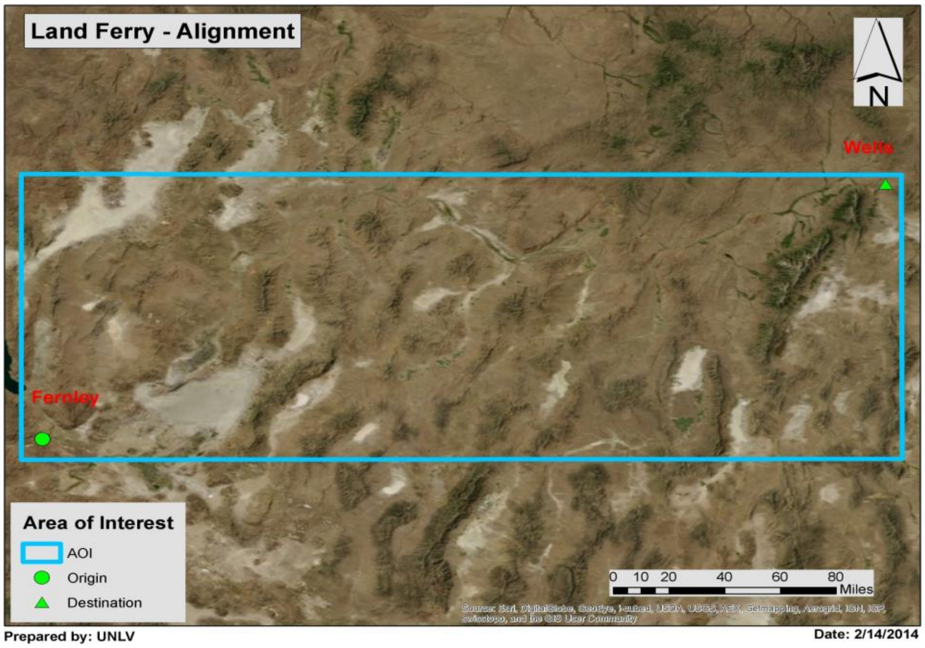


FIGURE 2 The project study area.

Approach

The optimal alignment would satisfy various design and operation constraints, such as gradient, length, construction, and operation cost as well as other design constraints, such as sight distance and curvature. The approach adapted for this project was to:

- Find an alignment that traverses along the flat area to minimize costs; the higher the slope, the higher the construction costs.
- Find an alignment that passes through an area less intervened by humans. Usage less intervened by humans will be less costly than more intervened areas; for example, barren land will be less costly than forest.
- Find an alignment that is short and involves minimal earthworks.

Data Collection and Preparation

The locations of the origin and destination along the I-80 corridor were identified from the Economic and Social Research Institute (ESRI) map and further confirmed by the shape file of U.S. cities. The GIS shape files of existing railroads and roads of Nevada were used as reference as well in order to learn the existing road and railroad network in the project area. All the GIS shape files and raster datasets collected were clipped and extracted, using a rectangular polygon for the region of interest. The coordinate and projection systems adopted in all the GIS operations were GCS_North_American_1983 and NAD_1983_UTM_Zone_11N, respectively.

Other data used in this study was obtained from the National Map of the United States Geological Survey (USGS). The Digital Elevation Models (DEM) used for analysis had elevation in meters, a cell size of 30m x 30m, and 32-bit raster. The Land Cover data, representing various types of existing conditions, had the same specifications as other files with the unique land cover values, as shown in Figure 3. Figures 4 and 5 show the land cover and landslides, respectively.

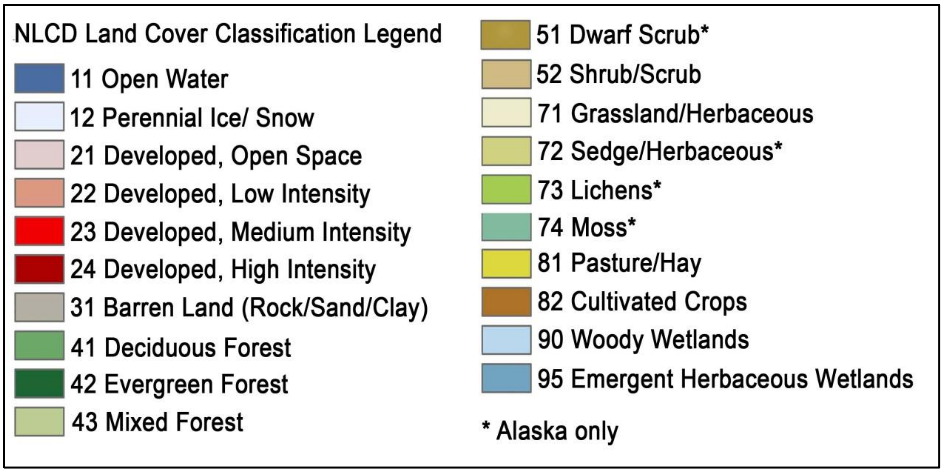


FIGURE 3   Legends for National Land Cover classifications.

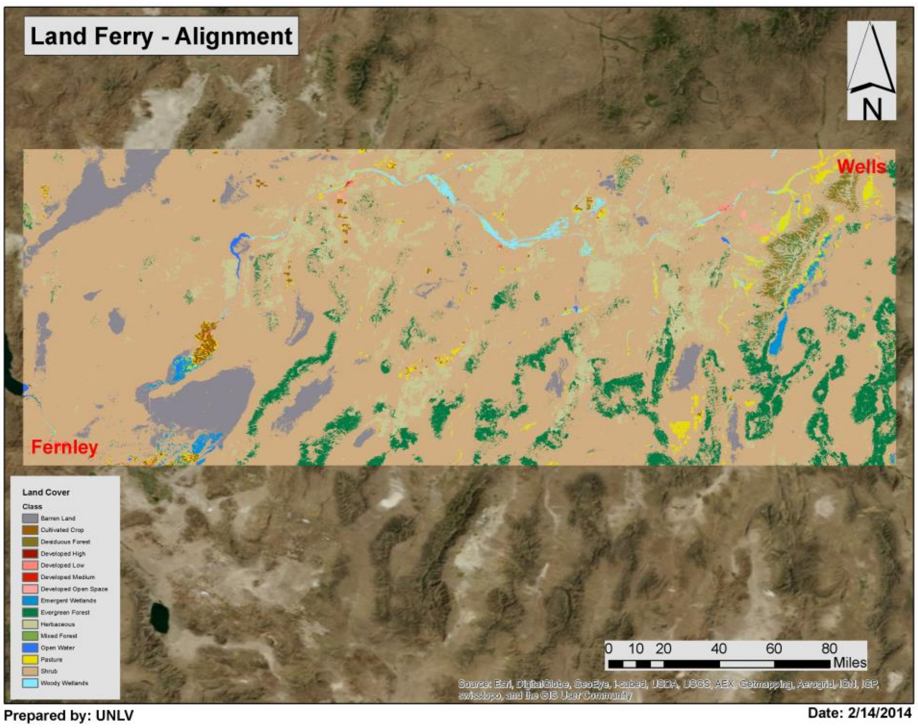


FIGURE 4 Land cover of the project study area.

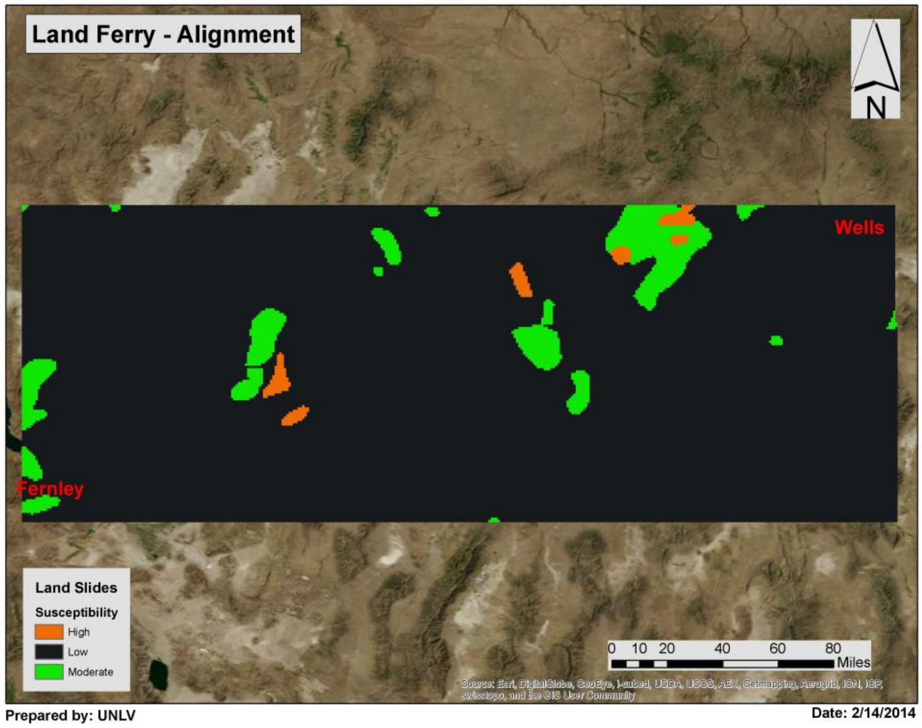


FIGURE 5 Landslides within the project study area.

Methodology

A literature review was performed to understand the various aspects of the Land Ferry project, such as requirements and objectives. Constraints regarding design, the environment, construction, and operation that affect the selection of the railroad alignment were identified as part of defining the methodology to be used for this project. Prevailing practices to determine the economic alignment using GIS were reviewed in order to identify the techniques and GIS analytical tools suitable for this project.

Using DEM and land cover maps, various GIS analyses were performed to evaluate an economical alignment connecting Fernley and Wells. The overall analysis consists of a methodology to find optimal path alignments, using GIS techniques. The spatial data could be used to develop tiles of a given dimension, which could be assigned individual information or data. To find the optimal route, it was beneficial to create raster images with assigned cell values, which could be used as weight factors for raster logarithms. The cell values acted as either the alignment placement that was desired or an alignment generation to avoid.

The use of a raster calculator, a tool within the Spatial Analyst extension, could be utilized to convert the raster cells to the desired parameters. Figure 6 shows an example area under study, which is represented as a matrix of accumulated costs of various raster overlays, such as slope and land cover. Using the ArcGIS raster and spatial analysis tools, the optimal path was found by using the weights and a set of parameters.

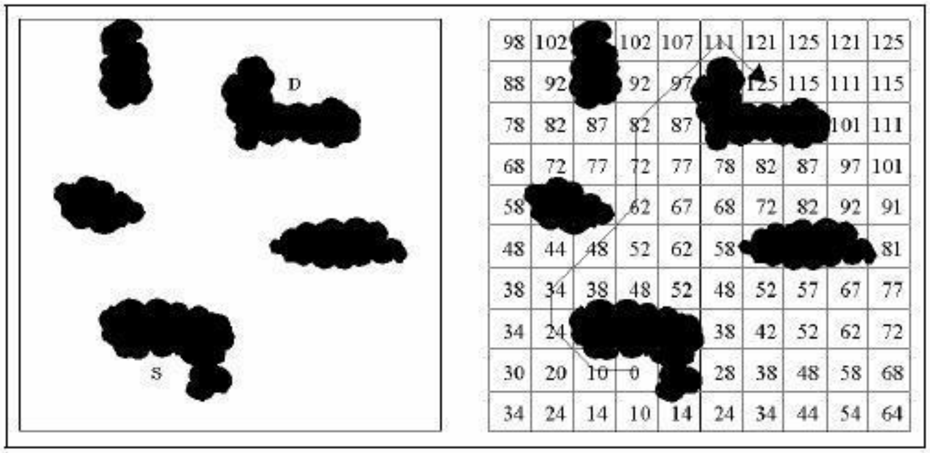


FIGURE 6 The optimal path between two points *(6)*.

After collecting the existing data for the land cover, GIS tools were used to find the slope map from the DEM raster, as shown in Figure 7. Then, the map was reclassified by assigning different values to the slopes, expressed in different colors. For example, the steepest terrain in the map had the highest value of slope assigned to it. For the area proposed for the Land Ferry, the areas in red represent the steepest slopes, green regions reflect the shallowest slopes, and yellow regions are intermediate slopes.

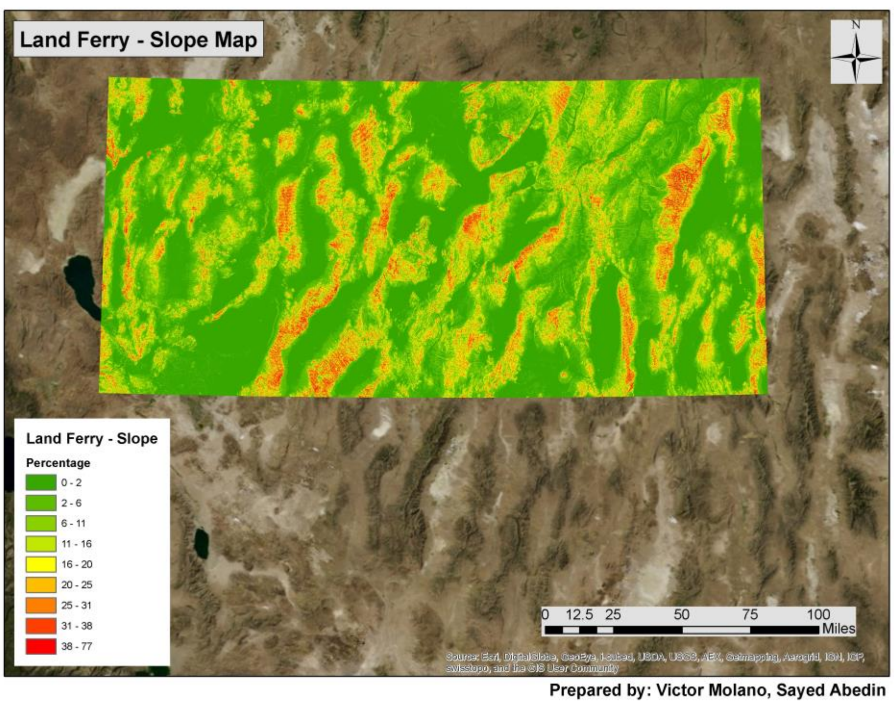
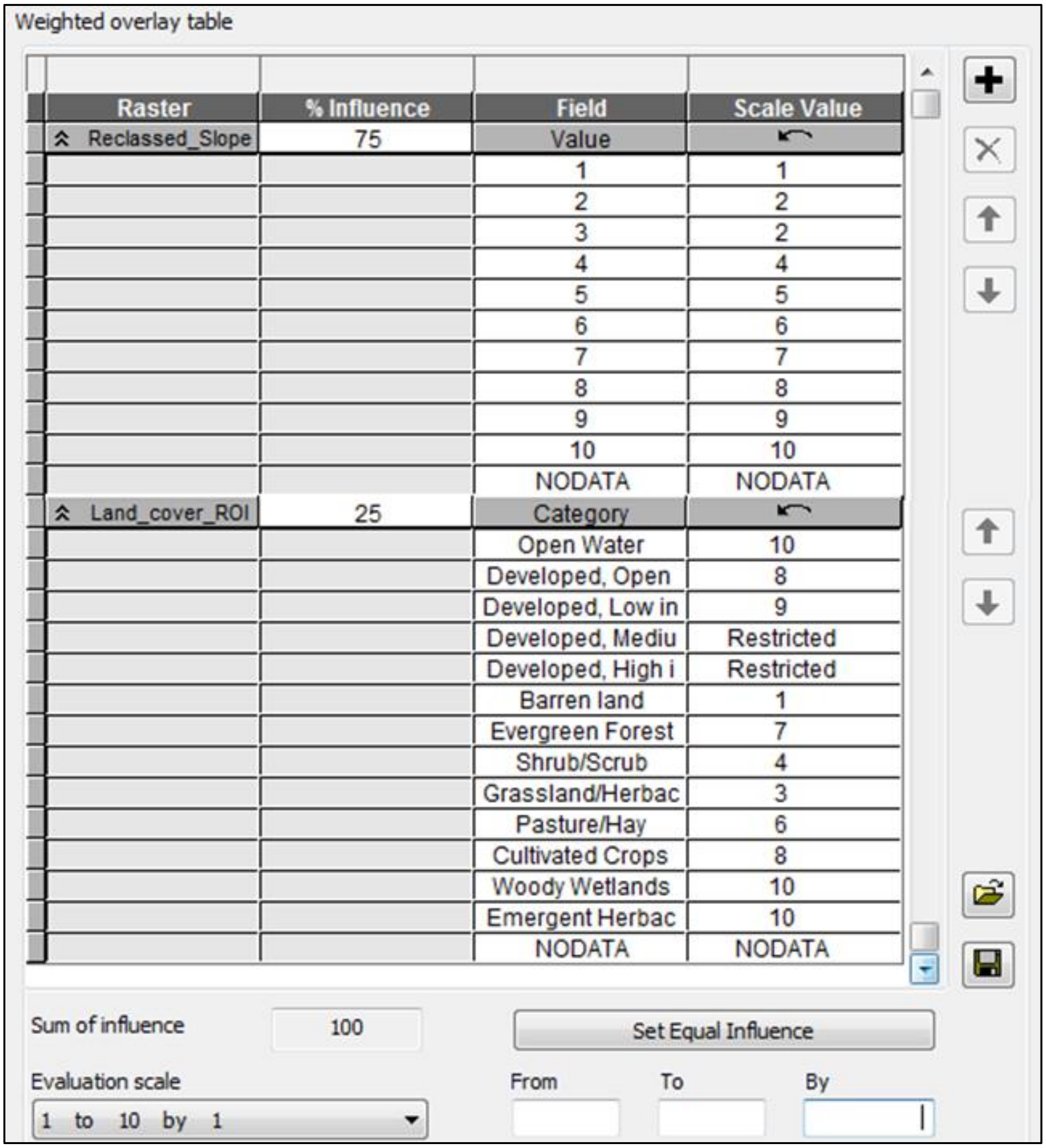


FIGURE 7 Slope analysis map of the project study area.

The next step involved a weighted overlay of maps in Figures 4, 5 and 7. Figure 8 provides the weights used. A cost was assigned to each raster value, which was the result of joining the data from the slope map (Fig. 7) and the land cover map (Fig. 4). The 'weighted overlay' tool was used to achieve this purpose. The two input maps (Figs. 4 and 7) were loaded, and the weights for each were assigned. A sensitivity analysis was performed to obtain the optimal weights for this step.


Weighted overlay table

Raster	% Influence	Field	Scale Value
Reclassed_Slope	75	Value	
		1	1
		2	2
		3	2
		4	4
		5	5
		6	6
		7	7
		8	8
		9	9
		10	10
		NODATA	NODATA
Land_cover_ROI	25	Category	
		Open Water	10
		Developed, Open	8
		Developed, Low in	9
		Developed, Mediu	Restricted
		Developed, High i	Restricted
		Barren land	1
		Evergreen Forest	7
		Shrub/Scrub	4
		Grassland/Herbac	3
		Pasture/Hay	6
		Cultivated Crops	8
		Woody Wetlands	10
		Emergent Herbac	10
		NODATA	NODATA

FIGURE 8 Weight factors given to various classes of land cover and slopes.

In the next step, the cost from each raster to the destination point of the project was calculated. The tool selected was 'cost distance', using the overlaid maps from the previous step as input. After the cost from each point to the destination point was calculated, shown visually in Figure 9, the last step involved calculating the least-cost path. To perform this operation, the 'cost path' tool was used. The inputs were a shape file, with the origin of the alignment and the results from the cost distance calculation. As a result, the optimal path from the origin to the destination of the alignment was obtained.

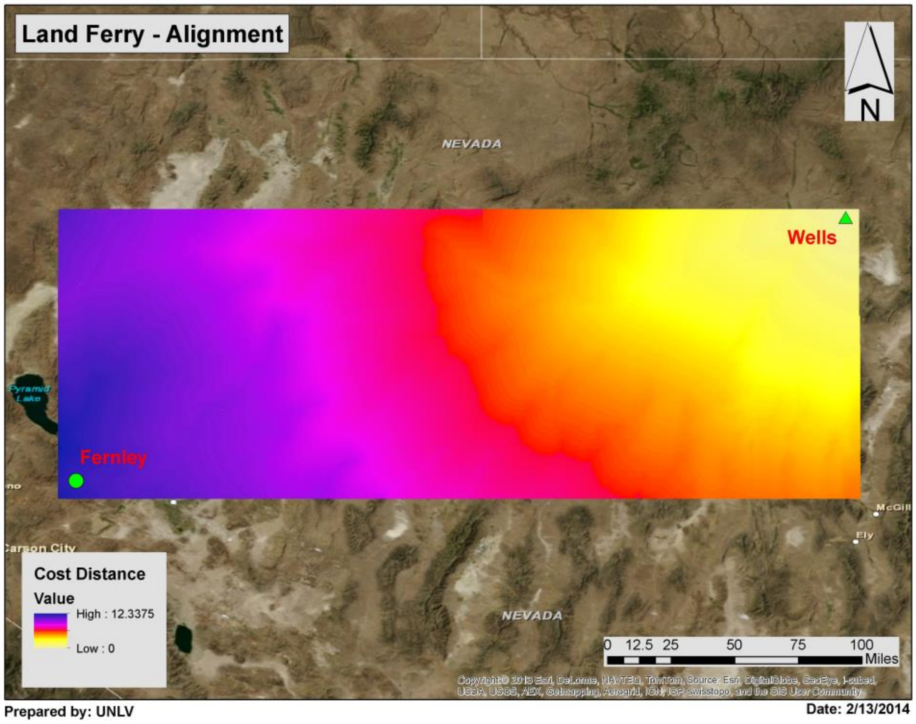


FIGURE 9 A visual map depicting the cost from each point to the destination point of the Land Ferry alignment.

The flow chart of the project methodology is shown in Figure 10. The blue circles represent the inputs and the yellow squares represent the ArcMap tools used for the calculations. Tthe green circles represent the outputs from each step.

Once the alternative least-cost path was found, an optimal route was proposed for this segment of the Land Ferry project. This optimal alignment was used to calculate the earthworks. The first step was to use the tool, Feature Vertices to Points to generate points for all the vertices of the alignment. The Interpolate Shape tool from the 3D analyst was used to interpolate elevation values for these points along the alignment. These elevation values were taken from the terrain's DEM raster and the coordinates in X, Y, and Z were calculated for all the points.

The attributes (coordinates) of the points were exported to Excel. Then, an optimization procedure was used to determine the optimal elevation that would minimize the earthworks. The constraints of this procedure were the maximum and minimum grades allowed for freight trains *(7)*. The width of the segment was assigned as 40 ft, and was based on measurements from existing structures.

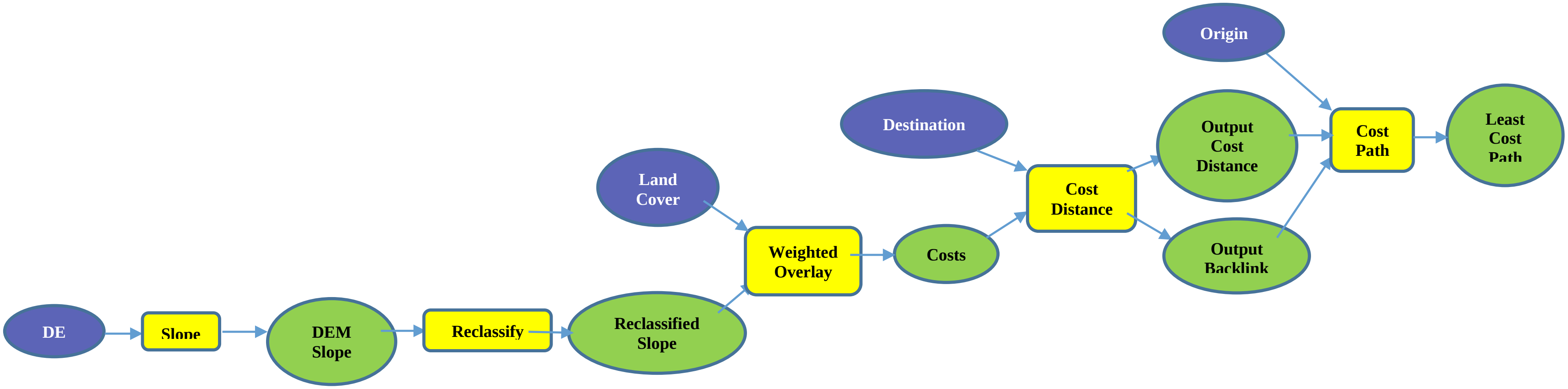


FIGURE 10 Flow chart of the methodology used to determine optimal alignment.

The objective function of the optimization was to minimize the absolute value of the difference between the cut-and-fill volumes. This procedure was repeated for various segments along the alignment. To perform the optimization, a non-linear programming tool was used from Microsoft Excel. The results from the optimization were the coordinates of the desired Land Ferry alignment, including X, Y, and the optimal Z. A new shape file was generated using the X, Y, and optimal Z coordinates; then, a new raster image was generated with the optimal altitude, using the Inverse Distance Weight (IDW) 3D analyst tool. IDW uses interpolation based on weighted distances to create an approximate surface with the optimal altitude values (Figure 11).

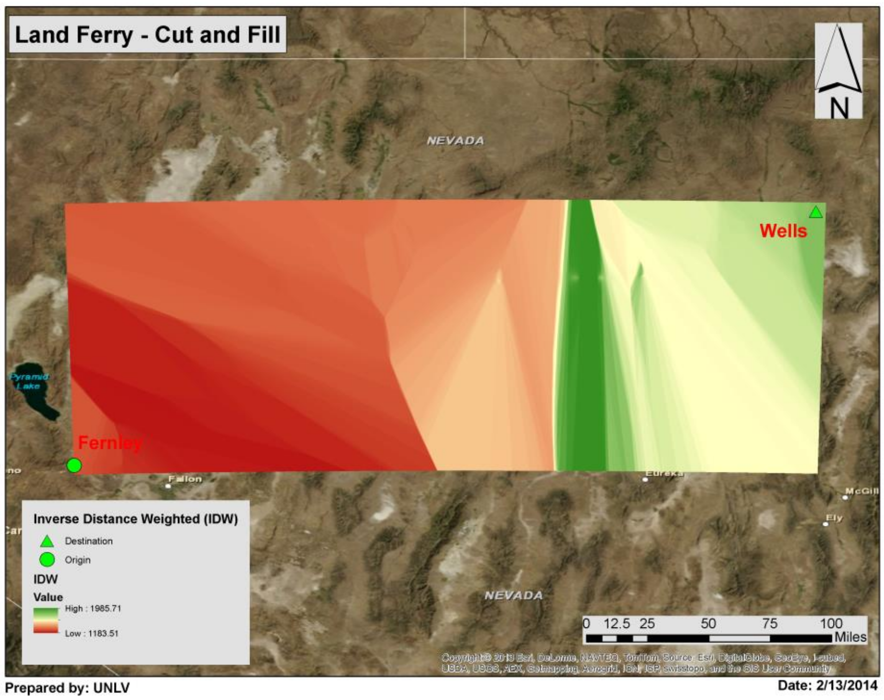


FIGURE 11 Map of the project study area using a 3D analyst tool map, Inverse Distance Weight (IDW).

A buffer of 20 ft on each side of the Land Ferry alignment was created, and the tool, Extract by Mask, was used to create maps from DEM and IDW maps. These two maps represent the 'before' and 'after' states of the project. Finally, the Cut Fill tool was used to calculate the volume change between the proposed surface (after) and the terrain surface (before). Table 2 represents the earthworks for the Land Ferry for all the five segments.

TABLE 2 Earthworks Estimated for the Land Ferry

Segment	Length (miles)	Total Cut (cu m)	Total Fill (cu m)	Difference (cu m)
1	70.00	1767623.36	1774381.64	6758.28
2	73.85	1767623.36	1774381.64	6758.28
3	79.37	9755343.56	9813407.65	58064.09
4	42.38	9259457.46	8612656.64	646800.82
5	54.85	4125244.56	4113889.90	11354.67

Figure 12 through Figure 16 represent the proposed Land Ferry alignment for Segment 1, Segment 2, Segment 3, Segment 4, and Segment 5, respectively.

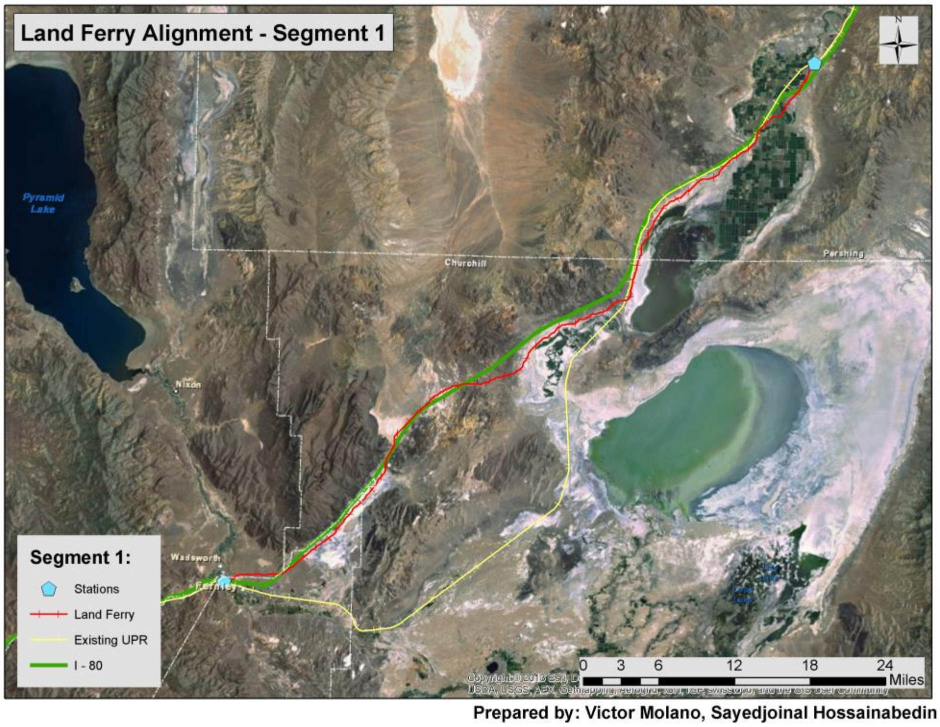


FIGURE 12 Proposed Land Ferry alignment for Segment 1.

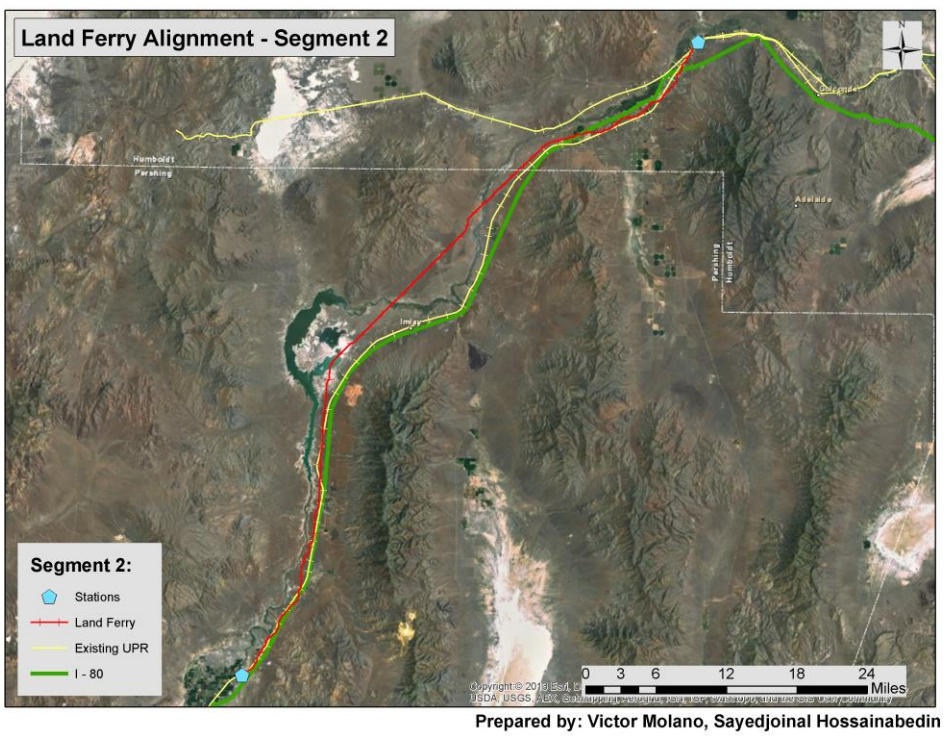


FIGURE 13 Proposed Land Ferry alignment for Segment 2.

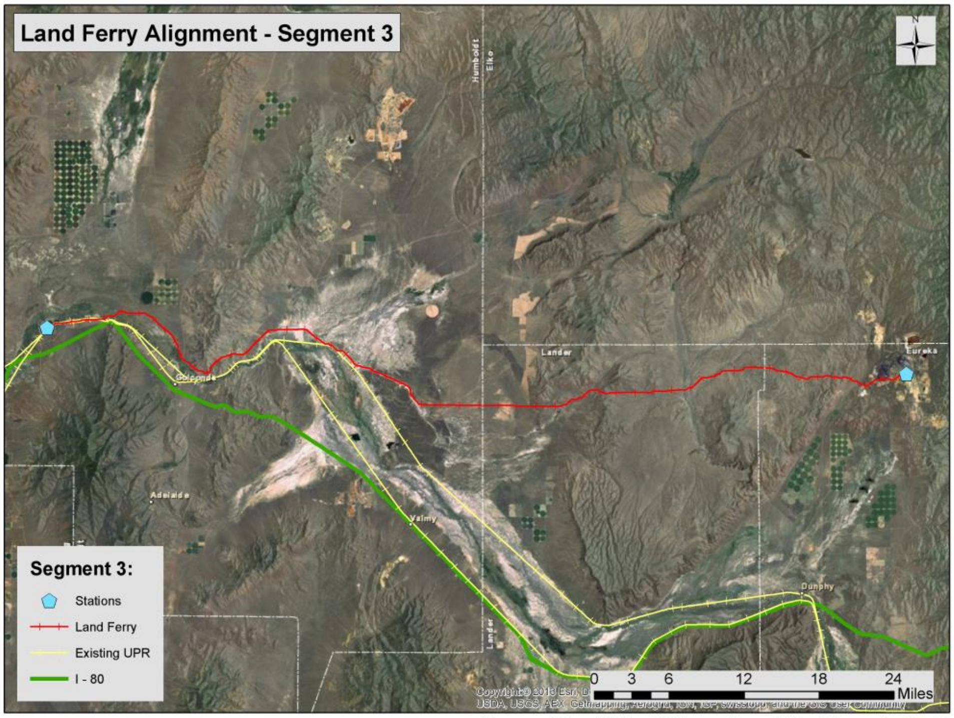


FIGURE 14 Proposed Land Ferry alignment for Segment 3.

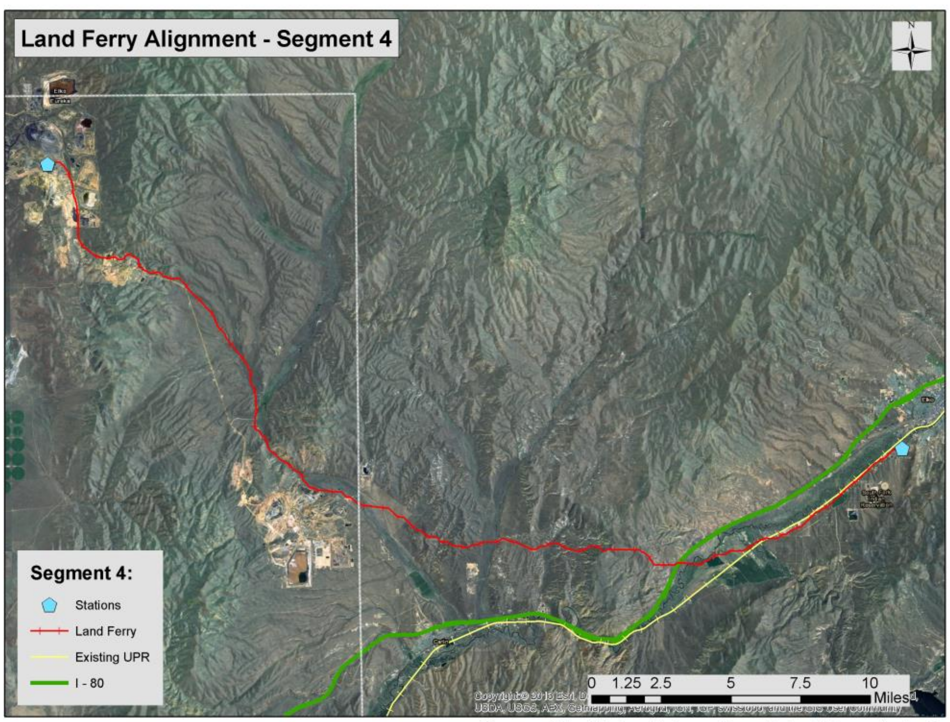


FIGURE 15 Proposed Land Ferry alignment for Segment 4.

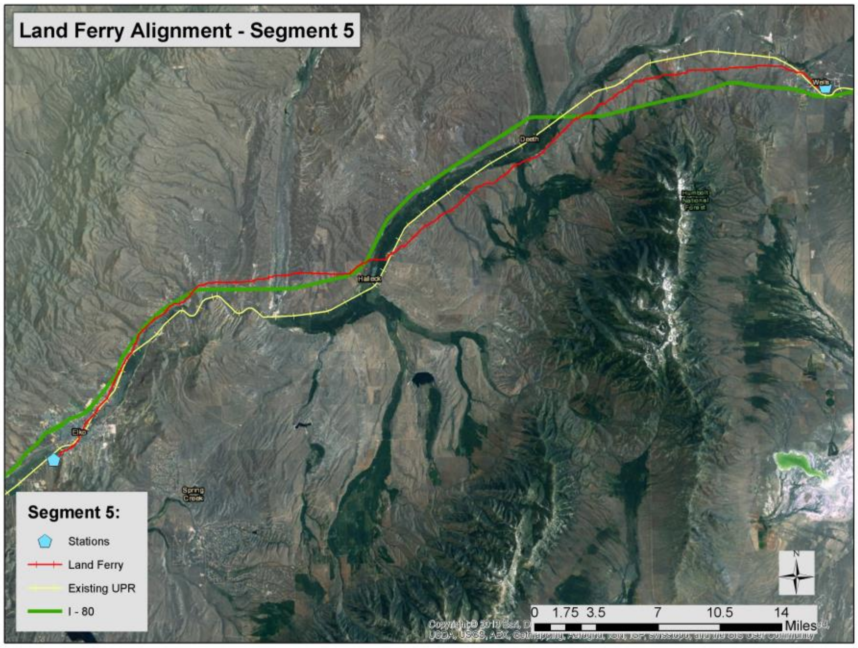


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FIGURE 16 Proposed Land Ferry alignment for Segment 5.

Figure 17 summarizes all the five segments with Land Ferry alignment crossing I-80 and UPR. The crossing points on UPR and I-80 were chosen by overlaying the proposed alignment to against a high-resolution satellite image. Later, a visual check was executed in the location where the alignment and the existing I-80 or UPR crosses (Figure 17).

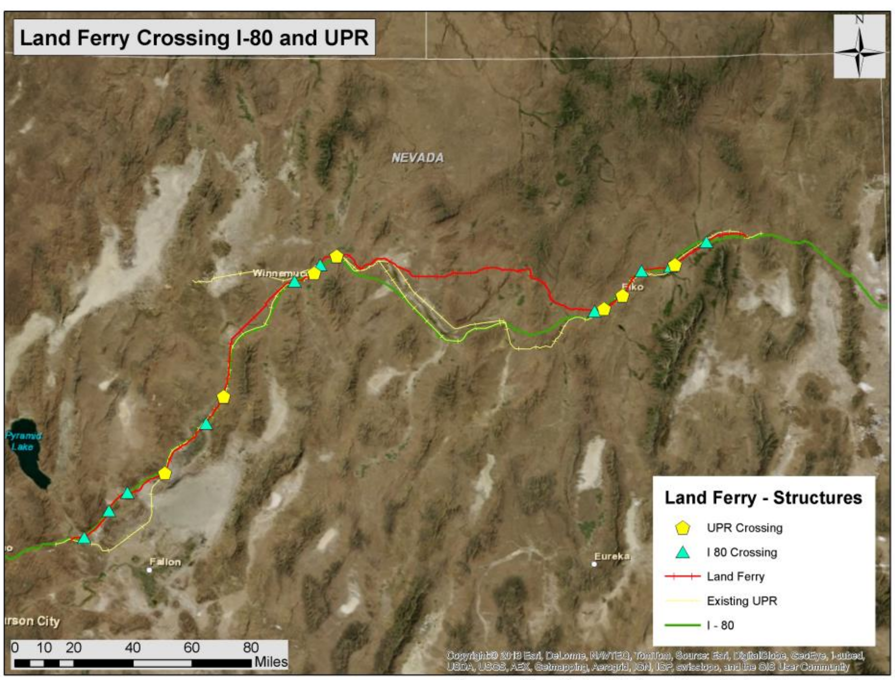

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FIGURE 17 Land Ferry crossings over the I-80 highway and the Union Pacific Railroad (UPR).

The Land Ferry crosses with the UPR railroad in seven places, and crosses I-80 in 10 places. Additionally, the alignment requires 10 bridges to overpass depressions and rivers. The spans for these bridges were measured from satellite images. The height of each bridge was measured to be the difference between the IDW and the DEM maps at those points. Table 3 shows the description, span, and height of the bridges proposed for the Land Ferry.

TABLE 3 Span and Height of Bridges for the Land Ferry

Bridge Number	Description	Span (m)	Ferry Elevation (m)	Field Elevation (m)	Height (m)	Segment
1	Canal	11.00	1212.79	1211.40	1.39	1
2	River	17.00	1213.97	1206.26	7.71	1
3	River/Wetlands	23.00	1270.21	1262.26	7.95	2
4	River/Wetlands	38.00	1296.04	1280.99	15.05	2
5	River/Wetlands	18.00	1318.30	1313.01	5.29	3
6	River/Wetlands	30.00	1525.82	1517.20	8.62	4
7	River/Wetlands	9.00	1527.16	1525.16	1.99	4
8	River	25.00	1542.75	1540.39	2.36	5
9	River/Wetlands	10.00	1602.84	1583.48	19.36	5
10	River/Wetlands	8.00	1613.33	1595.28	18.05	5

SECTION 3: CAPITAL COST ESTIMATING METHODOLOGY

The cost estimating methodology used in this report is based on the historical bid cost and unit cost for typical designs. The design of the proposed land ferry system is incomplete; therefore it is impossible to conduct a detailed cost estimate to obtain the accurate cost. The UNLV team tried to analyze the capital cost of the project as accurately as possible. However, due to the unavailability of the final design as well as other data, the research team used a standard typical design of railway tracks, and estimated according to that. Similarly, for station costs, a typical design of a station was used to calculate an estimated cost.

Table 4 shows the Cost Breakdown Structure (CBS) of the land ferry system and Table 5 shows the detailed cost estimate. To estimate the detailed cost of the land ferry system, first, the Work Breakdown Structures (WBS) of the project was established. Every single item used to build this Land Ferry system was identified and placed into the WBS. After the WBS was prepared, the cost of each work activity was estimated. The coding system provided in this report allowed the estimated cost to be organized and presented by categories and subcategories. The cost-code categories and subcategories used in this estimate were taken from standard cost categories established by the Federal Railroad Administration (FRA) as part of American Recovery and Reinvestment Act (ARRA) grant application requirements. Once the cost estimates of all these categories were completed, they were compiled in a CBS table for the project. The estimating process used in this cost calculation is explained as follows.

Estimating Process

The development of construction cost of the project activities was estimated using the historical bid price method and the unit cost analysis method. The historical bid price method was used in the construction activity in which typical designs for the activities were not conducted. The unit cost analysis method was used for activities in which the typical design was used and for which the quantity takeoffs of those activities were possible. These methods are described below.

Historical Bid Price Method

The time of historical bid price and the conditions of the historical project used for pricing was taken into account, and the following factors were applied as needed:

- The bid price of items taken from other sources was adjusted from the current date by using an appropriate escalator factors taken from *Engineering News Record* (*ENR*).
- The bid price was adjusted for the location using the location index from *ENR*.

Historical bid prices that were used in this estimate came from local, regional, statewide, and national high-speed rail projects.

Unit Cost Analysis Method

For a typical design proposed, the unit cost analysis method was used to estimate the cost of grading, cutting, filling, rock ballast, rails, ties, stations, and so forth. This method allowed developing the unit cost based on the current local construction market. The production rate of the equipment and labor were taken from the RS Means cost guide to determine the equipment and labor time *(8)*. The rental and operating cost of the equipment were taken from Caltrans rental book *(9)*. The labor cost was estimated based on the percentage of the total cost provided in the RS Means cost guide. The material cost for this estimating purpose was collected from the local market. An overhead and profit (O & P) cost of 20% was added to the direct cost of these items. Using this method, the following steps were used to develop a unit price:

1. Prepare a typical design of the system.
2. Perform quantity take-off.
3. Estimate the production rate based on the RS Means cost guide.
4. Compile the list of material required.
5. Obtain material pricing, using local available sources.
6. Obtain the equipment rental rate from Caltrans Equipment Rental book.
7. For labor costs, use the ratio of equipment-to-labor cost provided in the RS Mean Cost guide.
8. Calculate the direct unit price, using the above factors.
9. Add a 20% of overhead and profit (O & P) as the indirect cost.

Detailed cost estimates for each segment is discussed in the following sections.

TABLE 4 Cost Breakdown Structure (CBS) for the Land Ferry System

10. TRACK STRUCTURES AND TRACKS	
10.01	Track Structure: Grubbing, Cutting, and Filling
10.02	Track Structure: Major Bridges
10.03	Track Structure: Minor Bridges
10.04	Track Structure: Road or Railway Crossing Bridges
10.05	Track Structure: Retaining Walls and Systems
10.06	Track Structure: Culverts and Drainage Systems
10.07	Track Construction: Conventional Ballasted Subgrade
10.08	Track Construction: Components (rail, ties, etc.)
10.09	Track Construction: Special Track Work (switches, turnouts, insulated joints)
10.10	Track Construction: Major Interlocking
10.11	Track Construction: Switch Heaters (with power and control)
10.12	Track Construction: Vibration and Noise Dampening
10.13	Other Linear Structures, including Fencing and Sound Walls
20. STATIONS	
20.01	Station Buildings: Structures Only
20.01	Station Buildings: Service Buildings
20.03	Platforms
20.04	Truck Loading and Unloading Systems
20.05	Fare Collection System
20.06	Access System for Entering and Exiting the Loading Systems
20.07	Station Security System
20.08	Accommodation, Landscaping, and Parking Lots
30. SUPPORT FACILTIES: YARDS, SHOPS, AND ADMINISTRATION BUILDINGS	
30.01	Administration Buildings: Office, Sales, Storage, and Revenue Counting
30.02	Light Maintenance Facilities
30.03	Heavy Maintenance Facilities
30.04	Maintenance Storage
30.05	Yards and Yard Tracks
40. SITEWORK, RIGHT-OF-WAY, AND LAND, ETC.	
40.01	Demolition, Clearing, and Site Preparation
40.02	Site Utilities and Utility Relocation
40.03	Hazardous Material, Contaminated Soil Removal/ Mitigation, and Ground Water Treatment
40.04	Environmental Mitigation: Wetlands, Historic/ Archeology, and Parks

40.05	Temporary Facilities and Other Indirect Costs During Construction
40.06	Purchase of Real Estate
40.07	Relocation of Existing Households and Businesses
50. COMMUNICATONS AND SIGNALING	
50.01	Wayside Signaling Equipment
50.02	Signal Power Access and Distribution
50.03	Onboard Signaling Equipment
50.04	Traffic Control and Dispatching Systems
50.05	Communications
50.06	Grade Crossing Protections
50.07	Warning System for Trains Approaching Stations
60. DIESEL VEHICLES	
60.01	Vehicle Acquisition: Diesel Multiple Units
60.02	Vehicle Acquisition: Non-railroad Support Vehicles
60.03	Vehicle Acquisition: Railroad Maintenance-of-Way Vehicles
60.04	Spare Parts
70. PROFESSIONAL SERVICES (Applies to Items 10 – 50)	
70.01	Service Development Plan/ Service Environmental
70.02	Preliminary Engineering/ Project Environmental
70.03	Final Design
70.04	Project Management for Design and Construction
70.05	Construction Administration and Management
70.06	Professional Liability and Other Non-Construction Insurance
70.07	Legal: Permits: Review Fees by Other Agencies and Cities, etc.
70.08	Surveys, Testing, and Investigations
70.09	Engineering Inspection
70.10	Start-up Costs
80. CONTINGENCY COST	
90. CONTRACTORS' PROFITS (Applies to Items 10 – 60)	
TOTAL COST	

TABLE 5 Detailed Cost Estimate for the Land Ferry System

10	TRACK STRUCTURES & TRACK	$1,902,400,000
	SEGMENT 1	$321,480,000
10.01	Track Structure: Grubbing, Cutting, and Filling	$41,514,000
10.02	Track Structure: Major Bridges	$9,900,000
10.03	Track Structure: Minor Bridges	$1,075,000
10.04	Track Structure: Bridges Crossing Roads or Railways	$27,095,000
10.05	Track Structure: Retaining Walls and Systems	$74,171,000
10.06	Track Structure: Culverts and Drainage Systems	$11,235,000
10.07	Track Construction: Conventional Ballasted Subgrade	$57,470,000
10.08	Track Construction: Components (rail, ties, etc.)	$6,286,000
10.09	Track Construction: Special Track Work (switches, turnouts, insulated joints)	$1,208,000
10.10	Track Construction: Major Interlocking	$6,286,000
10.11	Track Construction: Switch Heaters (with power and control)	$9,429,000
10.12	Track Construction: Vibration and Noise Dampening	$6,286,000
10.13	Other Linear Structures, including Fencing and Sound Walls	$12,950,000
	SEGMENT 2	$335,663,000
10.01	Track Structure: Grubbing, Cutting, and Filling	$41,806,000
10.02	Track Structure: Major Bridges	$19,800,000
10.03	Track Structure: Minor Bridges	-
10.04	Track Structure: Bridges Crossing Roads or Railways	$19,090,000
10.05	Track Structure: Retaining Walls and Systems	$78,205,000
10.06	Track Structure: Culverts and Drainage Systems	$11,845,000
10.07	Track Construction: Conventional Ballasted Subgrade	$60,590,000
10.08	Track Construction: Components (rail, ties, etc.)	$66,272,000
10.09	Track Construction: Special Track Work (switches, turnouts, insulated joints)	$1,208,000
10.10	Track Construction: Major Interlocking	$6,627,000
10.11	Track Construction: Switch Heaters (with power and control)	$9,440,000
10.12	Track Construction: Vibration and Noise Dampening	$6,627,000
10.13	Other Linear Structures, including Fencing and Sound Walls	$13,653,000
	SEGMENT 3	$535,849,000
10.01	Track Structure: Grubbing, Cutting, and Filling	$205,962,000
10.02	Track Structure: Major Bridges	$9,900,000
10.03	Track Structure: Minor Bridges	-

10.04	Track Structure: Bridges Crossing Roads or Railways	$3,695,000
10.05	Track Structure: Retaining Walls and Systems	$126,208,000
10.06	Track Structure: Culverts and Drainage Systems	$12,744,000
10.07	Track Construction: Conventional Ballasted Subgrade	$65,187,000
10.08	Track Construction: Components (rail, ties, etc.)	$71,301,000
10.09	Track Construction: Special Track Work (switches, turnouts, insulated joints)	$1,208,000
10.10	Track Construction: Major Interlocking	$7,130,000
10.11	Track Construction: Switch Heaters (with power and control)	$10,695,000
10.12	Track Construction: Vibration and Noise Dampening	$7,130,000
10.13	Other Linear Structures, including Fencing and Sound Walls	$14,689,000
	SEGMENT 4	**$381,209,000**
10.01	Track Structure: Grubbing, Cutting, and Filling	$191,838,000
10.02	Track Structure: Major Bridges	$9,900,000
10.03	Track Structure: Minor Bridges	$1,075,000
10.04	Track Structure: Bridges Crossing Roads or Railways	$9,545,000
10.05	Track Structure: Retaining Walls and Systems	$67,388,000
10.06	Track Structure: Culverts and Drainage Systems	$6,805,000
10.07	Track Construction: Conventional Ballasted Subgrade	$34,810,000
10.08	Track Construction: Components (rail, ties, etc.)	$38,075,000
10.09	Track Construction: Special Track Work (switches, turnouts, insulated joints)	$604,000
10.10	Track Construction: Major Interlocking	$3,807,000
10.11	Track Construction: Switch Heaters (with power and control)	$5,711,000
10.12	Track Construction: Vibration and Noise Dampening	$3,807,000
10.13	Other Linear Structures, including Fencing and Sound Walls	$7,844,000
	SEGMENT 5	**$328,198,000**
10.01	Track Structure: Grubbing, Cutting, and Filling	$88,225,000
10.02	Track Structure: Major Bridges	$29,700,000
10.03	Track Structure: Minor Bridges	-
10.04	Track Structure: Bridges Crossing Roads or Railways	$21,245,000
10.05	Track Structure: Retaining Walls and Systems	$58,067,000
10.06	Track Structure: Culverts and Drainage Systems	$8,795,000
10.07	Track Construction: Conventional Ballasted Subgrades	$44,991,000
10.08	Track Construction: Components (rail, ties, etc.)	$49,210,000

10.09	Track Construction: Special Track Work (switches, turnouts, insulated joints)	$604,000
10.10	Track Construction: Major Interlocking	$4,921,000
10.11	Track Construction: Switch Heaters (with power and control)	$7,381,000
10.12	Track Construction: Vibration and Noise Dampening	$4,921,000
10.13	Other Linear Structures, including Fencing and Sound Walls	$10,138,000
20	**STATIONS**	**$71,204,000**
20.01	Station Buildings: Structures Only	$24,030,000
20.01	Station Buildings: Service Buildings	$6,070,000
20.03	Platforms	$4,806,000
20.04	Truck Loading and Unloading Systems	$30,000,000
20.05	Fare Collection System	$3,000,000
20.06	Access System for Entering and Exiting the Loading Systems	$961,000
20.07	Station Security System	$1,200,000
20.08	Accommodation, Landscaping, and Parking Lots	$1,200,000
30	**SUPPORT FACILTIES: YARDS, SHOPS, AND ADMINISTRATION BUILDINGS**	**$347,240,000**
30.01	Administration Building: Office, Sales, Storage, and Revenue Counting	$14,240,000
30.02	Light Maintenance Facilities	$160,000,000
30.03	Heavy Maintenance Facilities	$140,000,000
30.04	Maintenance Storage	$30,000,000
30.05	Yards and Yard Tracks	$3,000,000
40	**SITEWORK, RIGHT-OF-WAY, AND LAND, ETC.**	**$696,050,000**
40.01	Demolition, Clearing, and Site Preparation	$32,050,000
40.02	Site Utilities and Utility Relocation	$320,000,000
40.03	Hazardous Material, Contaminated Soil Removal/ Mitigation, and Ground Water Treatment	$48,000,000
40.04	Environmental Mitigation: Wetlands, Historic/ Archeology, and Parks	$128,000,000
40.05	Temporary Facilities and Other Indirect Costs During Construction	$18,000,000
40.06	Purchase of Real Estate	$50,000,000
40.07	Relocation of Existing Households and Businesses	$100,000,000
50	**COMMUNICATION AND SIGNALING**	**$79,150,000**
50.01	Wayside Signaling Equipment	$32,000,000
50.02	Signal Power Access and Distribution	$8,000,000
50.03	Onboard Signaling Equipment	$1,000,000

50.04	Traffic Control and Dispatching Systems	$5,000,000
50.05	Communications	$32,000,000
50.06	Grade Crossing Protections	$700,000
50.07	Warning System for Trains Approaching Stations	$450,000
60	**DIESEL VEHICLES**	**$15,000,000**
60.01	Vehicle Acquisition: Diesel Multiple Units	$12,000,000
60.02	Vehicle Acquisition: Non-railroad Support Vehicles	$1,000,000
60.03	Vehicle Acquisition: Railroad Maintenance-of-Way Vehicles	$1,000,000
60.04	Spare Parts	$1,000,000
	TOTAL CONSTRUCTION COST	**$3,111,033,000**
70	**PROFESSIONAL SERVICES (Items 10 – 60)**	**$704,981,000**
70.01	Service Development Plan/ Service Environmental	$31,110,000
70.02	Preliminary Engineering/ Project Environmental	$93,331,000
70.03	Final Design	$217,772,000
70.04	Project Management for Design and Construction	$46,665,000
70.05	Construction Administration and Management	$155,552,000
70.06	Professional Liability and Other Non-Construction Insurance	$62,221,000
70.07	Legal: Permits: Review Fees by Other Agencies and Cities, etc.	$31,110,000
70.08	Surveys, Testing, and Investigations	$31,110,000
70.09	Engineering Inspection	$31,110,000
70.10	Start-up Costs	$5,000,000
80	**CONTINGENCY COST**	**$155,552,000**
90	**CONTRACTORS' PROFITS (Applies to Items 10 – 60)**	**$62,221,000**
	TOTAL COST	**$4,033,787,000**
	COST PER MILE	**$12,606,000**

10 Cost for Track Structures and Tracks in Segment 1 (Length = 70 Miles)

The detailed estimate is shown in the tables below.

10.1 Grubbing, Cutting, and Filling $41,514,000

The quantity of cutting and filling was calculated based on the Geographical Information System (GIS) software. The design engineers set the alignment in order to balance the cut-and-fill quantity. Once the alignment was set, the GIS software calculated the cut-and-fill volume of the alignment; the unit cost and quantities were measured in bank cubic yards (BCY). The detailed cost estimate for Segment 1 is shown in Table 6.

TABLE 6 Grubbing, Cutting, and Fitting Costs for Segment 1

Item No.	Item Name	Unit Cost	Total Quantity	Total Cost
10.1.1	Grubbing & Clearing	$5,324.8/ acre	1,010 acres	$5,377,000
10.1.2	Cutting	$7.68/ BCY*	2,352,707 BCY	$18,069,000
10.1.3	Filling Cost	$7.62/ BCY	2,352,707 BCY	$17,931,000
10.1.4	Hauling & Filling Cost	$15.30/ BCY	8,995 BCY	$137,000
			Total Cost	$41,514,000

* BCY = bank cubic yards

10.2 Major Bridges $9,900,000

The cost estimate of bridge was based on the type of bridge. For this estimate, if the bridge had less than a 50-ft span and 10-ft height, then it was designated as a minor bridge. If either the span or height increased, then the bridge was designated as a major bridge. The cost of a major bridge was taken from a report by Quandel Consultants prepared in 2011 *(10).* This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 7.

TABLE 7 Cost of Major Bridges for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Major Bridges	$9,900,000	1	$9,900,000

10.3 Minor Bridges $1,075,000

The cost of minor bridges were calculated based on the same assumption similar to that of major bridges, as shown in Table 8.

TABLE 8 Cost of Minor Bridges for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Minor Bridges	$1,075,000	1	$1,075,000

10.4 Bridges Crossing Roads or Railways $27,095,000

The cost estimate of bridges crossing roads or railways were based on the types of highway or railroad. For this estimate, the cost of the bridge crossing a road or railway was taken from the Quandel Consultants report prepared in 2011. This cost was normalized based on the inflation factor. The *Engineering News Record* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 9.

TABLE 9 Cost of Bridges Crossing Roads or Railways for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Bridge over a four-lane urban expressway	$5,850,000	4	$23,400,000
2	Bridge over a two-lane rural expressway	$4,870,000	0	0
3	Bridge over a two-lane highway	$3,696,000	0	0
4	Bridge over a railway crossing	$3,695,000	1	$3,695,000
			Total Cost	27,095,000

10.5 Retaining Walls and Systems $74,171,000

The cost estimate of retaining walls and systems was based on the type of railroad. For this estimate, the costs of the retaining walls and systems for double track were taken from the report by Quandel Consultants, prepared in 2011. This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 10. It was estimated that 2% of the road will need retaining walls and systems. The total length of this segment is 70 mi (369,600 ft), and 2% of this length (7,392 ft) will require the retaining walls and systems.

TABLE 10 Cost of Retaining Walls and Systems for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Retaining walls for a double track railroad	$10,034/ft	7,392 ft	$74,171,000

10.6 Culverts and Drainage Systems $11,235,000

The cost estimate of culvert and drainage system was based on the installation of 30-in-diameter pipes to be installed as culverts. For this estimate, the cost of the culvert and drainage systems for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 11. It is estimated that about four culverts are required for each mile of the railroad. The total length of this segment is 70 miles.

TABLE 11 Cost of Culverts and Drainage Systems for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Culvert and drainage system in a double track railroad	$160,500/mi	70 mi	$11,235,000

10.7 Conventional Ballasted Subgrade $57,470,000

The cost estimate of the new roadbed with conventional ballasted was based on the thickness of the compacted ballast, which was 18 in. For this estimate, the cost of the compacted ballast was calculated based on a 35-ft-wide track for a double train. The detailed cost estimate is shown in Table 12. The total length of this segment is 70 miles.

TABLE 12 Cost of Conventional Ballasted Subgrade for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Conventional ballasted subgrade	$821,000/mi	70 mi	$57,470,000

10.8 Components (rail, ties, etc.) $62,860,000

The cost estimate of components of railroad – e.g., rails, ties, relay rail surface curves, and curvature reduction – was taken from Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 12. The total length of this segment is 70 miles.

TABLE 13 Cost of Components for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Installing rail ties	$400,000/mi	70 mi	$28,000,000
2	Installing rail, spikes, plates, and anchors	$428,000/mi	70 mi	$29,960,000
3	Preparing surface curves and adjusting super elevations	$70,000/mi	70 mi	$4,900,000
			Total Cost	62,860,000

10.9 Special Track Work (switches, turnouts, insulated joints) $1,208,000

The cost estimate for special track work was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 14. Four turnouts were needed in each segment of the railroad.

TABLE 14 Cost of Special Track Work for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Turnouts cost with concrete ties	$302,000/each	4	$1,208,000

10.10 Major Interlocking $6,286,000

The major interlocking cost was assumed to be 10% of the cost for rail components, or $6,286,000.

10.11 Switch Heaters (with power and control) $9,429,000

The switch heaters cost was assumed to be 15% of the rail component cost, equivalent to $9,429,000.

10.12 Vibration and Noise Dampening $6,286,000

The vibration and noise dampening cost was assumed to be 10% of the cost for rail components, or $6,286,000.

10.13 Other Linear Structures, including Fencing and Sound Walls $12,950,000

The cost estimate of fencing and sound walls was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 15. The total length of this segment is 70 miles. It was assumed that about 1% of rail road section would need sound walls; in addition, fencing will be used in the entire railroad, for safety purposes.

TABLE 15 Cost of Linear Structures for Segment 1

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Fencing with 6-ft chain link both sides of the right-of-way	$185,000/mi	70 mi	$12,950,000

10 Cost for Track Structures and Tracks in Segment 2 (Length = 73.8 miles)

The detailed estimate is shown in the tables below.

10.1 Grubbing, Cutting, and Filling $41,806,000

The detailed estimate of grubbing, cutting, and filling for Segment 2 is shown in Table 16.

TABLE 16 Cost for Grubbing, Cutting, and Filling for Segment 2

Item No.	Item Name	Unit Cost	Total Quantity	Total Cost
10.1.1	Grubbing & Clearing	$5,324.8/acre	1,065 acres	$5,669,000
10.1.2	Cutting	$7.68/ BCY	2,352,707 BCY	$18,069,000
10.1.3	Filling Cost	$7.62/ BCY	2,352,707 BCY	$17,931,000
10.1.4	Hauling & Filling Cost	$15.30/ BCY	8,995 BCY	$137,000
			Total Cost	$41,806,726

10.2 Major Bridges $19,800,000

The cost estimate of bridges was based on type of bridge. For this estimate, if the bridge had less than a 50-ft span and 10-ft height, then it was designated as a minor bridge. If either the span or height increased, then the bridge was designated as a major bridge. The cost of a major bridge was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 17.

TABLE 17 Cost of Major Bridges for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Major Bridges	$9,900,000	2	$19,800,000

10.3 Minor Bridges $0

The cost of minor bridges was calculated based on a similar assumption similar as for major bridges. This cost estimate is shown in Table 18.

TABLE 18 Cost of Minor Bridges for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Minor Bridges	$1,075,000	0	0

10.4 Bridges Crossing Roads or Railways $19,090,000

The cost estimate of bridges for roads or railway crossings was based on the type of highway or railroad. For this estimate, the cost of the bridge for a road or railway crossing was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 19.

TABLE 19 Cost of Bridges Crossing Roads or Railways for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Bridge over a four-lane urban expressway	$5,850,000	2	$11,700,000
2	Bridge over two-lane rural expressway	$4,870,000	0	0
3	Bridge over a two-lane highway	$3,696,000	0	0
4	Bridge over a railway crossing	$3,695,000	2	$7,390,000
			Total Cost	19,090,000

10.5 Retaining Walls and Systems $78,205,000

The cost estimate of retaining walls and systems was based on the type of railroad. For this estimate, the cost of the retaining walls and systems for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 20. It is estimated that 2% of the road will need retaining walls and systems. The total length of this segment is 73.8 mi (389,664 ft), and 2% of this length (7,794 ft) will require retaining walls and systems.

TABLE 20 Cost of Retaining Walls and Systems for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Retaining walls for a double track railroad	$10,034/ft	7,794 ft	$78,205,000

10.6 Culverts and Drainage Systems $11,845,000

The cost estimate of culverts and drainage systems was based on installation of 30-in-diameter pipes to be installed as culverts. For this estimate, the cost of the culvert and drainage systems for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 21. It is estimated that about 4 culverts are required in each mile of the railroad. The total length of this segment is 73.8 miles.

TABLE 21 Cost of Culverts and Draining Systems for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Culvert and drainage system in a double track railroad	$160,500/mi	73.8 mi	$11,845,000

10.7 Conventional Ballasted Subgrade $60,590,000

The cost estimate of a new roadbed with conventional ballasted subgrade is based on the thickness of the compacted ballast, or 18 inches. For this estimate, the cost of the compacted ballast was calculated based on 35-ft-wide track for a double train. The detailed cost estimate is shown in Table 22. The total length of this segment is 73.8 miles.

TABLE 22 Cost of Conventional Ballasted Subgrade for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Conventional ballasted subgrade	$821,000/mi	73.8 mi	$60,590,000

10.8 Components (rail, ties, etc.) $66,272,000

The cost estimate of components of the railroad – e.g. rails, ties, relay rail surface curves, and curvature reduction – was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 23. The total length of this segment is 73.8 miles.

TABLE 23 Cost of Components for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Installing Rail Ties	$400,000/mi	73.8 mi	$29,520,000
2	Installing rail, spikes, plates, and anchors	$428,000/mi	73.8 mi	$31,586,000
3	Preparing surface curves and adjusting super elevations	$70,000/ mi	73.8 mi	$5,166,000
			Total Cost	66,272,000

10.9 Special Track Work (switches, turnouts, insulated joints) $1,208,000

The cost estimate of special track work was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 24. Four turnouts are needed in each segment of the railroad.

TABLE 24 Cost of Special Track Work for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Turnouts cost with concrete ties	$302,000/each	4	$1,208,000

10.10 Major Interlocking $6,627,000

The major interlocking cost was assumed to be 10% of rail component cost, or $6,627,000.

10.11 Switch Heaters (with power and control) $9,940,000

The cost for switch heaters was assumed to be 15% of the cost for rail components, or $9,940,000.

10.12 Vibration and Noise Dampening $6,627,000

The vibration and noise dampening cost was assumed to be 10% of the cost for rail components, or $6,627,000.

10.13 Other Linear Structures, including Fencing and Sound Walls $13,653,000

The cost estimate of fencing and sound walls was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 25. The total length of this segment is 73.8 miles. It was assumed that about 1% of rail road section would need sound walls. Fencing will be used throughout the entire rail road for safety purposes.

TABLE 25 Cost of Linear Structures for Segment 2

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Fencing with 6-ft chain link both sides of the right-of-way	$185,000/mi	73.8 mi	$13,653,000

10 Cost for Track Structures and Tracks in Segment 3 (Length = 79.4 Miles)

10.1 Grubbing, Cutting, and Filling $205,962,000

The detailed estimate of grubbing, cutting, and filling for Segment 3 is shown in Table 26.

TABLE 26 Cost for Grubbing, Cutting, and Fitting for Segment 3

Item No.	Item Name	Unit Cost	Total Quantity	Total Cost
10.1.1	Grubbing & Clearing	$5,324.8/ acre	1,145 acres	$6,099,000
10.1.2	Cutting	$7.68/ BCY	12,984,363 BCY	$99,720,000
10.1.3	Filling Cost	$7.62/ BCY	12,984,363 BCY	$98,961,000
10.1.4	Hauling & Filling Cost	$15.30/ BCY	77,283 BCY	$1,182,000
			Total Cost	$205,962,000

10.2 Major Bridges $9,900,000

The cost estimate of bridges was based on the type of bridge. For this estimate, if the bridge had less than a 50-ft span and 10-ft height, then it was designated as a minor bridge. If either the span or height increased, then the bridge was designated as a major bridge. The cost of a major bridge was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate for major bridges is shown in Table 27.

TABLE 27 Cost of Major Bridges for Segment 328

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Major Bridges	$9,900,000	1	$9,900,000

10.3 Minor Bridges $0

The cost of minor bridges was calculated based on an assumption similar to that of major bridges, as shown in Table 28.

TABLE 28 Cost of Minor Bridges For Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Minor Bridges	$1,075,000	-	-

10.4 Bridges Crossing Roads or Railways $3,695,000

The cost estimate for bridges of roads or railway crossings was based on the type of highway or railroad. For this estimate, the cost of a bridge for a road or railway crossing was taken from the Quandel Consultants (2011). This cost was normalized based on the inflation factor. The *Engineering News Record* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 29.

TABLE 29 Cost of Bridges Crossing Roads or Railways for Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Bridge over a four-lane urban expressway	$5,850,000	-	-
2	Bridge over a two-lane rural expressway	$4,870,000	-	-
3	Bridge over a two-lane highway	$3,696,000	-	-
4	Bridge over a railway crossing	$3,695,000	1	$3,695,000
			Total Cost	$3,695,000

10.5 Retaining Walls and Systems $126,208,000

The cost estimate of retaining walls and systems was based on the type of railroad. For this estimate, the cost of the retaining walls and systems for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *Engineering News Record* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 30. It is estimated that 3% of the road will need retaining walls and systems. The total length of this segment is 79.4 miles (419,232 ft), and 3% of this length (12,578 ft) will require retaining walls and systems.

TABLE 30 Cost of Retaining Walls and Systems for Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Retaining walls for double track railroad	$10,034/ft	12,578 ft	$126,208,000

10.6 Culverts and Drainage Systems $12,744,000

The cost estimate of culverts and drainage systems was based on installation of 30-inch-diameter pipes to be installed as culverts. For this estimate, the cost of the culvert and drainage systems for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 31. It is estimated that about four culverts are required in each mile of the railroad. The total length of this segment is 79.4 miles.

TABLE 31 Cost of Culvert and Drainage Systems for Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Culvert and drainage system in a double track railroad	$160,500/mi	79.4 mi	$12,744,000

10.7 Conventional Ballasted Subgrade $65,187,000

The cost estimate of new roadbed with conventional ballasted was based on the thickness of the compacted ballast, or 18 in. For this estimate, the cost of the compacted ballast was calculated based on 35-ft-wide track for a double train. The detailed cost estimate is shown in Table 32. The total length of this segment is 79.4 miles.

TABLE 32 Cost of Conventional Ballasted Subgrade for Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Conventional ballasted subgrade	$821,000/mi	79.4 mi	$65,187,000

10.8 Components (rail, ties, etc.) $71,301,000

The cost estimate of components of rail road e.g. rails, ties, relay rail surface curves, curvature reduction was taken from Quandel Consultants report prepared in 2011. Then, this cost was normalized based on the inflation factor. The Engineering News Record cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 33. The total length of this segment is 79.4 miles.

TABLE 33 Cost of Components for Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Installing rail ties	$400,000/mi	79.4 mi	$31,760,000
2	Installing rail, spikes, plates, and anchors	$428,000/mi	79.4 mi	$33,983,000
3	Preparing surface curves and adjusting super elevations	$70,000/mi	79.4 mi	$5,558,000
			Total Cost	$71,301,000

10.9 Special Track Work (switches, turnouts, insulated joints) $1,208,000

The cost estimate of special track work was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index used to calculate the inflation factor. The detailed cost estimate is shown in Table 34. Four turnouts are needed in each segment of the railroad.

TABLE 34 Cost of Special Track Work for Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Turnouts cost with concrete ties	$302,000/each	4	$1,208,000

10.10 Major Interlocking $7,130,000

The major interlocking cost was assumed to be 10% of the cost for rail components, or $7,130,000.

10.11 Switch Heaters (with power and control) $10,695,000

The cost for switch heaters cost was assumed to be 15% of the rail component cost, or $10,695,000.

10.12 Vibration and Noise Dampening $7,130,000

The cost for vibration and noise dampening was assumed 10% of the rail component cost, or $7,130,000.

10.13 Other Linear Structures, including Fencing and Sound Walls $14,689,000

The cost estimate of fencing and sound walls was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 35. The total length of this segment is 79.4 miles. It was assumed about 1% of rail road section will need sound walls, and fencing will be used in the entire railroad for safety purposes.

TABLE 35 Cost of Linear Structures for Segment 3

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Fencing with 6-ft chain link on both sides of the right-of-way	$185,000/mi	79.4 mi	$14,689,000

10 Cost of Track Structures and Tracks for Segment 4 (Length = 42.4 Miles)

10.1 Grubbing, Cutting, and Filling $191,838,000

The detailed estimate of grubbing, cutting, and fitting for Segment 4 is shown in Table 36.

TABLE 36 Cost of Grubbing, Cutting, and Fitting for Segment 4

Item No.	Item Name	Unit Cost	Total Quantity	Total Cost
10.1.1	Grubbing & Clearing	$5,324.8/ acre	612 acres	$3,257,000
10.1.2	Cutting	$7.68/ BCY	12,324,337 BCY	$94,651,000
10.1.3	Filling Cost	$7.62/ BCY	11,463,445BCY	$93,930,000
			Total Cost	$191,838,000

10.2 Major Bridges $9,900,000

The cost estimate of bridges was based on type of bridge. For this estimate, if the bridge had less than 50-ft span and 10-ft height, it was designated as a minor bridge. If either the span or height increased, then the bridge was designated as a major bridge. The cost of a major bridge was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 37.

TABLE 37 Cost of Major Bridges for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Major Bridges	$9,900,000	1	$9,900,000

10.3 Minor Bridges $1,075,000

The cost of minor bridges was calculated based on similar to that of major bridges, as shown in Table 38.

TABLE 38 Cost of Minor Bridges for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Minor Bridges	$1,075,000	1	$1,075,000

10.4 Bridges Crossing Roads or Railways $9,545,000

The cost estimate of bridges for road or railway crossings was based on the type of highway or railroad. For this estimate, the cost of the bridge for a road or railway crossing was taken from the Quandel Consultants (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 39.

TABLE 39 Cost of Bridges Crossing Roads or Railways for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost

1	Bridge over a four-lane urban expressway	$5,850,000	1	$5,850,000
2	Bridge over a two-lane rural expressway	$4,870,000	-	-
3	Bridge over a two-lane highway	$3,696,000	-	-
4	Bridge over a railway crossing	$3,695,000	1	$3,695,000
			Total Cost	$9,545,000

10.5 Retaining Walls and Systems $67,388,000

The cost estimate of retaining walls and systems was based on the type of railroad. For this estimate, the cost of retaining walls and systems for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 40. It was estimated that 3% of the road will need retaining walls and systems. The total length of this segment is 42.4 mi (223,872 ft) and 3% of this length (6,716 ft) will require the retaining walls and systems.

TABLE 40 Cost of Retaining Walls and Systems for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Retaining walls for a double track railroad	$10,034/ft	6,716 ft	$67,388,000

10.6 Culverts and Drainage Systems $6,805,000

The cost estimate of a culvert and drainage system was based on installation of 30-in-diameter pipes to be installed as culverts. For this estimate, the cost of a culvert and drainage system for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *Engineering News Record* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 41. It was estimated that about four culverts are required in each mile of the railroad. The total length of this segment is 42.4 miles.

TABLE 41 Cost of Culverts and Drainage Systems for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Culvert and drainage system in a double track railroad	$160,500/mi	42.4 mi	$6,805,000

10.7 Conventional Ballasted Subgrade $34,810,000

The cost estimate of new roadbed with conventional ballasted subgrade was based on thickness of the compacted ballast, or 18 in. For this estimate, the cost of the compacted ballast was calculated based on 35-ft-wide track for a double train. The detailed cost estimate is shown in Table 42. The total length of this segment is 42.4 miles.

TABLE 42 Cost of Conventional Ballasted Subgrade for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Conventional ballasted subgrade	$821,000/mi	42.4 mi	$34,810,000

10.8 Components (rail, ties, etc.) $38,075,000

The cost estimate of components of railroad – e.g. rails, ties, relay rail surface curves, and curvature reduction – was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 43. The total length of this segment is 42.4 miles.

TABLE 43 Cost of Components for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Installing rail ties	$400,000/mile	42.4 miles	$16,960,000
2	Installing rail, spikes, plates, and anchors	$428,000/mile	42.4 miles	$18,147,000
3	Preparing surface curves and adjusting super elevations	$70,000/mile	42.4 miles	$2,968,000
			Total Cost	38,075,000

10.9 Special Track Work (switches, turnouts, insulated joints) $604,000

The cost estimate of special track work was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 44. Two turnouts are needed in this segment of the railroad, because the length of the railroad in this segment is half of that the rest of the segments.

TABLE 44 Cost of Special Track Work for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Turnouts cost with concrete ties	$302,000/each	2	$604,000

10.10 Major Interlocking $3,807,000

The cost for major interlocking was assumed to be 10% of the cost of rail components, or $3,807,000.

10.11 Switch Heaters (with power and control) $5,711,000

The cost of switch heaters was assumed to be 15% of the cost of rail components, or $5,711,000.

10.12 Vibration and Noise Dampening $3,807,000

The cost of vibration and noise dampening was assumed to be 10% of the cost of rail components, or $3,807,000.

10.13 Other Linear Structures, including Fencing and Sound walls $7,844,000

The cost estimate of fencing and sound walls was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 45. The total length of this segment is 42.4 miles. It is assumed about 1% of rail road section will need sound walls, and the fencing will be used in the entire rail road for safety purposes.

TABLE 45 Cost of Linear Structures for Segment 4

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Fencing with 6- ft chain link on both sides of the right-of-way	$185,000/mi	42.4 mi	$7,844,000

10 Cost of Track Structures and Tracks for Segment 5 (Length = 54.8 Miles)

10.1 Grubbing, Cutting, and Filling $88,225,000

The detailed estimate of grubbing, cutting, and fitting for Segment 5 is shown in Table 46.

TABLE 46 Cost of Grubbing, Cutting, and Fitting for Segment 5

Item No.	Item Name	Unit Cost	Total Quantity	Total Cost
10.1.1	Grubbing & Clearing	$5,324.8/ Acre	791 Acres	$4,209,000
10.1.2	Cutting	$7.68/ BCY	5,490,000 BCY	$42,169,000
10.1.3	Filling Cost	$7.62/ BCY	5,475,586 BCY	$41,847,000
			Total Cost	$88,225,000

10.2 Major Bridges $29,700,000

The cost estimate of bridges was based on the type of bridge. For this estimate, if the bridge had less than a 50-ft span and 10-ft height, then it was designated as a minor bridge. If either the span or height increased, then the bridge was designated as a major bridge. The cost of a major bridge was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 47.

TABLE 47 Cost of Major Bridges for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Major Bridges	$9,900,000	3	$29,700,000

10.3 Minor Bridges $0

The cost of a minor bridge was calculated based on a similar assumption used for a major bridge, as shown in Table 48.

TABLE 48 Cost of Minor Bridges for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Minor Bridges	$1,075,000	-	-

10.4 Bridges Crossing Roads or Railways $21,245,000

The cost estimate of bridges for road or railway crossings was based on the type of highway or railroad. For this estimate, the cost of the bridge crossing a road or railway was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 49.

TABLE 49 Cost of Bridges Crossing Roads or Railways for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Bridge over a four-lane urban expressway	$5,850,000	3	$17,550,000
2	Bridge over a two-lane rural expressway	$4,870,000	-	-
3	Bridge over a two-lane highway	$3,696,000	-	-
4	Bridge over a railway crossing	$3,695,000	2	$3,695,000
			Total Cost	$21,245,000

10.5 Retaining Walls and Systems $58,067,000

The cost estimate of retaining walls and systems was based on the type of railroad. For this estimate, the cost of the retaining walls and systems for a double track was taken from the Quandel Consultants (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 50. It was estimated that 2% of the road will need retaining walls and systems. The total length of this segment is 54.8 mi (289,344 ft) and 2% of this length (5,787 ft) will require retaining walls and systems.

TABLE 50 Cost of Retaining Walls and Systems for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Retaining walls for a double track railroad	$10,034/ft	5,787 ft	$58,067,000

10.6 Culverts and Drainage Systems $8,795,000

The cost estimate of culvert and drainage systems was based on the installation of 30-inch-diameter pipes to be installed as culverts. For this estimate, the cost of the culvert and drainage systems for a double track was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *Engineering News Record* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 51. It was estimated that about four culverts are required in each mile of the railroad. The total length of this segment is 54.8 miles.

TABLE 51 Cost of Culvert and Drainage Systems for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Culvert and drainage system for a double track railroad	$160,500/mi	54.8 mi	$8,795,000

10.7 Conventional Ballasted Subgrade $44,991,000

The cost estimate of new roadbed with conventional ballasted subgrade was based on the thickness of the compacted ballast, or 18 inches. For this estimate, the cost of the compacted ballast was calculated based on 35-ft-wide track for a double train. The detailed cost estimate is shown in Table 52. The total length of this segment is 54.8 miles.

TABLE 52 Cost of Conventional Ballasted Subgrade for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Conventional ballasted subgrade	$821,000/mi	54.8 mi	$44,991,000

10.8 Components (rail, ties, etc.) $49,210,000

The detailed cost estimate of components is shown in Table 53.

TABLE 53 Cost of Components for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Installing rail ties	$400,000/mi	54.8 mi	$21,920,000
2	Installing rail, spikes, plates, and anchors	$428,000/mi	54.8 mi	$23,454,000
3	Preparing surface curves and adjusting super elevations	$70,000/mi	54.8 mi	$3,836,000
			Total Cost	49,210,000

10.9 Special Track Work (switches, turnouts, insulated joints) $604,000

The cost estimate of special track work was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 54. Two turnouts are needed in this segment of the railroad because the length of the railroad in this segment is half of that for the rest of the segments.

TABLE 54 Cost of Special Track Work for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Turnouts cost with concrete ties	$302,000/each	2	$604,000

10.10 Major Interlocking $4,921,000

The major interlocking cost was assumed to be 10% of the cost for rail components, or $4,921,000.

10.11 Switch Heaters (with power and control) $7,381,000

The cost for switch heaters cost was assumed to be 15% of the cost for rail components, or $7,381,000.

10.12 Vibration and Noise Dampening $4,921,000

The cost for vibration and noise dampening was assumed to be 10% of the cost for rail components, or $4,921,000.

10.13 Other Linear Structures, including Fencing and Sound Walls $10,138,000

The cost estimate of fencing and sound walls was taken from the Quandel Consultants report (2011). This cost was normalized based on the inflation factor. The *ENR* cost index was used to calculate the inflation factor. The detailed cost estimate is shown in Table 55. The total length of this segment is 54.8 miles. It is assumed about 1% of railroad section will need sound walls, and fencing will be used in the entire railroad for safety purposes.

TABLE 55 Cost of Linear Structures for Segment 5

No.	Item Name	Unit Cost	Total Quantity	Total Cost
1	Fencing with 6-ft chain link on both sides of the right-of-way	$185,000/mi	54.8 mi	$10,138,000

20 Stations ($71,204,000)

20.01 Station Buildings: Structures Only

After the design was completed, the quantity of each item of the structures was calculated. The detailed estimate is shown in the Appendix A.

- Cost of each station = $4,005,000
- It was assumed there are stations on the end of each segment. Therefore, there are six stations.
- Total cost of the stations = 6 x $4,005,000 = $24,030,000

20.02 Station Buildings: Service Buildings

The cost of the service buildings was assumed as 25% of the station cost. The total cost of the station buildings = 0.25 x $24,030,000 = $6,007,000.

20.03 Platforms

The cost of platforms for loading and unloading the trucks was assumed to be 20% of the station building cost. The total cost of platforms = 0.20 x $24,030,000 = $4,806,000

20.04 Truck Loading and Unloading Systems

The cost for the truck loading and unloading system was not found because it is a hydraulic-based system. It was assumed that the system could cost $5,000,000 for each station. The total cost of truck loading and unloading system = 6 x $5,000,000 = $30,000,000.

20.05 Fare Collection System

The fare collection system in each station was assumed to cost about $500,000. The total cost of the fare collection system = 6 x $500,000 = $3,000,000

20.06 Access System for Entering and Existing the Loading Systems

The cost of an access system for entering and exiting the loading system was assumed to be 20% of the cost for the platforms. The total cost of access system for entering and existing the loading systems = 0.20 x $4,806,000 = $961,000.

20.07 Station Security System

The cost of station security system was estimated to be 5% of the station cost. The total cost for the station security system = 0.05 x $24,030,000 = $1,200,000.

20.08 Accommodation, Landscaping, Parking Lots

This cost was estimated to be 5% of the station cost, or $1,200,000.

30 Support Facilities: Yards, Shops, and Administration Buildings ($347,240,000)

30.01 Administration Building: Office, Sales, Storage, Revenue Counting

The cost of administration buildings was estimated as 20% of the station cost. The total cost for administration buildings = 0.20 x $71,204,000 = $14,240,000.

30.02 Light Maintenance Facilities

The cost of light maintenance facilities was estimated to be $40,000,000 each. It was assumed that there will be four light maintenance facilities in this route, each located at stations midway. Total cost of light maintenance facilities = 4 x $40,000,000 = $160,000,000.

30.03 Heavy Maintenance Facilities

The cost of heavy maintenance facilities was estimated as $70,000,000 each. It is assumed that there will be two heavy maintenance facilities in this route, one at the start and other at the end of the route. The total cost of the heavy maintenance facilities = 2 x $70,000,000 = $140,000,000.

30.04 Maintenance Storage

The cost of maintenance storage buildings was about $5,000,000 each. There will be six maintenance storage facilities. The total cost of maintenance storage buildings = 6 x $5,000,000 = $30,000,000.

30.05 Yards and Yard Tracks

The cost of yard and yard track was about $500,000. There will be six yards and yard tracks along this alignment. The total cost of yards and yard tracks = 6 x $500,000 = $3,000,000.

40 Sitework, Right-of-Way, Land, etc. ($696,050,000)

40.01 Demolition, Clearing, Site Preparation

The cost of demolition, clearing, and site preparation was estimated to be $100,000/mi.
The total cost of demolition, clearing, and site preparation = 320 mi x $100,000 = $32,050,000.

40.02 Site Utilities and Utility Relocation

The cost of site utilities and utility relocation was estimated to be $1,000,000/mi. The total cost of site utilities and utility relocation =320 mi x $1,000,000 = $320,000,000

40.03 Hazardous Material, Contaminated Soil Removal/ Mitigation, and Ground Water Treatment

The cost of hazardous material, contaminated soil removal, and ground water treatment was estimated as $150,000/mi. The total cost of hazardous material, contaminated soil removal, and ground water treatment = 320 mi x $150,000 = $48,000,000.

40.04 Environmental Mitigation: Wetlands, Historic/ Archeology, and Parks

The cost of environmental mitigation – e.g., wetlands, historic or archeology, and parks – was estimated to be $400,000/mi. The total cost of environmental mitigation = 320 mi x $400,000 = $128,000,000.

40.05 Temporary Facilities and Other Indirect Cost during Construction

The cost of temporary facilities and other indirect cost during construction was estimated to be $3,000,000 per segment of roads. The total cost of temporary facilities = 6 x $3,000,000 = $18,000,000.

40.06 Purchase of Real Estate

The cost of purchasing real estate was estimated to be $50,000,000 (lump sum).

40.07 Relocation of Existing Households and Business

The relocation of existing households and business was estimated to be $100,000,000 (lump sum).

50 Communication and Signaling ($79,150,000)

50.01 Wayside Signaling Equipment

The cost of wayside signaling equipment was estimated to be $100,000/mi. The total cost of wayside signaling equipment = 320 mi x $100,000 = $32,000,000.

50.02 Signal Power Access and Distribution

The cost of signal power access and distribution was estimated to be $25,000/mi. The total cost of signal power access and distribution = 320 mi x $25,000 = $8,000,000.

50.03 Onboard Signaling Equipment

The cost of onboard signaling equipment was estimated to be $1,000,000 (lump sum).

50.04 Traffic Control and Dispatching Systems

The cost of traffic control and dispatching systems was estimated to be $5,000,000.

50.05 Communications

The cost of communications was estimated to be $100,000/mi. The total cost of communication = 320 mi x $100,000 = $32,000,000.

50.06 Grade Crossing Protections

The cost of grade crossing protections was estimated as $100,000 per crossings. There are seven grade crossings on this alignment. The total cost of grade crossings = $100,000 x 7= $700,000.

50.07 Warning System for Trains Approaching Stations

The cost of flashing lights with warning bells cost $75,000 per station. The total cost of warning systems of trains approaching a station = 6 stations x $75,000 = $450,000.

60 Diesel Vehicles ($15,000,000)

60.01 Vehicle Acquisition: Diesel Multiple Units

The cost of diesel multiple units was estimated to cost $3,000,000. There will be four units. The total cost of diesel multiple units = 4 x $3,000,000 = $12,000,000.

60.02 Vehicle Acquisition: Non-railroad Support Vehicles

The cost of non-railroad support vehicles was estimated to be $1,000,000.

60.03 Vehicle Acquisition: Railroad Maintenance-of-Way Vehicles

The railroad maintenance-of-way vehicles was estimated as $1,000,000.

60.04 Spare Parts

The cost of spare parts was estimated to be $1,000,000.

70 Professional Services (Items 10 – 60) ($704,981,000)

70.01 Service Development Plan / Service Environmental

The cost of a service development plan and service environmental was estimated as 1% of the total construction cost. The total service development plan = 0.01 x $3,111,033,000 = $31,110,000

70.02 Preliminary Engineering / Project Environmental

The cost of preliminary design was estimated as 3% of the total construction cost. The total cost of preliminary design = 0.03 x $3,111,033,000 = $93,331,000.

70.03 Final Design

The total cost of the final design was estimated as 7% of the construction cost. The total cost of final design = 0.07 x $3,111,033,000 = $217,772,000.

70.04 Project Management for Design and Construction

The total cost of the project management for design and construction is 1.5% of the total construction cost. The total cost of project management = 0.015 x $3,111,033,000 = $46,665,000.

70.05 Construction Administration and Management

The cost of construction administration and management was estimated as 5% of the total construction cost. The total cost of construction administration and management = 0.05 x $$3,111,033,000 = $155,552,000.

70.06 Professional Liability and Other Non-Construction Insurance

The cost of insurance and bonding was estimated as 2% of the total construction cost. The total cost of insurance and bonding = 0.02 x $3,111,033,000 = $62,221,000.

70.07 Legal: Permits: Review Fees by Other Agencies and Cities, etc.

The cost of legal work was estimated as 1% of the total construction cost. The total legal cost = 0.01 x $3,111,033,000 = $31,110,000.

70.08 Surveys, Testing, and Investigations

The cost of surveys testing, and investigation was estimated as 1% of the total construction cost. The total cost for surveys, testing, and investigations = 0.01 x $3,111,033,000 = $31,110,000.

70.09 Engineering Inspection

The cost of engineering inspection was estimated as 1% of the total construction cost. The total cost for engineering inspections = 0.01 x $3,111,033,000 = $31,110,000.

70.10 Start-up Costs

The total cost of start-up was estimated as $5,000,000.

80 Contingency Cost ($155,552,000)

The total contingency cost was estimated as 5% of the total construction cost. The total Contingency Cost = 0.05 x $3,111,033,000 = $155,552,000.

90 Contractors' Profits (Applies to Items 10 – 80) ($62,221,000)

The total contractors' profit was estimated as 2% of the total construction cost. Contractor's profit = 0.02 x $3,111,033,000 = $62,221,000.

Total Cost ($4,033,787,000)

The total cost of the project = **$4,033,787,000.** The cost per lane mile = $4,033,787,000 / 320 = **$12,606,000/mi.**

Operating and Maintenance Costs

This section discusses the Operating and Maintenance (O&M) costs of the Land Ferry.

Operating Cost

The operating cost of the Land Ferry includes the cost of fuel, oils, operators, and spare parts to operate the train. In addition, it includes the cost of running the stations, administrative buildings, and other facilities. According to the research, for a 30-year life cycle, the cost of buildings, utilities, services, and system replacement is about 36%; the maintenance cost is about 6%; and the initial cost of the project is about 58% *(11)*. Based on this assumption, the cost of utilities, service, and system replacement can be calculated as follows.

- The cost of stations and administrative buildings = $71,204,000 + $347,240,000 = $418,444,000.
- The cost of utilities, service, and system replacement for 30 years = (0.36/0.58) x $418,444,000 = $259,724,000 for 30 yrs.
- The cost of utilities, services, and system replacement for each year = $259,724,000 / 30 **= $8,657,000/yr.**

The operating cost of the railroad can be calculated based on the number of trips travelled every day. Assume that the Land Ferry will make two trips every day in each direction.

- The total distance travelled by the Land Ferry every day = 4 x 320 mi = 1,280 mi
- Diesel consumption for the Land Ferry = 3 gal/mi
- Total diesel consumption per day = 1280 mi x 3 gal/mi = 3,840 gal
- The cost of diesel = 3,840 gal x $4.00/gal = $15,360 per day
- The cost of oil is 20% of the diesel cost = 0.20 x $15,360 = $3,072
- Total diesel and oil cost per day = $15,360 + $3,072 = $18,432
- Total cost for diesel and oil per year = 365 x $18,432 = **$6,727,000 per year**

It was assumed that four operators will be required to operate the Land Ferry. Based on a $50/hr wage for the operators, and 4.5 hours (320 mi/70 mph) of travel time per trip:

- The total cost of an operator for one year = 364 days x $75/hr x 12 hours per day = **$328,000/yr.**
- The total operating cost = $8,657,000 + $6,727,000 + $328,000 = $15,712,000/yr.

Maintenance Cost

The maintenance cost includes the maintenance of the stations, administrative buildings, tracks, and railroad engines. For stations and administrative buildings, the maintenance cost can be calculated based on previous assumptions.

- Maintenance cost of stations and administrative buildings = (0.06/0.58) x $418,444,000 = $43,287,000 for 30 yrs = $43,287,000 / 30 = **$1,443,000/yr**
- The cost of track maintenance was assumed to be 10% of the track cost
- The track maintenance cost = 0.10 x $263,048,000 = **$26,304,000/yr**
- The maintenance cost of a rail engine was assumed to be 50% of its total lifecycle cost

- The maintenance cost for a railroad engine = 0.50 x $15,000,000 / 10 yr (the life of a rail engine) = **$750,000/yr**
- Total maintenance cost = $1,443,000 + $265,304,000 + $750,000 = $28,497,000/yr
- Total maintenance cost per mile = $28,497,000 / 320 = $89,000/mi/yr
- Total O&M cost = $15,712,000 + $28,497,000 = $44,209,000/yr
- Total O&M cost = $138,200/mi

SECTION 4: SYSTEM DESCRIPTION

The ability to move trucks on and off the train in an efficient and safe manner is crucial for the Land Ferry to be attractive to potential clients. If the loading and/or unloading times are too high, leading to longer delivery times, the Land Ferry will not be an option that will be used by trucking companies because they hold to strict deadlines.

In similar systems across the world, a truck ramp is utilized to load and unload trucks. The ramp is portable, and can be moved to the end of the train when it is at a station stop. In addition, it is important to consider the safety of the drivers while loading and/or unloading. Hence, this study proposes using a sliding system to move trains on and off the train. How this system works is as follows.

While waiting at the train station, a truck is secured to the platform. When the train arrives, a sliding system moves the platform and truck onto the train. Then, the platform locks into place on the train. This system will increase the safety of the loading process because it takes away almost all human contact; specifically, it relies on a machine to move a truck to and from the train. Furthermore, it remove the issue of ordering because the platform could be removed from train without interfering with any other trucks currently on the train.

This section describes an automated loading mechanism for sliding vehicles on and off platforms.

Introduction

The automated loading mechanism proposed for sliding vehicles on and off platforms expands existing opportunities to develop and build such alternative systems for multi-modal transportation systems as the Land Ferry, which is a train loaded with vehicles. In order to facilitate the description of the proposed mechanism, the case of the Land Ferry is used in this document. However, other potential applications may be derived in the future from application of this system to the Land Ferry.

Stations

The stations provide the conditions required for loading and unloading by having a long, raised, and wide lane that is parallel to the rails. A lane on each side of the rails is required to enable simultaneous loading and uploading. This is important to save time and ensure efficiency so that truck drivers are encouraged to use the Land Ferry. Ramps on each end of the lanes are required. One of the ramps is used to drive the vehicle up into the platform where the sliding mechanism is installed. The other ramp is used to drive the vehicle off the platform.

The lanes include walking space on the outside of the station to allow workers to get from section to section easily, if the platform is located on the other side. The station is constructed with materials that are suited to bear the weight of several fully loaded semi-trailers, many times per day.

Loading Platforms

Each station consists of a number of loading platforms located along the station lanes; each with the ability to load or unload a loading board carrying a vehicle onto or off a single railcar. The loading platform includes a section where strong, low-friction casters are installed on the bottom of a steel-loading board, which can be rolled from the platform to the railcar. Guide rails ensure that the boards slide into and from the railcars properly. Hydraulic arms and motors are used to slide or roll the boards, with the vehicles on them. They can be located underneath the walkway part of the loading section. The area where a board sits, known as the pit area, is slightly elevated off the ground; it has several metal guide rails attached to its floor. The elevation of the guide rails in the pit area matches the elevation of the guide rails located on the railcars. This ensures a smooth transition on and off the railcar. In addition, the area separating the walkway from the platform contains a mechanical railing, which prevents any accidental falls into the pit area.

Loading Boards

The boards are made of steel or a similar type of weight-bearing material, and have the strength required to support the weight of any vehicle(s), fully loaded. The boards are as long as an average railcar and wide enough to fit a typical semi-truck, with walking space on each side. As shown in Figure 18, each board is able to fit both one full semi-trailer and its cab, or up to three personal vehicles of various sizes.

FIGURE 18 An example of loading board with a semi-trailer *(12)*.

They slide onto the railcars or platform sections, using the hydraulic arms. As described before, strong, low-friction casters or wheels are installed onto the bottom of the board. Figure 19 shows an example of guide rails, which ensure that the boards slide into the railcars and platform sections properly.

FIGURE 19 An example of guide rails *(13)*.

Several rows of these railway trolleys are required to support the weight of the loading board and a fully loaded semi-trailer. These trolleys are fastened parallel to each other on the bottom of the loading board. They ride along on rails similar to those shown in Figure 19. The railcar has these rails fastened to it. Each loading board has a series of durable, hard, rubber bumpers on each side to prevent them from bumping into each other. As shown in Figure 20, the boards include several areas at which to tie down vehicles in order to ensure that they do not move.

FIGURE 20 An example of a board to tie down vehicles *(14)*.

These forks could be fastened permanently to the loading boards, and would be durable enough to be driven over and into proper position.

The Railcar

Railcars of typical size and strength can be used for the Land Ferry. However, each railcar is required to be equipped with a number of metal guiderails, which flare out at both ends. This allows for a margin of error when the train pulls into the station. The loading board runs inside these guiderails, ensuring that the board stays in its proper location when the hydraulic arms are pushing it. Then, the board is secured to the railcar by using a series of heavy-duty hooks, as shown in Figure 21.

FIGURE 21 A railcar supported by heavy-duty hooks (*15*).

These hooks can be automated, and run along the length of the railcar on both sides. In addition, the hooks prevent the loading board from moving during transit. A typical railcar specification is listed below *(16).*

- Length: 86.5 - 92.5 ft
- Width: 9.5 - 10.5 ft

- Capacity: 80,000 lb

In addition, the railcars may include charging equipment for electric vehicles and a pantograph to pull in electricity for the charging equipment.

The Hydraulics

The telescopic hydraulic cylinders can be housed underneath the walkway area on both sides of the station. These cylinders need to be at least two-thirds the width of the station length in order to push a platform from one side of the rail to the other. The hydraulic cylinders need to be powerful enough to slide two platforms, one on the platform section and one on the train. The first slides from the platform onto the railcar. The second slides from the railcar to the platform onto the other side of the rail. The controls for the hydraulic arms and motors can be located on top of the platform section.

Figure 22 demonstrates the ability of just two telescopic hydraulic cylinders, which are capable of lifting a fully loaded semi vertically into the air. The cylinders would have to be repositioned onto the sides of the loading board so that the loading board – which will be on wheels – is pushed horizontally.

FIGURE 22 Hydraulic cylinder holding a fully loaded semi-trailer *(17*).

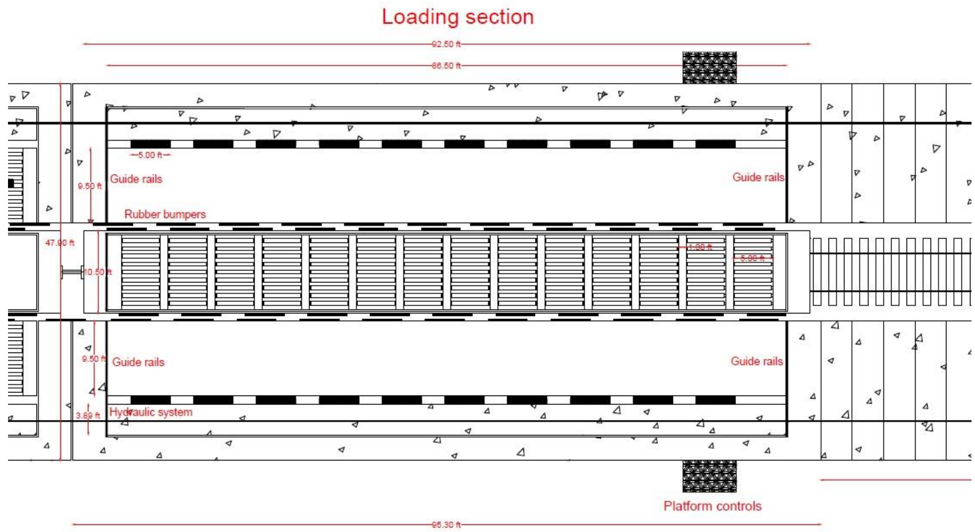
Spare Railcars

After the addition of several stations along the route, a potential problem appeared when some vehicles exit the train at a given station and the rest continue onto another location down the line. This could leave some platforms on one side of the rail and the rest of the platforms on the other side. Ultimately, it would block the exits and entrances to each side of the station. As a result, this system requires that the loading boards all be on the same side of the station because they form the pathway that allows the vehicles to enter or exit.

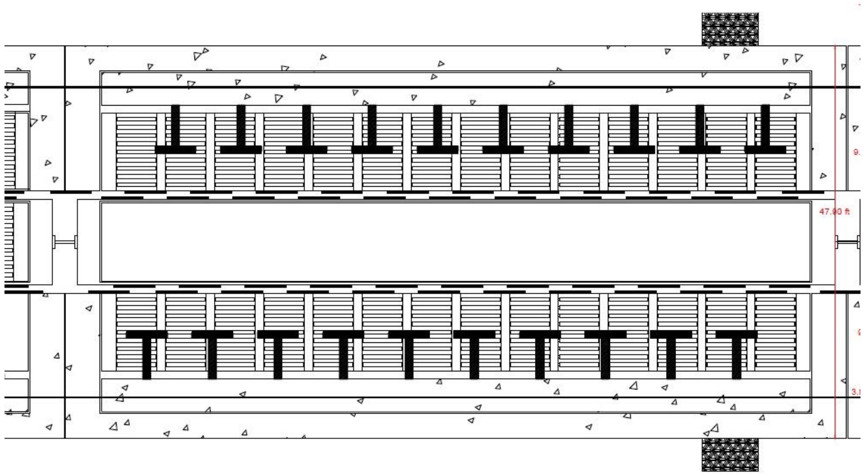
To address this problem, it is required to have a series of spare railcars and a switch track at each station. After the train has departed, workers can move the spare railcar into position between platform sections. The spare railcar will bridge the gap between the two platform sections and allow them to slide the board(s) back onto the correct side of the rail in preparation for the next train. As mentioned before, the hydraulic arms need to be able to extend to the edge of the opposing platform section.

Loading/Unloading Process

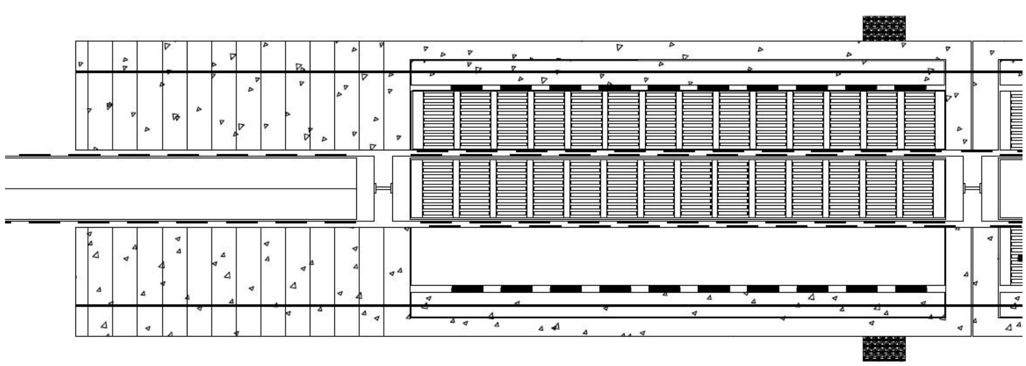
Vehicles approach the station, where workers guide the vehicle up the station ramp and over the platforms until they positioned correctly in their designated loading-board section. The workers assist the vehicle owner/operator in securing the vehicle to the platform. As the train stops at the station, workers operate the hydraulic arms to slide the new loading board into contact with the board present on the train. The board on the train slides off into the board section onto the other side of the track. The new board slides onto the train and locks into position. The train leaves the station, and workers throughout the station and down the ramp guide the vehicles that have just exited the train to the other end. Similarly, this process is repeated on the other side of the track. Figure 23a, 23b, and 23c provide a conceptual schematic of the proposed sliding loading mechanism.



a) Top view of one loading platform section alongside the rail.



b) Top view of how the hydraulics extends out from underneath the loading section.



c) Top view of two loading boards, one that will be offloaded and one that will be loaded onto the train.

FIGURE 23 Conceptual schematic of the proposed slide-loading mechanism.

SECTION 5: POWER GENERATION

This section discusses various renewable and non-renewable sources of power generation to operate a Land Ferry System.

Energy Consumption

The cost of installation of a renewable energy system begins with calculating the required amount of power consumed by the load. In order to find the power required by the locomotive, the tractive effort must be calculated and translated in terms of horsepower. Tractive effort is calculated *(18)* by determining the total weight of the train, including its locomotive, and comparing it to a series of features of the route from one location to the next.

A large number of factors are considered in order to compute the tractive effort. First, a force of 2 – 5 pounds per ton (lb/T) is required to maintain the speed of the train on a straight level track. Second, the curvature of the track can increase the tractive effort needed to move a train. For the cars in a curve, 0.8 lb of tractive effort is needed per ton per degree of curvature. In general, the maximum curvature experienced is 12 degrees. Third, and most important, the percent grade is the largest factor when calculating tractive effort. Twenty pounds (20 lb) of tractive effort per ton per 1% of slope is required. The fourth and final factor for calculating tractive effort is acceleration of the train. Acceleration requires 10 lb/T to accelerate 6 mi/hr in one minute. In order to accelerate the train to 70 mi/hr, it takes approximately 11.5 min of tractive effort at 10 lb/T, which is an insignificant amount of time when calculating power usage.

Several scenarios were considered for the Land Ferry project. Regarding number of trucks per train, as this factor changes, the weight of the train changes as well. When determining the total tractive effort for a single, one-way trip, it is important to note that the tractive effort required at any given moment will be different from one point to another because of the four factors listed above. This presents several variables that are difficult to calculate precisely. As a result, an approximate average horsepower for an entire trip is used to calculate the necessary electric power requirements.

Generally, the largest amount of tractive effort is required when the train is moving uphill. Thus, calculations will be based almost exclusively on this information in order to determine a worst-case scenario. The calculations will assume a grade of 1.5% for the entire trip in order to allow for some leeway in the other factors on tractive effort. For example, using the details above for tractive effort on a grade, if the grade is 1.5% for the duration of the trip and the maximum weight of the train is 2000 T, a tractive effort of 20 lb x 2000 T x 1.5 = 60,000 lb is required. Table 56 shows the tractive effort required for a single, one-way trip, using various sizes of trains.

TABLE 56 Tractive Effort Required Based on Train Size

Number of Trucks per Train	Total Weight (lb)	Tons	Tractive Effort Required (lb)
15	2325000	1162.5	34875
20	2820000	1410.0	42300
25	3315000	1657.5	49725
30	3810000	1905.0	57150

It is important to note that the entire trip will not be on a 1.5% grade, and at several points, there will be downhill portions, curves, accelerations, and decelerations. Therefore, a 1.5% grade factor provides a worst-case scenario for electrical power generation.

Horsepower is calculated *(18)* by multiplying the tractive effort and the speed of the train (70 mph is the target for this project) and dividing by 375. For the same example, the estimated horsepower of the train is $60000 * \frac{70}{375} = 11200$ horsepower (hp). In order to convert mechanical horsepower into electrical power, some losses will be sustained in terms of efficiency.

In general, electric locomotives are approximately 85% efficient. Therefore, 11200 hp is approximately equal to an electric motor that provides $\frac{11200}{0.85} = 13200$ hp. Since electric power is measured in watts or kilowatts or megawatts, horsepower must be converted to the appropriate units. The conversion factor is 746 W = 1 hp.

The required power is calculated in terms of megawatts (MW) is:

$$13200 * \frac{746}{1000000} = 9.8 \text{ MW}$$

Table 57 shows the conversion from tractive effort to horsepower and to megawatts.

TABLE 57 Conversion of Tractive Effort to Megawatts (MW)

Number of Trucks per Train	Tractive Effort (lb)	Horsepower (hp)	Megawatts (MW)
15	34875	7659	5.71
20	42300	9289	6.93
25	49725	10920	8.15
30	57150	12551	9.36

This project evaluated various possibilities for the number of trips per day for each of the train sizes. The required amount of electricity per day is equivalent to the amount of electricity times the number of trips made each day. In addition, electricity cost is calculated in terms of megawatt-hours (MWh), which implies that the calculation must include the number of hours that this amount of electricity is being consumed. The train is averaging approximately 70 mi/hr over a distance of 330 mi; therefore, the trip will take about 4.75 hr. As an example, the electricity consumption for the smallest train (15 trucks per train) to make the trip 12 times per day is equal to 5.71 MW x 4.75 x 12 = 423.88 MWh. Tables 58, 59, 60, and 61 show the prospective scenarios for each train size, the projected number of trips per day, and the amount of electricity consumed in terms of MWh.

TABLE 58 Electricity Consumption Based on Multiple Scenarios for 15 Trucks per Train (5.71 MW)

Number of Trips per Day	Total Power Consumed per Day (MW)	Total Power Consumed per Day (Mwh)
12	68.40	324.88
24	136.79	649.76
36	205.19	974.65
48	273.58	1299.53

TABLE 59 Electricity Consumption Based on Multiple Scenarios for 20 Trucks per Train (6.93 MW)

Number of Trips per Day	Total Power Consumed per Day (MW)	Total Power Consumed per Day (Mwh)
9	62.22	295.54
18	124.44	591.08
27	186.66	886.61
36	248.87	1182.15

TABLE 60 Electricity Consumption Based on Multiple Scenarios for 25 Trucks per Train (8.15 MW)

Number of Trips per Day	Total Power Consumed per Day (MW)	Total Power Consumed per Day (Mwh)
7	58.51	277.93
14	117.02	555.86
22	175.54	833.79
29	234.05	1111.72

TABLE 61 Electricity Consumption Based on Multiple Scenarios for 30 Trucks per Train (9.36 MW)

Number of Trips per Day	Total Power Consumed per Day (MW)	Total Power Consumed per Day (Mwh)
6	56.04	266.19
12	112.08	532.39
18	168.12	798.58
24	224.16	1064.77

Solar Photovoltaic System

Planning the size of a solar photovoltaic (PV) system depends upon the average amount of direct sunlight that shines on the solar panels. This varies depending upon geographic location. For northern Nevada, the average amount of sunlight in one day is approximately 5.5 to 6 hours (*19*). Solar PV systems are rated in terms of MW, since the amount of sunlight varies from location to location. The estimated size of a solar system is determined by dividing the MWh required by the average hours of direct sunlight. This equates to a system size of $\frac{324.88 \text{ MWh}}{5.5 \text{ h}} = 59$ MW.

The average cost of a solar PV system is approximately \$2.00/W (*20*). The system for this example would cost approximately 59 x 100000 x 2 = \$118 million. Tables 62, 63, 64, and 65 show the size as well the as approximate cost for each scenario.

TABLE 62 Cost of a Solar Photovoltaic (PV) System Based on Multiple Scenarios for 15 Trucks per Train (5.71 MW)

Number of Trips per Day	Size of PV System (MW)	Approximate Cost of a PV System (in millions)
12	59.07	\$118.1
24	118.14	\$236.3
36	177.21	\$354.4
48	236.28	\$472.6

TABLE 63 Cost of a Solar PV System Based on Multiple Scenarios for 20 Trucks per Train (6.92 MW)

Number of Trips per Day	Size of PV System (MW)	Approximate Cost of a PV System (in millions)
9	53.73	\$107.4
18	107.47	\$215.0
27	161.20	\$322.4
36	214.94	\$429.9

TABLE 64 Cost of a Solar PV System Based on Multiple Scenarios for 25 Trucks per Train (8.15 MW)

Number of Trips per Day	Size of PV System (MW)	Approximate Cost of a PV System (in millions)
7	50.53	$101.0
14	101.07	$202.1
22	151.60	$303.2
29	202.13	$404.3

TABLE 65 Cost of a Solar PV System Based on Multiple Scenarios for 30 Trucks per Train (9.36 MW)

Number of Trips per Day	Size of PV System (MW)	Approximate Cost of a PV System (in millions)
6	48.40	$96.8
12	96.80	$193.6
18	145.2	$290.4
24	193.60	$387.2

Geothermal System

Calculating the size and cost of a geothermal plant is very similar with one big difference. Because a geothermal plant uses heat from the earth's core, it can be used to produce electricity 24 hours a day. Thus, the size of the plant necessary can be determined by dividing the load in terms of MWh by 24 instead of 5.5 in the case of Solar PV. This means that the size of geothermal plant that is required for this project calculated as $\frac{324.88MWh}{24h} = 13.5$ MW. The average cost of a geothermal power plant ranges between $3 and $4 per watt (*21*). The cost of a geothermal plant for this example is approximately 13.5 x 4 x 100,000 = $54 million. Tables 66, 67, 68, and 69 show the geothermal size necessary as well as the cost for each scenario.

TABLE 66 Cost of a Geothermal Energy System Based on Multiple Scenarios for 15 Trucks per Train (5.71 MW)

Number of Trips per Day	Size of the Geothermal System (MW)	Approximate Cost of a Geothermal System (in millions)
12	13.54	$54.1
24	27.07	$108.3
36	40.61	$162.4
48	54.15	$216.6

TABLE 67 Cost of a Geothermal Energy System Based on Multiple Scenarios for 20 Trucks per Train (6.93 MW)

Number of Trips per Day	Size of a Geothermal System (MW)	Approximate Cost of a Geothermal System (in millions)
9	12.31	$49.3
18	24.63	$98.5
27	36.94	$147.8
36	49.26	$197.0

TABLE 68 Cost of a Geothermal Energy System Based on Multiple Scenarios for 25 Trucks per Train (8.15 MW)

Number of Trips per Day	Size of a Geothermal System (MW)	Approximate Cost of a Geothermal System (in millions)
7	11.58	$46.3
14	23.16	$92.6
22	34.74	$139.0
29	46.32	$185.3

TABLE 69 Cost of a Geothermal Energy System Based on Multiple Scenarios for 30 Trucks per Train (9.36 MW)

Number of Trips per Day	Size of a Geothermal System (MW)	Approximate Cost of a Geothermal System (in millions)
6	11.09	$44.4
12	22.18	$88.7
18	33.27	$133.1
24	44.37	$177.5

Wind Turbine System

Wind energy is similar to geothermal energy in that it can be harnessed 24 hours a day. However, wind speed can vary depending on the weather and the surrounding topographic area. Wind turbines of the most common utility scale have power capacities between 700 kW and 1.8 MW. Moreover, they tend to be grouped together in order to maximize the potential wind energy in a given location.

The National Renewable Energy Laboratory (NREL) uses a scale of 1 to 7, with 1 being ‘poor’ and 7 ‘superb’; it rates the areas in northern Nevada anywhere from 1 to 5 (*22*), which varies drastically due to the surrounding mountain terrain. This makes finding a suitable, reliable location very difficult. Assuming a suitable location can be found, in general, wind farms can cost approximately $1000/kW (*23*). The cost of a wind farm for this example is approximately 13.5 x 1000 x 1000 = $13.5 million. Tables 70, 71, 72, and 73 show various sizes of wind farms and the cost of a wind turbine system for each scenario.

TABLE 70 Cost of a Wind Turbine Energy System Based on Multiple Scenarios for 15 Trucks per Train (5.71 MW)

Number of Trips per Day	Size of a Wind Turbine System (MW)	Approximate Cost of a Wind Turbine System (in millions)
12	13.54	$13.5
24	27.07	$27.1
36	40.61	$40.6
48	54.15	$54.2

TABLE 71 Cost of a Wind Turbine Energy System Based on Multiple Scenarios for 20 Trucks per Train (6.93 MW)

Number of Trips per Day	Size of a Wind Turbine System (MW)	Approximate Cost of a Wind Turbine System (in millions)
9	12.31	$12.3
18	24.63	$24.6
27	36.94	$36.9
36	49.26	$49.3

TABLE 72 Cost of a Wind Turbine Energy System Based on Multiple Scenarios for 25 Trucks per Train (8.15 MW)

Number of Trips per Day	Size of a Wind Turbine System (MW)	Approximate Cost of a Wind Turbine System (in millions)
7	11.58	$11.6
14	23.16	$23.2
22	34.74	$34.7
29	46.32	$46.3

TABLE 73 Cost of a Wind Turbine Energy System Based on Multiple Scenarios for 30 Trucks per Train (9.36 MW)

Number of Trips per Day	Size of a Wind Turbine System (MW)	Approximate Cost of a Wind Turbine System (in millions)
6	11.09	$11.1
12	22.18	$22.2
18	33.27	$33.3
24	44.37	$44.4

Diesel Engines

If a diesel locomotive is chosen to move the train, diesel fuel must be purchased regularly for the life of the system. The fuel efficiency of a diesel locomotive is approximately equivalent to 450 mi/gal/T (*24*). To calculate the diesel fuel cost per year, the average fuel efficiency is divided by the total weight of the train, in tons. If the train weight is 1162.5 T, the corresponding miles per gallon (mpg) is $\frac{450}{1162.5} = 0.39$ mpg. The number of gallons consumed in the trip is $\frac{330 \text{ mi}}{0.39 \text{ mpg}} = 852.50$ gal. Assuming that the average cost of diesel fuel is $3.90/gal, the cost per trip is $3.90 x 852.50 = $3324.75. This number multiplied by the number of times the train will make the trip in one day.

If the trip is 12 times per day, the cost becomes $3324.75 x 12 = $39897. Multiplying this number with the number of days in one year gives the total cost of diesel fuel per year, $39897.64 x 365 = $14.5 million. Tables 74, 75, 76, and 77 show the cost per day and cost per year for diesel fuel for each of the scenarios.

TABLE 74 Cost of Diesel Fuel per Year Based on Multiple Scenarios for 15 Trucks per Train (852.5 gal/trip)

Number of Trips per Day	Cost per Day (in thousands)	Cost per Year (in millions)
12	$39.8	$14.5
24	$79.6	$29.1
36	$119.4	$43.5
48	$159.2	$58.1

TABLE 75 Cost of Diesel Fuel per Year Based on Multiple Scenarios for 20 Trucks per Train (1034.0 gallons/trip)

Number of Trips per Day	Cost per Day (in thousands)	Cost per Year (in millions)
9	$36.2	$13.2
18	$72.4	$26.4
27	$108.6	$39.6
36	$144.8	$52.9

TABLE 76 Cost of Diesel Fuel per Year Based on Multiple Scenarios 25 Trucks per Train (1215.5 gallons/trip)

Number of Trips per Day	Cost per Day (in thousands)	Cost per Year (in millions)
7	$34.0	$12.4
14	$68.1	$24.9
22	$102.1	$37.3
29	$136.2	$49.7

TABLE 77 Cost of Diesel Fuel per Year Based on Multiple Scenarios 30 Trucks per Train (1397 gallons/trip)

Number of Trips per Day	Cost per Day (in thousands)	Cost per Year (in millions)
6	$32.6	$11.9
12	$65.2	$23.8
18	$97.8	$35.7
24	$130.4	$47.6

Potential Combinations

For comparison purposes, here are the approximate costs associated with some potential combinations of renewable energy sources. Table 78 shows the associated costs for just one scenario for 30 trucks per train making the trip 24 times per day.

TABLE 78 Cost of a Combination of Renewable Energy Sources (in millions) for 30 Trucks per Train, 24 Trips per Day

Renewable Resource	Cost/Resource (50% Wind and 50% Geothermal)	Cost/Resource (33% each for Wind, Geothermal and Solar)	Cost/Resource (50% Wind, 25% Geothermal, 25% Solar)
Wind	$22.2	$14.8	$22.2
Geothermal	$88.8	$59.2	$44.4
Solar	N/A	$129.1	$96.8
Total Cost	$111.0	$203.1	$163.4

Annual Operating Costs

All of the renewable energy data comes from three separate feasibility studies in other parts of the country for each of the potential energy sources. The National Renewable Energy Laboratory collected the data.

Wind Turbine System

The annual operating expenses for wind were calculated using information gained in a feasibility study for a wind project in Iowa (*25*). In the report, the range of operation and maintenance (O&M) is $16-$25/kW per year. For purposes of obtaining a worst-case scenario, $25/kW was chosen for this calculation. This means that the cost for O&M is $25000/MW. This number is multiplied by the size of system needed, in MW. For instance, a 13.54 MW system requires 13.54 x $25,000 = $338,500 in annual operating costs. This number is multiplied by 40 in order to obtain the total operating cost over the life of the project (Table 79).

Solar PV System

The annual operating expenses for a solar PV system were calculated using information gained in a feasibility study for a solar PV project in Kansas (*26*). The report states that, on average, the annual O&M cost of 0.17% of the total installed cost is used, based on O&M costs of other fixed-tilt grid-tied PV systems. Therefore, the total installed cost is multiplied by 0.17% to obtain the annual operating cost. For instance, for a 59.07 MW system that costs approximately $118.1 million to install, the annual O&M cost will be 0.0017 x 118,100,000 = $200,770. To obtain the total operating cost over the life of the project (Table 80), multiply by 40.

TABLE 79 Annual Operating Cost of a Wind Turbine System Based on Multiple Scenarios

15 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
12	13.54	$13.5	$0.3	$27.0
24	27.07	$27.1	$0.7	$54.2
36	40.61	$40.6	$1.0	$81.2
48	54.15	$54.2	$1.4	$108.4
20 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
9	12.31	$12.3	$0.3	$24.6
18	24.63	$24.6	$0.6	$49.2
27	36.94	$36.9	$0.9	$73.8
36	49.26	$49.3	$1.2	$98.6
25 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
7	11.58	$11.6	$0.3	$23.2
14	23.16	$23.2	$0.6	$46.4
22	34.74	$34.7	$0.9	$69.4
29	46.32	$46.3	$1.2	$92.6
30 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
6	11.09	$11.1	$0.3	$22.2
12	22.18	$22.2	$0.6	$44.4
18	33.27	$33.3	$0.8	$66.6
24	44.37	$44.4	$1.1	$88.8

* In millions

TABLE 80 Annual Operating Cost of a Solar PV System Based on Multiple Scenarios

15 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
12	59.07	$118.1	$0.2	$126.1
24	118.14	$236.3	$0.4	$252.4
36	177.21	$354.4	$0.6	$378.5
48	236.28	$472.6	$0.8	$504.7
20 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
9	53.73	$107.4	$0.2	$114.7
18	107.47	$215.0	$0.4	$229.6
27	161.2	$322.4	$0.5	$344.3
36	214.94	$429.9	$0.7	$459.1
25 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
7	50.53	$101.0	$0.2	$107.9
14	101.07	$202.1	$0.3	$215.8
22	151.6	$303.2	$0.5	$323.8
29	202.1	$404.3	$0.7	$431.8
30 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
6	48.4	$96.8	$0.2	$103.4
12	96.8	$193.6	$0.3	$206.8
18	145.2	$290.4	$0.5	$310.1
24	193.6	$387.2	$0.7	$413.5

* In millions

Geothermal System

The annual operating expenses for a geothermal power plant were calculated using information gained in a feasibility study for a geothermal power plant in Oregon (27). The report shows that the average O&M cost is about \$240/kW. This means that the annual O&M cost is about \$240,000/MW. Therefore, the size of system needed, in MW, is multiplied by \$240,000. For example, a 13.54MW system will require an annual O&M budget$\$240{,}000 * 13.54 = \$3{,}249{,}600$. Once again, to obtain the total operating cost over the life of the project (Table 81) multiply by 40.

Diesel Energy

An average cost per gallon of \$3.90 was used throughout this project. The total cost of diesel in one year was calculated by evaluating number of gallons of diesel used in one trip, multiplying that times the number of trips per day, and that multiplied by the number of days per year. This number was multiplied by \$3.90 to obtain the total cost per year. Once again, to obtain the cost over the life of the project (Table 82) multiply by 40.

TABLE 81 Annual Operating Cost of Geothermal System Based on Multiple Scenarios

15 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
12	13.54	$54.1	$3.2	$184.1
24	27.07	$108.3	$6.5	$368.2
36	40.61	$162.4	$9.7	$552.3
48	54.15	$216.6	$13.0	$736.4
20 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
9	12.31	$49.3	$3.0	$167.5
18	24.63	$98.5	$5.9	$334.9
27	36.94	$147.8	$8.9	$502.4
36	49.26	$197.0	$11.8	$669.9
25 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
7	11.58	$46.3	$2.8	$157.5
14	23.16	$92.6	$5.6	$314.9
22	34.74	$139.0	$8.3	$472.5
29	46.32	$185.3	$11.1	$630.0
30 Trucks per Train				
Trips Per Day	Size (MW)	Installation Cost*	Annual Operation Cost*	Total cost over 40 years*
6	11.09	$44.4	$2.7	$150.9
12	22.18	$88.7	$5.3	$301.6
18	33.27	$133.1	$8.0	$452.5
24	44.37	$177.5	$10.6	$603.5

* In millions

TABLE 82 Annual Operating Cost of Diesel Energy, Based on Multiple Scenarios

15 Trucks per Train		
Trips Per Day	Annual Operation Cost*	Total cost over 40 years*
12	$14.5	$580.0
24	$29.1	$1,164.0
36	$43.5	$1,740.0
48	$58.1	$2,324.0
20 Trucks per Train		
Trips Per Day	Annual Operation Cost*	Total cost over 40 years*
9	$13.2	$528.0
18	$26.4	$1,056.0
27	$39.6	$1,584.0
36	$52.9	$2,116.0
25 Trucks per Train		
Trips Per Day	Annual Operation Cost*	Total cost over 40 years*
7	$12.4	$496.0
14	$24.9	$996.0
22	$37.3	$1,492.0
29	$49.7	$1,988.0
30 Trucks per Train		
Trips Per Day	Annual Operation Cost*	Total cost over 40 years*
6	$11.9	$476.0
12	$23.8	$952.0
18	$35.7	$1,428.0
24	$47.6	$1,904.0

* In millions

Conclusions

All the types of renewable energy systems have similarities and differences. In all cases, the system would have to be connected to a grid. This allows operation during outages, maintenance, cloudy/windless days, etc. In addition, it allows the possibility to sell any excess power generated back to the grid. If the system produces more electricity than required, the excess energy can be sold back to the electric company or, perhaps, to another state. California, for instance, purchases hundreds of megawatts of electricity from various renewable energy plants located in Nevada.

One significant difference between passive electricity generators, such as solar PV and wind energy, and active generators, such as geothermal power plants, is labor costs. Because solar and wind plants are passive, they require less in terms of labor. Geothermal plants require more labor because they involve generators, wells, turbines, and various other controls. Monitoring these moving parts and other components 24 hours a day is necessary to ensure proper functionality.

For the evaluation of the capital costs for each alternative, it is clear that wind energy is the cheapest. However, finding a suitable location could prove extremely difficult in northern Nevada. A geothermal plant costs approximately half as much as a solar PV system. On the other hand, when the potential labor cost over the life of the plant is considered, it is possible that the overall cost of a geothermal plant is more expensive than solar PV.

One possible solution is to build a combination of wind and geothermal systems. Ideally, as much wind energy as possible should be produced. In order to minimize costs, the remaining portion of electricity can be produced from the geothermal plant. If a suitable location for wind energy cannot be found, another potential solution is to build a geothermal plant that is larger than required for the Land Ferry Project. This will cost more money, but still could be less than the cost of a solar PV system. Conversely, it could produce twice the amount of electricity necessary. This means that the excess electricity could be sold to another state or to such companies as NV Energy. It could help cover the cost of labor over the life of the plant, in addition to potentially being another source of revenue for the Land Ferry Project.

Description of the Locomotives

This section discusses the types of locomotives that are primarily used worldwide. Some of the common types of freight locomotive are listed below.

Bombardier TRAXX 140 AC - Re 485

FIGURE 24 Bombardier TRAXX 140 AC – Re 485.

Source: http://www.deviantart.com/art/BLS-Re-485-014-5-216143671

Operation
Years of construction: 1999-2005
Road numbers (UIC): BLS Re 485 001-020
Quantity built: 377
Quantity (BLS): 20
Application: Mainly freight traffic

Technical data
Vehicle type: Bombardier TRAXX 140AC
Manufacturer: Bombardier Transportation
Wheel arrangement: Bo'Bo'
Top speed: 140 kph
Continuous power: 4'200 kW
Hourly rating: 5'600 kW
Starting Tractive effort: 300 kN
Power system: 15 kV 16.7 Hz AC / 25 kV 50 Hz ACGauge: 1435 mm
Brakes: Knorr brake (Disc brake), electric brakes
Drive system: Cannon box

Mass and weight
Length over buffer: 18'900 mm
Width: 2'980 mm
Height: mm
Weight: 84 T

Electric Locomotive - Re 421

FIGURE 25 Electric Locomotive – Re 421.

Source: http://www.deviantart.com/art/SBB-Re-4-4-II-11297-210431192

Operation
Remodeling (Re 421): 2003-2004
Quantity built: 276
Quantity today: 259
Application: all-purpose locomotive
Maintenance work: Yverdon and Bellinzona
Sale to BLS: 2004-2005, 12 units
Road numbers (UIC): BLS Re 420 501-512

Technical data
Vehicle type: Electric locomotive
Manufacturer: SLM Winterthur, BBC Baden, MFO Zürich, SAAS Genève
Wheel arrangement: Bo'Bo'
Top speed: 140 kph, 120 kph (Re 421)
Continuous power: 4'700 kW
Tensile hours: 167 kN
Starting tractive effort: 255 kN
Mountain Power: 500-T train to 26 ‰ slope at 80 kph
Power system: 15 kV 16,7 Hz
Gauge: 1435 mm

Mass and weight
Length over buffer: 14'800 mm 1, 14'900 mm 2, 15'410 mm 3
Width: 2'970 mm
Height: 4'500 mm
Weight: 80 T, 85 T (Re 421)

Electric Locomotive ÖBB Rh 1016, 1116, Siemens ES64U2

FIGURE 26 Electric Locomotive Siemens ES64U2.
Source: http://www.deviantart.com/morelikethis/269074968/photography

Operation
Road numbers (UIC): 1016 001-050, 1116 001-282
Quantity built: 382
Quantity today: 382

Technical data
Vehicle type: Electric locomotive
Manufacturer: Siemens München, ÖBB TS Werk Linz
Wheel arrangement: Bo'bo'
Top speed: 230 kph
Continuous power: 6'400 kW
Hourly rating: 7'000 kW
Starting tractive effort: 300 kN
Power system: 15 kV 16.7 Hz, 25 kV 50 Hz
Gauge: 1435 mm

Mass and weight
Length over buffer: 19'280 mm
Width: 3'000 mm
Weight: 86 T

Bombardier TRAXX 140 AC - Re 485

FIGURE 27 Bombardier TRAXX 140 AC – Re 485.

Source: http://www.deviantart.com/art/BLS-Re-485-011-1-342050403

Operation
Years of construction: 1999-2005
Road numbers (UIC): BLS Re 485 001-020
Quantity built: 377
Quantity (BLS): 20
Application: Mainly freight traffic

Technical data
Vehicle type: Bombardier TRAXX 140AC
Manufacturer: Bombardier Transportation
Wheel arrangement: Bo'Bo'
Top speed: 140 kph
Continuous power: 4'200 kW
Hourly rating: 5'600 kW
Starting Tractive effort: 300 kN
Power system: 15 kV 16.7 Hz AC / 25 kV 50 Hz AC
Gauge: 1435 mm
Brakes: Knorr brake (Disc brake), electric brakes
Drive system: Cannon box

Mass and weight
Length over buffer: 18'900 mm
Width: 2'980 mm
Weight: 84 T

SBB Re 460

FIGURE 31 Four Axle Multipurpose Electric Locomotive SBB Re 460.
Source: http://www.deviantart.com/art/SBB-Re-460-021-9-342049270

Operation
Years of construction: 1991-1996
Road numbers (old): Re 4/4 VI 10701+ (never used)
Road numbers (UIC): Re 460 000 - 118
Quantity built: 119
Quantity today: 119
Application: Passenger traffic

Technical data
Vehicle type: Four axle multipurpose electric locomotive
Manufacturer: SLM, ABB
Wheel arrangement: Bo'Bo'
Top speed: 230 kph
Continuous power: kW
Hourly rating: 6'100 kW
Continuous tractive effort: 100 kN
Tensile hours: 300 kN
Starting tractive effort: 300 kN
Power system: 15 kV 16.7 Hz
Gauge: 1435 mm

Mass and weight
Length over buffer: 18'500 mm
Width: 3'000 mm
Height: 4'300 mm
Weight: 84 T

KORAIL Electric Freight Locomotives (Hyundai)

FIGURE 33 KORAIL Electric Freight Locomotives.
Source: https://www.hyundai-rotem.co.kr/Eng/Business/Rail/Railroad/Product/rail1_pop27.asp

Maximum design speed : 165 km/h
Dimensions (L x W x H) : 20,400 x 3,060 x 4,000 (mm)
Power supply : AC 25 kV/60 Hz
Performance (capacity): over 6,600 kW
Maximum traction power : 450kN
Weight : 132 T
Carbody : Mild steel
Regeneration & pneumatic braking system controlled by electric signals
Bogie : Bolsterless 3axle (Co-Co)
IGBT / Regenerative VVVF inverter
Signals : ATS/ATP(ETRMS)

SECTION 6: ECONOMIC IMPACT ANALYSIS

This section discusses the economic impacts of the proposed Land Ferry.

Overview

How does the economy of Nevada benefit from the building a Land Ferry? This report applies a model designed to quantify the answer to this question. Through the direct employment of workers on the project, new earnings made will indirectly affect the incomes and wellbeing of other businesses within the region. Consequently, these indirect beneficiaries induce yet another level of higher incomes and greater prosperity for businesses throughout the community. The model attempts to show the combined economic impact as a sum of these direct, indirect, and induced impacts. In this way, an initial investment of $3.8 billion will return much more than just $3.8 billion for the region.

In fact, after construction, a combined $6.1 billion will affect the economic output of Nevada. It will generate $1.9 billion of new income and 45,788 temporary jobs for Nevada residents. During the first 40 years of the Land Ferry's operations and maintenance phase, an annual investment of $44 million will provide Nevada $1.8 billion in output, $510 million in earnings, and 318 permanent jobs.

The primary purpose of the Land Ferry is to reduce the damage to roadways caused by consistent and intense heavy vehicle traffic, mainly commercial trucks shipping goods along Interstate I-80 (*28*). The project seeks to reduce highway truck traffic to decrease maintenance costs, accidents, congestion, and emissions. In addition, travel time reliability will improve. Further, the project is likely to positively affect the economic development of the region.

Interstate I-80 is the main route from San Francisco to New York City through Chicago. Although the highway traverses 11 states and makes its way through several state capitals and points of interest, the 410-mile trip through northern Nevada virtually is void of any special destinations for the commercial trucking industry. The Union Pacific already owns rail track that nearly parallels the interstate. However, this existing system is near capacity. Consequently, a new track is required for the proposed Land Ferry.

The Affected Region

It is expected that the Land Ferry will affect the entire state of Nevada. Although I-80 is limited to the northern half of the state, we anticipate that engineers and construction workers would travel from all over the state for the opportunity to work on this project. With the exception of the manufacture of some goods, it is assumed that no out-of-state workers or firms will be directly involved and that income dollars will be spent within the state.

It is expected that truck drivers and shipping companies will be the most heavily affected by the Land Ferry. Aside from the physical benefits of keeping the trucks off the roads and keeping truckers from having to drive long, monotonous distances, the Land Ferry reduces truck maintenance, fuel costs, emissions, and accidents caused by tired driving (*29*). A study conducted by the Virginia Tech Transportation Institute revealed that fatigue is a factor in approximately 12% of all traffic accidents (*30*). The Land Ferry would provide an opportunity for truck drivers to rest or sleep while traversing Nevada. Furthermore, non-commercial automobile drivers on the highway will benefit from a smoother drive, less congestion, and fewer accidents. NDOT would be able to reserve funds previously allocated for highway maintenance, which would allow for a greater range of projects to be taken up elsewhere within the state.

Initially, a concern was that some businesses along the interstate would lose income from truck drivers leaving the highway. After conducting interviews and gathering anecdotal evidence from several shops along the route, however, it was determined that the main source of revenue for these businesses, by a large margin, came from tourists, local residents, and families passing through and not from commercial truckers. Additionally, it is anticipated that any lost business will be restored by a boost in incomes throughout the region, an increase in employment, and more vitality in the tourism of the area once the project has been completed.

Another concern is that truckers may reject the Land Ferry because it could lead to a reduction in their pay. It is typical for drivers to be reimbursed for the number of miles they have driven and not necessarily by the number of miles they have covered. The amount of money saved on truck maintenance and fuel, however, is a primary selling point to drivers.

A final concern is that it is possible that fuel taxes from truck drivers travelling through the state will be lost unless that money can be re-couped from taxes placed on ridership of the Land Ferry.

Methodology

The purpose of this study was to determine the immediate and consequential effects to the regional economics resulting from this project. The Regional Input-Output Modeling System (RIMS II) was proposed to determine these effects based on finite, measurable changes to demand, earnings, and employment.

Multipliers specific to each county or state were used to manipulate the expected final demand change – the initial investment – or proposed changes in regional employment and earnings in order to anticipate the direct, indirect, and induced effects of this project. These multipliers were determined from nationwide, statewide, and countywide accounting tables that were adjusted to reflect a region's particular industrial structure and trading patterns. The multipliers were applied directly to expected changes in the final demand (initial investment), earnings, and jobs; moreover, they were dependent upon the industries that incur these changes. There are 406 detailed industries that were defined for the RIMS II model, each labeled using a specific six-digit industry code (*31*).

The multipliers chosen for this study resulted in three anticipated impacts – output, earnings, and jobs – based on a single estimated change in final demand. Output is equal to the sum of the direct investment, the indirect expenditures made after the first investment by households earning income directly from the investment, and the induced expenditures made by those receiving an income from these households. Output is determined by multiplying the initial investment (final demand change) by the final demand output multiplier. Similarly, earnings is the sum of the direct, indirect, and induced incomes of all parties. This value is the product of the final demand change and the final demand earnings multiplier. The jobs generated is equal to the amount of jobs created for every $1,000,000 increase in the final demand change. Again, this value is equal to the sum of the direct, indirect, and induced job creation.

This study analyzed two phases of the Land Ferry project. The first phase is the temporary impact to the region of the construction phase. This phase is considered temporary because it is assumed that once construction has ceased, all the jobs in construction, design, and project management will be finished as well. The second phase is the operations phase, and includes the costs of operating the facilities and maintaining all aspects of the completed project.

Finally, it should be noted that this study was concerned only with the economic impact on the State of Nevada. It is not reasonable to assume that all jobs and money spent will circulate only within the state. Some more scarce resources must be imported. Unlike a perfect, uniformly contained economy, this model is affected by regional employment quotients, or 'location quotients', which are determined by comparing the ratios of employment in each industry sector within a region to employment in that sector within a greater region. In this case, the employment ratios of Nevada were compared to those of the United States by using values published by the U.S. Census Bureau for 2011 (*32*). A ratio greater than or equal to one implies that the employment within that sector is self-sufficient: all workers and goods can be found within the region. All industries having a ratio greater than 1 will use a location multiplier of 1. A ratio of less than 1, however, implies that employment and materials imported from outside of the region. Because of this issue, a portion of output, jobs, and household earnings will not circulate within the region and are considered an imported resource.

The location quotient is a best estimate of employment ratios within a regional economy. Two significant assumptions have to be made, however, in order to use the quotient. First, the economy used to measure the local economy must be self-sufficient. This is an inherently unrealistic assumption, as most countries in the world import goods, to some extent. Second, the quotient assumes that the industrial makeup and employment ratios remain consistent throughout the country in question. Again, this is an unrealistic expectation because efficiency and spending patterns vary across regions and throughout all industries. Even so, the location quotient is a useful tool, even after considering these limitations; however, it must be used with an understanding of its inaccuracies.

All analyses include 1) a table of total output, earnings, and jobs and 2) a table of Nevada-only output, earnings, and jobs. A ratio of the two shows which aspects of the project are expected to be handled by 'foreign' companies, i.e., outside of Nevada.

Analysis Summary

Each analysis has been performed using a Microsoft Excel spreadsheet. The tables are included in Appendix B. Below is a breakdown of the results that can be found in the tables.

Phase One: Construction

Construction costs are separated into nine different segments:

- Tract Structures and Track
- Stations
- Support Facilities: Yards, Shops, and Administration Buildings
- Site-work, Right-of-Way, Land, Etc.
- Communication and Signaling
- Diesel Vehicles
- Professional Services
- Contingency Cost
- Contractors' Profits

When performing the analysis, all aspects listed above were considered except for the contingency costs and contractors' profits; hence, these latter two costs were not included in the analysis. For that reason, it was assumed that the estimates derived in the analysis were the minimum expected results. This causes the final analysis cost to drop from $4,033,787,000 to $3,816,014,000.

With an initial investment of $3,816,014,000, the grand total for the Nevada output is equal to $6,102,242,316; Nevada earnings total $1,889,632,140; and Nevada job creation totals 45,788 temporary jobs. These estimates total between 86% and 88% of the total output, earnings, and jobs created during the construction phase.

Phase Two: Operations

The operational phase is simpler to analyze, as it contains only one cost: $44,209,000 per year for combined operations and maintenance. Over 40 years, the total cost is equal to $1,768,360,000. The technique of using final demand and location quotient multipliers was used for this phase, similar to Phase One, with one minor change. When used over time, the output and earnings multipliers were applied to the sum of the final demand over the defined time (in this case, $44,209,000 per year × 40 years). The jobs multiplier, however, was applied only to a one-year investment: $44,209,000. This was because jobs are created initially and then are maintained over time. No new jobs will be created after the first year unless there is a change in the yearly investment. Table 164 through 171 in Appendix B consists of the analysis for the operations phase. After an initial investment of $44,209,000 over 40 years, Nevada output is equal to $1,825,586,234; Nevada earnings are equal to $510,365,134; and 318 jobs are created in Nevada.

Conclusions

In summary, the initial $4.2 billion investment in the Land Ferry can be shown to have a $6.1 billion impact on the economic output of Nevada; $1.9 billion worth of new income for Nevada residents; and 45,788 temporary jobs for Nevada locals over its construction phase. Over 40 years, the Land Ferry's operations and maintenance investment of $1.77 billion will provide an Nevada $1.83 billion in output, $510 million in earnings, and 318 permanent jobs.

SECTION 7: BENEFIT-COST ANALYSIS

The Land Ferry project was analyzed using the California Benefit Cost (Cal-B/C) model. The complete analysis was divided into three segments in order to examine the projected operations for the proposed Land Ferry and its effects on Interstate 80. The Cal-B/C bypass model estimated the effects of reduced trips on the existing I-80 and then placed those reduced trips on the proposed Land Ferry to complete the analysis and account for all trips.

Analyses were conducted for Build and No Build conditions to model project benefits of the following three segments of I-80.

- Fernley, NV to Winnemucca, NV
- Winnemucca, NV to Elko, NV
- Elko, NV to Wells, NV

Build and No Build conditions were analyzed to model the project benefits for the proposed system. Project trips on the proposed Land Ferry were estimated primarily using traffic information obtained from NDOT and travel demand models to project growth in the corridor.
This study used a 40-year horizon to estimate benefits and cost. This 40-year horizon enabled comparisons with most other benefit-cost analyses.

Benefits and Costs

The following performance measures were considered to estimate the following benefits and costs:

- Travel time savings
- Accident reductions
- Savings in vehicle operating costs
- Reductions in vehicle emissions
- Pavement roughness
- Project capital costs
- Project operation and maintenance costs

Where possible, benefits and costs were calculated for each user group (e.g., personal vehicles and commercial vehicles or trucks).

Travel Time Savings

Travel Time Savings were calculated using Vehicle Miles Traveled (VMT); speeds; vehicle occupancy; value of time; and other components, including such expansion factors as the daily expansion factor. The Traffic Operation Analyses provided volumes and speeds. Parameters for value of time are shown in Table 83. Travel time related to incident delays was calculated at three times the standard in-vehicle value of time.

TABLE 83 Value of Time

Wages		
NV Statewide - Average Hourly Wage	19.85	$/hr
Heavy & Light Truck Drivers - Average Hourly Wage	19.19	$/hr
Heavy & Light Truck Drivers - Fringe Benefits (50% of wage)	9.60	$/hr
Value of Time (in-vehicle; non-incident)		
Automobile (50% of wage)	9.95	$/hr/per
Truck (100% of wage + fringe)	28.80	$/hr/veh
Value of Time Conversions		
Incident Delay Value of Time	3x	Non-incident

Source: 2012 Nevada Occupational Employment & Wages (OES), nevadaworkforce.com

Accident Rates

Accident rates for the I-80 corridor in Nevada were obtained from the NDOT GIS Accident Database. Rates from 2006 to 2011 are included in Tables 84 to 86, broken down by severity of the accident. The categories are property damage only (PDO), injury (Inj), and fatality (Fat).

TABLE 84 Accident Rate for Zone 1

Year	No. of Accidents			AADT (veh/ day)	Annual Traffic (veh/yr)	Dist (mi)	VMT (veh-mi/yr)	MVMT	Accident Rates (accidents per MVMT)		
	PDO	Inj	Fat						PDO	Inj	Fat
2006	560	258	8	24,020	8,767,300	129	1,130,981,700	1130.98	0.495	0.228	0.007
2007	550	253	2	23,990	8,756,350	129	1,129,569,150	1129.57	0.487	0.224	0.002
2008	537	220	6	23,435	8,553,775	129	1,103,436,975	1103.44	0.487	0.199	0.005
2010	480	200	7	23,600	8,614,000	129	1,111,206,000	1111.21	0.432	0.180	0.006
2011	351	153	3	23,273	8,494,463	129	1,095,785,663	1095.79	0.320	0.140	0.003
Average									0.444	0.194	0.005

Source: NDOT GIS Accident Database, 2006-2011.

TABLE 85 Accident Rate for Zone 2

Year	No. of Accidents			AADT (veh/ day)	Annual Traffic (veh/yr)	Dist (mi)	VMT (veh-mi/yr)	MVMT	Accident Rates (accidents per MVMT)		
	PDO	Inj	Fat						PDO	Inj	Fat
2006	187	51	3	7,917	2,889,583	123	355,418,750	355.42	0.526	0.143	0.008
2007	159	75	3	8,219	2,999,952	123	368,994,143	368.99	0.431	0.203	0.008
2008	132	66	5	7,319	2,671,452	123	328,588,643	328.59	0.402	0.201	0.015
2010	172	64	4	7,510	2,740,976	123	337,140,071	337.14	0.510	0.190	0.012
2011	126	43	3	7,686	2,805,286	123	345,050,143	345.05	0.365	0.125	0.009
Average									0.447	0.172	0.010

Source: NDOT GIS Accident Database, 2006-2011.

TABLE 86 Accident Rate for Zone 3

Year	No. of Accidents			AADT (veh/ day)	Annual Traffic (veh/yr)	Dist (mi)	VMT (veh-mi/yr)	MVMT	Accident Rates (accidents per MVMT)		
	PDO	Inj	Fat						PDO	Inj	Fat
2006	70	42	1	5,852	2,136,119	58	123,894,905	123.89	0.565	0.339	0.008
2007	101	43	6	6,510	2,375,976	58	137,806,619	137.81	0.733	0.312	0.044
2008	101	48	1	6,457	2,356,857	58	136,697,714	136.70	0.739	0.351	0.007
2010	121	34	5	6,619	2,415,952	58	140,125,238	140.13	0.864	0.243	0.036
2011	126	33	2	6,348	2,316,881	58	134,379,095	134.38	0.938	0.246	0.015
Average									0.768	0.298	0.022

Source: NDOT GIS Accident Database, 2006-2011.

Project Cost Estimate

A project cost estimate was completed previously in Section 3. A summary of the initial capital costs is provided in Table 71.

TABLE 87 Project Capital Costs

Capital Costs (2013$)					
Professional Services ($)	Construction ($)	Contingency ($)	Contractor Profits ($)	Wind Power Installation ($)	Total ($)
704,981,000	3,111,033,000	155,552,000	62,221,000	54,200,000	4,087,987,000

Additionally, Table 88 provides a summary of annual Operations and Maintenance (O&M) costs. Usually, a one-time update cost – equivalent to 50% of the initial costs of wind power installation – will be spent after 20 years in order to accommodate increased truck traffic. The detailed annual maintenance cost for the Land Ferry and wind power was discussed in Section 3 and Section 5, respectively.

TABLE 88 Operations and Maintenance Costs

Annual Operations and Maintenance Costs (2013 $)		
Land Ferry ($)	Wind Power ($)	Total ($)
44,209,000	1,350,000	45,559,000

Vehicle Operating Costs

Vehicle operating costs consist of fuel and non-fuel operating costs, including tires, depreciation, maintenance, insurance, license, registration, taxes, and financing. Fuel costs vary with speed, fuel consumption rates, and unit fuel prices. The rates in Tables 89 and 90 were used to estimate fuel costs.

TABLE 89 Fuel Prices

Average Fuel Price	$/gal
Automobile (regular unleaded)	3.86
Truck (diesel)	4.25
Sales and Fuel Taxes	
Federal Fuel Excise Tax (gasoline)	0.184
Federal Fuel Excise Tax (diesel)	0.244
NV State Fuel Excise Tax (gasoline)	0.18455
NV State Fuel Excise Tax (diesel)	0.275
Clark County Fuel Excise Tax (gasoline)	0.1535
Fuel Cost Per Gallon (Exclude Taxes)	
Automobile	3.35
Truck	3.75

Sources: Fuel Price from AAA Daily Fuel Gauge Report, Las Vegas, Nevada Metro Average. October 6, 2012. Tax rates from Nevada VMT Fee Study. NDOT. December 2010.

TABLE 90 Fuel Consumption Rates

Speed (mph)	Auto (gal/veh-mi)	Truck (gal/veh-mi)
5	0.1439	0.2234
10	0.1074	0.1714
15	0.0832	0.1300
20	0.0670	0.1032
25	0.0559	0.0856
30	0.0485	0.0738
35	0.0435	0.0663
40	0.0405	0.0617
45	0.0391	0.0596
50	0.0390	0.0596
55	0.0404	0.0617
60	0.0433	0.0662
65	0.0482	0.0738
70	0.0515	0.0810
75	0.0517	0.0865
80	0.0520	0.0953

Source: California Air Resources Board, EMFAC2011, 2011 & 2031 average.

Vehicle Emissions

Vehicle emissions are associated negatively with health effects and costs. Vehicle emission was calculated based on vehicles speed and estimated VMT. The emission values were monetized into health costs, using the rates in Table 91. The proposed Land Ferry project lies in a rural area. Therefore, rural areas rates are applicable for this project.

TABLE 91 Health Costs due to Vehicle Emissions

Emission Type	Rate ($/ton)
CO	70
CO_2e	23
NO_X	12,900
PM_{10}	99,700
SO_X	50,400
VOC	950

Source: Discussion of the Calculations of Costs and Benefits. NDOT. 2012 Update.

Pavement Roughness

Pavement roughness, measured by the International Roughness Index (IRI), is associated with slower speeds because it impedes traffic flows. In addition, rough pavement increases operating costs due to increased wear on vehicles and increased fuel consumption (*33*).

Existing IRI values for the project obtained from NDOT. The complete project was divided into three segments, as summarized in Table 92. For this analysis, the IRI was estimated from 2012 to the Build Year.

TABLE 92 Project Pavement Data

Route	Zone	Description	Direction	Total Miles	Average IRI
I-80	1	Fernley to Winnemucca	Eastbound	129.00	54
	2	Winnemucca to Elko		123.00	75
	3	Elko to Wells		58	64
	1	Winnemucca to Fernley	Westbound	129.00	53
	2	Elko to Winnemucca		123.00	81
	3	Wells to Elko		58	68

Source: NDOT, Materials Division, Pavement Analysis. 2012.

Future IRI was projected using the index shown in Table 93. These estimates are used by Cal-B/C, which bases loading on the AADT and percent of Heavy Vehicles (*34*). Intermediate values were calculated using linear interpolation.

TABLE 93 Pavement Deterioration

Pavement Roughness (IRI in inches/mile)			
Year	Year 20 By Loading		
	Light	Medium	Heavy
0	125	150	350
25	150	200	500
50	175	250	675
75	200	300	750
100	275	400	750
125	325	475	750
150	400	575	750
175	500	700	750
200	575	750	750
225	650	750	750
250	750	750	750

Source: Road Deterioration and Maintenance Effects: Models for Planning and Management. Paterson, W. 1987.

Benefit-Cost Analysis Results

This section presents the benefit-cost analysis of the Land Ferry project for 40 years.

Tolling

This section discusses the tolling scheme for the proposed Land Ferry system. For the year 2012, it was assumed that an average of 30 trucks per train with 25 trips per day would generate 750 truck trips per day. The trucks were assumed to increase at a rate of 2% per year for a safe generation of toll revenue. Typically, a modern long-haul truck gets an average of 5 miles per gallon. An analysis of the operations cost of trucks suggests a rate of $1.73/mi (*35*).

The Land Ferry runs through a length of 320 miles. As a result, the operational cost per truck per trip becomes $1.73 x 320 = $554.00. Table 94 shows that the daily expense in 2016 will be 825 x $554 = $456,617. The daily expense is converted to annual expense by multiplying by 365. Finally, the tolling revenue was estimated to be half the actual expenses since it provides freight companies and drivers an incentive to use the Land Ferry as a safe and efficient mode of transportation. Table 94 shows the tolling analysis for a period of 40 years.

TABLE 94 Tolling Analysis using a 40-year Horizon

Year	Trucks on the Land Ferry	Daily Expense	Annual Expense	Tolling Revenue
2016	825	$456,617	$166,665,076	$83,332,538
2017	841	$465,749	$169,998,377	$84,999,189
2018	858	$475,064	$173,398,345	$86,699,172
2019	875	$484,565	$176,866,312	$88,433,156
2020	893	$494,257	$180,403,638	$90,201,819
2021	911	$504,142	$184,011,711	$92,005,855
2022	929	$514,225	$187,691,945	$93,845,973
2023	947	$524,509	$191,445,784	$95,722,892
2024	966	$534,999	$195,274,700	$97,637,350
2025	986	$545,699	$199,180,194	$99,590,097
2026	1005	$556,613	$203,163,797	$101,581,899
2027	1026	$567,745	$207,227,073	$103,613,537
2028	1046	$579,100	$211,371,615	$105,685,807
2029	1067	$590,682	$215,599,047	$107,799,524
2030	1088	$602,496	$219,911,028	$109,955,514
2031	1110	$614,546	$224,309,249	$112,154,624
2032	1132	$626,837	$228,795,434	$114,397,717
2033	1155	$639,374	$233,371,342	$116,685,671
2034	1178	$652,161	$238,038,769	$119,019,385
2035	1202	$665,204	$242,799,545	$121,399,772
2036	1226	$678,508	$247,655,535	$123,827,768
2037	1250	$692,078	$252,608,646	$126,304,323
2038	1275	$705,920	$257,660,819	$128,830,410
2039	1301	$720,038	$262,814,035	$131,407,018
2040	1327	$734,439	$268,070,316	$134,035,158
2041	1353	$749,128	$273,431,723	$136,715,861
2042	1380	$764,111	$278,900,357	$139,450,178
2043	1408	$779,393	$284,478,364	$142,239,182
2044	1436	$794,981	$290,167,931	$145,083,966
2045	1465	$810,880	$295,971,290	$147,985,645
2046	1494	$827,098	$301,890,716	$150,945,358
2047	1524	$843,640	$307,928,530	$153,964,265
2048	1554	$860,513	$314,087,101	$157,043,550
2049	1585	$877,723	$320,368,843	$160,184,421
2050	1617	$895,277	$326,776,220	$163,388,110
2051	1650	$913,183	$333,311,744	$166,655,872
2052	1683	$931,447	$339,977,979	$169,988,989
2053	1716	$950,075	$346,777,538	$173,388,769
2054	1751	$969,077	$353,713,089	$176,856,545
2055	1786	$988,458	$360,787,351	$180,393,675
Total		$27,580,551	$10,066,901,108	$5,033,450,554

Annual Maintenance Cost Savings

Shifting the trucks from the highway to the Land Ferry directly reduces their impact on pavement and the associated maintenance costs. Heavy trucks, in particular, cause a tremendous amount of wear and tear to the pavement. The annual cost for routine roadway maintenance used in this analysis was based on actual costs incurred on similar rural regions throughout northern Nevada (*36*). Once calculated, the cost per mile was applied to the reduction in maintenance cost on I-80 because of the Land Ferry. Studies have suggested that the daily maintenance cost due to a heavy truck (60 kip 5-axle comb/rural interstate) was $0.033 per mile (*37*). The base cost was assumed to increase by 2.5% annually due to inflation (*38*). For year 2016, the maintenance cost will be $0.049 per mile. Hence, the annual maintenance cost savings on the I-80 in year 2016 is equal to 825*.049*320*365 = $4.72 million. Over 40 years, the total maintenance cost savings will be $511.2 million. This is a substantial savings to NDOT in terms of expenditure towards pavement maintenance.

Results and Analysis

The 40-year benefit-cost analysis is shown in Tables 95 and 96. Table 95 shows the net present value calculations and Table 80 presents the benefit cost analysis summary. This project shows significant travel timesaving ($356.4M), vehicle operating cost savings ($1000.4M), and accident reductions ($674.7M), as expected due to a large percentage of trucks being removed from the I-80 corridor.

The costs and benefits for this project are approximately $4.36 billion and $7.59 billion, respectively. The benefit-cost ratio is 1.7 and the net present value is $3.23 billion.

TABLE 95 Calculation of Net Present Value

Year	PRESENT VALUE OF USER BENEFITS						Present Value of Total User Benefits	Present Value of Total Project Costs	Net Present Value
	Travel Time Savings	Vehicle Operating Cost Savings	Accident Reduction Savings	Vehicle Emission Reductions	Tolling Revenue	Annual Maintenance Cost Savings			
1							$0	$1,378,055,333	($1,378,055,333)
2							$0	$1,237,247,975	($1,237,247,975)
3							$0	$1,156,306,519	($1,156,306,519)
4							$0	$50,790,870	($50,790,870)
5							$0	$0	$0
1	$14,051,372	$42,731,274	$34,935,402	$942,870	$83,332,538	$4,719,481	$180,712,938	$37,189,715	$143,523,223
2	$13,823,240	$40,570,816	$33,661,246	$856,740	$84,999,189	$4,934,218	$178,845,449	$34,756,743	$144,088,706
3	$13,583,088	$38,700,439	$32,404,283	$769,631	$86,699,172	$5,158,725	$177,315,338	$32,482,937	$144,832,401
4	$13,332,485	$36,841,454	$31,167,718	$679,662	$88,433,156	$5,393,447	$175,847,922	$30,357,885	$145,490,037
5	$13,072,898	$35,406,713	$29,954,261	$652,952	$90,201,819	$5,638,849	$174,927,491	$28,371,855	$146,555,636
6	$12,805,697	$34,002,019	$28,766,181	$626,811	$92,005,855	$5,895,416	$174,101,978	$26,515,753	$147,586,226
7	$12,532,159	$32,629,581	$27,605,351	$601,279	$93,845,973	$6,163,658	$173,378,001	$24,781,077	$148,596,923
8	$12,253,471	$31,386,667	$26,473,290	$347,874	$95,722,892	$6,444,104	$172,628,298	$23,159,885	$149,468,413
9	$11,970,737	$30,079,769	$25,371,203	$333,192	$97,637,350	$6,737,311	$172,129,562	$21,644,753	$150,484,809
10	$11,684,975	$28,809,537	$24,300,012	$318,930	$99,590,097	$7,043,858	$171,747,410	$20,228,741	$151,518,669
11	$11,397,128	$27,418,498	$23,260,392	$291,567	$101,581,899	$7,364,354	$171,313,838	$18,905,365	$152,408,473
12	$11,108,063	$26,122,251	$22,252,797	$265,534	$103,613,537	$7,699,432	$171,061,614	$17,668,566	$153,393,048
13	$10,818,576	$25,211,554	$21,277,486	$277,913	$105,685,807	$8,049,756	$171,321,093	$16,512,678	$154,808,414
14	$10,529,400	$24,094,104	$20,334,546	$265,426	$107,799,524	$8,416,020	$171,439,020	$15,432,410	$156,006,610
15	$10,241,198	$23,014,960	$19,423,918	$253,373	$109,955,514	$8,798,949	$171,687,913	$14,422,813	$157,265,100
16	$9,954,580	$35,785,081	$18,545,408	$230,710	$112,154,624	$9,199,301	$185,869,704	$13,479,264	$172,390,440
17	$9,670,095	$34,051,592	$17,698,713	$207,383	$114,397,717	$9,617,870	$185,643,369	$12,597,443	$173,045,926
18	$9,388,240	$32,482,903	$16,883,428	$197,354	$116,685,671	$10,055,483	$185,693,078	$11,773,311	$173,919,766
19	$9,109,463	$30,973,726	$16,099,068	$187,722	$119,019,385	$10,513,007	$185,902,371	$11,003,095	$174,899,277
20	$8,834,164	$29,522,990	$15,345,076	$178,480	$121,399,772	$10,991,349	$186,271,832	$16,095,380	$170,176,452
21	$8,562,700	$28,055,251	$14,620,836	$159,898	$123,827,768	$11,491,455	$186,717,908	$9,610,529	$177,107,379
22	$8,295,387	$26,721,270	$13,925,682	$151,735	$126,304,323	$12,014,316	$187,412,712	$8,981,803	$178,430,910
23	$8,032,502	$25,514,535	$13,258,907	$151,256	$128,830,410	$12,560,968	$188,348,577	$8,394,208	$179,954,369
24	$7,774,287	$24,213,556	$12,619,774	$134,031	$131,407,018	$13,132,492	$189,281,157	$7,845,054	$181,436,103
25	$7,520,949	$22,977,777	$12,007,520	$119,242	$134,035,158	$13,730,020	$190,390,666	$7,331,827	$183,058,840
26	$7,272,668	$21,856,040	$11,421,363	$112,775	$136,715,861	$14,354,736	$191,733,443	$6,852,174	$184,881,268
27	$7,029,591	$20,782,731	$10,860,509	$106,610	$139,450,178	$15,007,877	$193,237,495	$6,403,901	$186,833,594
28	$6,791,841	$19,756,315	$10,324,156	$100,737	$142,239,182	$15,690,735	$194,902,966	$5,984,954	$188,918,011
29	$6,559,517	$18,775,249	$9,811,499	$94,248	$145,083,966	$16,404,664	$196,729,142	$5,593,415	$191,135,726
30	$6,332,693	$17,837,993	$9,321,732	$88,972	$147,985,645	$17,151,076	$198,718,111	$5,227,491	$193,490,620
31	$6,111,425	$16,893,194	$8,854,056	$76,277	$150,945,358	$17,931,450	$200,811,760	$4,885,506	$195,926,255
32	$5,895,749	$16,041,482	$8,407,675	$71,784	$153,964,265	$18,747,331	$203,128,286	$4,565,893	$198,562,393
33	$5,685,684	$15,228,909	$7,981,805	$67,520	$157,043,550	$19,600,334	$205,607,802	$4,267,190	$201,340,612
34	$5,481,231	$14,314,448	$7,575,673	$44,611	$160,184,421	$20,492,149	$208,092,533	$3,988,028	$204,104,505
35	$5,282,380	$13,582,882	$7,188,519	$41,411	$163,388,110	$21,424,542	$210,907,844	$3,727,129	$207,180,715
36	$5,089,106	$12,885,771	$6,819,597	$38,396	$166,655,872	$22,399,359	$213,888,101	$3,483,298	$210,404,803
37	$4,901,371	$12,185,344	$6,468,180	$29,839	$169,988,989	$23,418,530	$216,992,253	$3,255,419	$213,736,835
38	$4,719,129	$11,554,927	$6,133,556	$26,781	$173,388,769	$24,484,073	$220,307,236	$3,042,447	$217,264,788
39	$4,542,323	$10,980,380	$5,815,032	$28,989	$176,856,545	$25,598,098	$223,821,367	$2,843,409	$220,977,958
40	$4,370,888	$10,408,028	$5,511,933	$26,681	$180,393,675	$26,762,812	$227,474,016	$2,657,391	$224,816,624
					Totals				
	$356,412,447	$1,000,402,010	$674,687,783	$10,157,197	$5,033,450,554	511,231,604	7,586,341,595	$4,358,721,435	3,227,620,160

Source: Benefit-Cost Analysis Results. University of Nevada, Las Vegas. May2014.

TABLE 96 Summary of the Benefit-Cost Analysis

Costs	$4.36B
Benefits	$7.59B
Net Present Value	$3.23B
Benefit / Cost Ratio	1.7

Source: Benefit-Cost Analysis Results. University of Nevada, Las Vegas. May 2014.

Sensitivity Analysis

The benefit-cost analysis, as summarized above, uses a real discount rate of 7%, as recommended by the Office of Management and Budget (OMG) Circular A-94 (*39*). A real discount rate is a discount rate that reflects the opportunity cost of money net of the rate of inflation (*40*). The same reference encourages a sensitivity analysis for the discount rate using a rate of 3%, as shown in Table 97.

TABLE 97 Sensitivity Analysis

Discount Rate	3%	7%
Costs	$4.98B	$4.36B
Benefits	$9.97B	$7.59B
Net Present Value	$4.99B	$3.23B
Benefit / Cost Ratio	2.0	1.7

Source: Benefit-Cost Analysis Results. University of Nevada, Las Vegas. May 2014.

This analysis shows how sensitive the cost and benefits are relative to a discount rate. The benefit/cost (B/C) ratio changed from 1.7 to 2.0, implying that additional potential benefits.

Conclusions

In terms of the benefit-cost ratio for the project, the economic assessment of the ability of a Land Ferry system to alleviate increasing costs of maintaining the I-80 transportation corridor is 1.7 with a 7% discount rate. Hence, the project provides significant benefits; consequently, it can be justified financially. Specifically, the benefits are a consequence of improving travel by removing trucks from I-80 and transferring them onto a Land Ferry. The majority of the savings will be in terms of travel time, accident reductions, and vehicle operating cost. It should be noted that this analysis shows cost effectiveness of an investment because the money invested will be returned to users and non-users; it is not exactly a monetary return on investment.

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REFERENCES

1. Konkan Railway Corporation LTD. Roll On – Roll Off Services. *Mangalore: Konkan Railway's Ro-ro Service Enables Easy, Fuel-efficient Transport*, 2012. http://www.daijiworld.com/news/news_disp.asp?n_id=144826. Accessed Dec. 15, 2013.
2. United States Geological Survey. Maps, Imagery and Publications, 2013. http://www.usgs.gov/pubprod/. Accessed Sep. 21, 2013.
3. Banks, J.H. *Introduction to Traffic Engineering*, 2nd Ed. McGraw-Hill Science, 2001. http://www.mhhe.com/engcs/civil/banks/graphics/chap10.pdf. Accessed Nov 21, 2013.
4. Jong, J.C. Optimizing highway alignments with genetic algorithms. Adapted from Ph.D. dissertation, University of Maryland, College Park, 1998.
5. Banks, J.H. *Introduction to Traffic Engineering*, 2nd Ed. McGraw-Hill Science, 2001. http://www.mhhe.com/engcs/civil/banks/graphics/chap4.pdf. Accessed Oct 20, 2013.
6. Kavarouras, M. and E. Stefanakis. Determination of the optimum path on the earth's surface. *Proceedings of the 17th International Cartographic Association Conference*, Barcelona, Spain, 1995.
7. Roberts, R. Model Train Track Grades and Maximum Grade Issues. http://modeltrains.about.com/od/layoutconstruction/tp/track_grades.htm. Accessed March 8, 2014.
8. RS Means. *RSMeans Building Construction Cost Data*, RSMeans, 2014.
9. California Department of Transportation, Equipment Rental Rates and Labor Surcharge, Caltrans Division of Construction. http://www.dot.ca.gov/hq/construc/equipmnt.html Accessed on July 15, 2014.
10. Quandel Consultants, LLC. Draft Final Alternatives Selection Report: Identification of Reasonable and Feasible Passenger Rail Alternatives, 2011. http://www.dot.state.mn.us/passengerrail/mwrri/files/AltSelectionReport_FinalDraft.pdf. Accessed Feb. 22, 2014.
11. Guidelines for Life cycle cost analysis, Stanford University, Land and Buildings, 2005. http://lbre.stanford.edu/dpm/sites/all/lbre-shared/files/docs_public/LCCA121405.pdf. Accessed March 18, 2014.
12. Waste truck on Scale, 2013. http://www.nmisite.org/nmisite/first-shipment-of-waste-leaves-the-site/olympus-digital-camera-9/. Accessed Jan 18, 2014.
13. Chandra Industrial Works. http://www.chandraindustrialworks.co.in/railway-trolley.html. Accessed Jan 18, 2014. http://www.zacklift.com/Forks/forks_Old.htm.
14. http://www.zacklift.com/Forks/forks_Old.htm. Accessed Jan 18, 2014.
15. A330F Main Deck cargo loading FM25DAT13S00001.WMV, 2011. http://www.youtube.com/watch?v=iajqm_wFJ2g . Accessed 18 July, 2013.

16. CSX Corporation. Railroad equipment: Auto Boxcar specifications. http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/?keywords=boxcar%20specifications. Accessed Nov. 22, 2013.

17. Phelps Industries Inc. http://www.phelpsindustries.com/semiportable.html. Accessed Nov 18, 2013.

18. Republic Locomotive. *Tractive Effort and Power calculations*, 2010. http://www.republiclocomotive.com/tractive_effort_and_power_calculations.html. Accessed Jan 18, 2014.

19. National Renewable Energy Laboratory. *Photovoltaic Solar Resource of the United States*, 2012. http://www.nrel.gov/gis/images/eere_pv/national_photovoltaic_2012-01.jpg. Accessed March 14, 2014.

20. Mearian, L. Solar power installation costs fall through the floor, *Computer World Magazine*, 2013. http://www.computerworld.com/s/article/9244836/Solar_power_installation_costs_fall_through_the_floor. Accessed Feb 8, 2014.

21. Salmon, J.P., J. Maurice, N.Wobus, F.Stern, and M.Duaime. *Guidebook to Geothermal Power Finance*. National Renewable Energy Laboratory, 2011. http://www.nrel.gov/geothermal/financing/pdfs/49391.pdf. Accessed March 17, 2014.

22. National Renewable Energy Laboratory. *Wind Energy Resources in the Unites States*, US. Department of Energy, 2000. http://windeis.anl.gov/guide/maps/map2.html. Accessed Jan 18, 2014.

23. Tegen, S., M. Hand, B. Maples, E. Lantz, P. Schwabe, and A. Smith. *2010 Cost of Wind Energy Review*. National Renewable Energy Laboratory, 2012. http://www.nrel.gov/docs/fy12osti/52920.pdf. Accessed Feb. 18, 2014.

24. CSX Corporation. http://www.csx.com/index.cfm/about-csx/projects-and-partnerships/fuel-efficiency/. Accessed Feb. 27, 2014.

25. Halvatzis, S., and D. Keyser. *Estimated Economic Impacts of Utility Scale Wind Power In Iowa*, National Renewable Energy Laboratory, 2013. www.nrel.gov/docs/fy14osti/53187.pdf#page14. Accessed May 5, 2014.

26. Salasovich, J., and G. Mosey. *Feasibility Study of Economics and Performance of Solar Photovoltaics at Johnson County Landfill*. National Renewable Energy Laboratory, 2012. www.nrel.gov/docs/fy12osti/53186.pdf#page15. Accessed May 14, 2014.

27. Hillesheim, M., and G. Mosey. *Feasibility Study of Economics and Performance of Geothermal Power Generation at the Lakeview Uranium Mill Site in Lakeview, Oregon*. National Renewable Energy Laboratory, 2013. http://www.nrel.gov/docs/fy14osti/60251.pdf#page26. Accessed May 19, 2014.

28. Rollins, K., and R. Bartholet. *Economic assessment of the ability of a "Land Ferry" system*. Nevada Department of Transportation, 2013. http://www.nevadadot.com/uploadedFiles/NDOT/About_NDOT/NDOT_Divisions/Planning/Research/Documents/14-

76%20Land%20Ferry%20Benefit%20Cost%20Analysis_Rollins_UNR.pdf. Accessed August 26, 2013.

29. Barradas, S. The Real Cost of Trucking – Per Mile Operating Cost of a Commercial Truck. The Trucker's Report, 2013. http://www.thetruckersreport.com/infographics/cost-of-trucking/. Accessed Nov 4, 2013.
30. Craig, A. Day or night, driving while tired a leading cause of accidents. Virginia Tech Transportation Institute, 2013. http://www.vtnews.vt.edu/articles/2013/04/041513-vtti-fatigue.html. Accessed September 10, 2013.
31. Bureau of Labor Statistics. Occupational Employment Statistics. U.S. Department of Labor, 2013. http://www.bls.gov/oes/current/oes_stru.htm. Accessed November 19, 2013.
32. United States Census Bureau. County Business Patterns. U.S. Department of Commerce, 2013. http://www.census.gov/econ/cbp/. Accessed August 28, 2013.
33. Paterson, W. *Road Deterioration and Maintenance Effects: Models for Planning and Management*, 1987.
34. CALTRANS. California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C). *California Department of Transportation*, 2009. http://www.dot.ca.gov/hq/tpp/offices/eab/benefit_files/CalBC_User_Guide_v8.pdf. Accessed Apr. 19, 2010.
35. American Transportation Research Institute. *An Analysis of the Operational Costs of Trucking*, 2013. http://www.atri-online.org/research/results/economicanalysis/Operational_Costs_OnePager.pdf. Accessed April 20, 2014.
36. State of Nevada, Transportation Facts and Figures, 2013. http://nevadadot.com/uploadedFiles/NDOT/About_NDOT/NDOT_Divisions/Planning/Performance_Analysis/2013_factbook.pdf. Accessed June 18, 2014.
37. Addendum to the 1997 Federal Highway Cost Allocation Study - Final Report. U.S. Department of Transportation Federal Highway Administration, 2000. https://www.fhwa.dot.gov/policy/hcas/addendum.htm. Accessed June 20, 2014.
38. Eskaf, S. Using an Index to Help Project Capital Costs into the Future. *UNC Environmental Finance Center*, 2012.

    http://efc.web.unc.edu/2012/09/26/using-an-index-to-help-project-capital-costs-into-the-future/. Accessed June 24, 2014.
39. Office of Management and Budget (OMB) Circular A-94. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, 1992. Accessed Jan. 5, 2013.
40. TIGER Benefit-Cost Analysis (BCA) Resource Guide, 2014. http://www.dot.gov/sites/dot.gov/files/docs/TIGER%20BCA%20Resource%20Guide%202014.pdf. Accessed August 12, 2011.

Acronyms

ARRA	American Recovery and Reinvestment Act
B/C	Benefit / Cost
BCY	Bank Cubic Yard
BLM	Bureau of Land Management
Cal-B/C	California Benefit Cost
CO_2	Carbon Dioxide
CBS	Cost Breakdown Structure
DEM	Digital Elevation Maps
FRA	Federal Railroad Administration
GIS	Geographic Information Systems
IRI	International Roughness Index
NDOT	Nevada Department of Transportation
NREL	National Renewable Energy Laboratory
O&M	Operating and Maintenance (costs)
O&P	Overhead and Profit
OMG	Office of Management and Budget
PDO	Property damage only (PDO
RIMS II	Regional Input-Output Modeling System
RORO	Roll-on Roll-off
UPR	Union Pacific Railroad
VMT	Vehicle Miles Traveled
WBS	Work Breakdown Structure

APPENDIX A: Unit Cost Analyses

A.1 Unit Cost Analysis of Clearing and Grubbing

Table 98: Unit Cost Analysis of Clearing and Grubbing

Items	Cubic Meter	Conversion Factor	Bank Cubic Yard (BCY)
Earthwork Excavation	1,767,623	1,331	2,352,707
Earthwork Filling	1,774, 382	1,331	2,361,702
Difference	6,758		

Table 99: Total Area of Clearing and Grubbing the Land

Items	Mile (mi)	Yards (yd)	Width of the Cut (yd)	Total Area (sq-yd)
Clearing and grubbing the land	70	123,200	40	4,928,000

Table 100: Cost of Using 300 HP CAT 980 G Wheeler Loaders for Clearing and Grubbing

Production Rate	0.075 Acre/hr
Total Hours	13,464 hrs
Rent Cost of CAT	$2,800,612
Operating Cost	$560,122
Total Equipment Cost	$3,360,734
Labor Cost (25% of Total Cost)	$1,120,245
Total Cost	$4,480,979
Total Cost with O&P (20%)	**$5,377,175**
Unit Cost / Acre	**$5,324.80**

A.2 Unit Cost Analysis of Excavation

Excavation is done by a Caterpillar 980 G Wheel Load. The soil type is common earth, and the hauling distance is 300 ft.

Table 101: Unit Cost of Excavation

Production Rate	52 BCY/ hr
Total Hours Required	45,244 hrs
Cost from Caltrans book (CAT 980 G)	$208 / hrs
Rental Cost of Equipment	$9,410,827
Operating Cost (20%) of Rental Cost	$1,882,165
Total Equipment Cost	$11,292,992
Labor Cost (25% of Total Direct Cost)	$5,646,496
Total Direct Cost of Excavation	**$15,057,323**
Total Cost with O & P (20 %)	**$18,068,787.80**
Cost / BCY	$7.68

A.3 Unit Cost Analysis of Filling without Hauling

Fill cost without hauling, assuming a swell factor of common earth to be 20%. This includes spreading, dumping, and compacting the earthworks.

Table 102: Factors Regarding Filling without Hauling.

Production Rate	27.5 LCY /hr	
Quantity of Fill without Hauling	2,352,707 BCY*	2,940,883 Liner Cubic Yard (LCY)
Total Hours Required		106,941 hrs
CAT Vibratory Roller	$87.33/hr	

*1 BCY = 1.25 LCY

Table 103: Cost of Fill without Hauling

Total Cost of Roller	9,339,176
Operating Cost	1,867,835
Total Equipment Cost	11,207,012
Labor Cost (25%) of Total Equipment Cost	3,735,670.55
Total Cost of Fill without Hauling Earthwork	14,942,682.19
Total Cost with O & P (20%)	**17,931,218.62**
Cost of Fill without Hauling per LCY	6.10 / LCY
Cost of Fill without Hauling per BCY	7.62 / BCY

A.4 Unit Cost Analysis of Filling with 300-ft of Hauling

Table 104: Quantity of Fill with 300-ft of Hauling

Quantity of Fill with Hauling	8,995 BCY*	11,244 LCY

*1 BCY = 1.25 LCY

Table 105: Cost of Fill with 300-ft of Hauling

Cost of Excavation & Hauling	$6.14 / LCY
Cost of Compaction	$6.10 / LCY
Total Cost of Filling with Hauling	$12.24 / LCY
Total Cost of Fill with Hauling	**$137, 640**
Filling Cost with Hauling	$15.30 / BCY*

A.5 Unit Cost Analysis of Station Costs

Table 106: Foundation Cost for Steel Columns

Items	Height (ft)	Width (ft)	Breadth (ft)	Volume	Unit	Quantity	Unit Cost	Total Cost
Earthwork Excavation	8	7	7	392 cu-ft	CY	15	$7.68	$111.50
Concrete	3	7	7	147 cu-ft	CY	5	$125.00	$205.33
Formwork	4	3	7	84 sq-ft	CY	5	$125.00	$205.33
Back Fill				245 cu-ft	SY	9	$22.00	$1,066.54

Cost of steel columns and connections: $800
Total cost of erection of steel columns and foundation: $1,867
Total cost of steel columns for 116 columns: $216,518

Table 107: Unit Cost for Steel Columns

Items	Quantity	Unit Cost	Cost
Cost of Metal Joist for Roofing	31,185 ft	$40	$1,247,400
Cost of Metal Decking	161,000 sq-ft	$10	$1,610,000
Total			**$2,857,400**
Pavement for Loading Platform	20,444 sq-yd		
Sub-base Course		$6	$122,667
Concrete 12 in. thick paving		$50	$1,022,222
Total			**$1,144,889**
Total Cost			**$4,004,155**

APPENDIX B: Detailed Tables for Analysis of the Economic Impact of the Land Ferry

- Table 108 through 172 in Appendix B provides the values used to perform the RIMS II analyses.
- Tables XA (108, 116, 124, 132, 140, 148, 156, 164) give the initial cost estimates, or expected changes in final demand.
- Tables XB (109, 117, 125, 133, 141, 149, 157, 165) list the final demand and location quotient multipliers for each particular cost.
- Tables XC.i (110, 118, 126, 134, 142, 150, 158, 166), XD.i (112, 120, 128, 136, 144, 152, 160, 168) and XE.i (114, 122, 130, 138, 146, 154, 162, 170) are the total output, total earnings, and total jobs tables, respectively. These tables were created by multiplying the values in Table XA by the corresponding output, earnings, and jobs multiplier columns from Table XB.
- Specific to the jobs table, the final demand is multiplied by the jobs multiplier, divided by 1,000,000, as the job multiplier is equal to the anticipated job creation per $1,000,000 investment.
- Tables XC.ii (111, 119, 127, 135, 143, 151, 159, 167), XD.ii (113, 121, 129, 137, 145, 153, 161, 169) and XE.ii (115, 123, 131, 139, 147, 155, 163, 171) are Nevada specific output, earnings, and jobs tables, respectively. These tables were created by multiplying the XC.i, XD.i, and XE.i tables by the location quotient multiplier found in Table XB.

B.1 Cost of Track Structures and Tracks

Table 108: Cost of Track Structures and Tracks for Each Segment

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Component Total
10.1	Grubbing, Cutting, and Filling	$41,514,000	$41,806,000	$205,962,000	$191,838,000	$88,225,000	$569,345,000
10.2	Major Bridges	$9,900,000	$19,800,000	$9,900,000	$9,900,000	$29,700,000	$79,200,000
10.3	Minor Bridges	$1,075,000	$0	$0	$1,075,000	$0	$2,150,000
10.4	Road or Railway Crossing Bridges	$27,095,000	$19,090,000	$3,695,000	$9,545,000	$21,245,000	$80,670,000
10.5	Retaining Walls and Systems	$74,171,000	$78,205,000	$126,208,000	$67,388,000	$58,067,000	$404,039,000
10.6	Culverts and Drainage Systems	$11,235,000	$11,845,000	$12,744,000	$6,805,000	$8,795,000	$51,424,000
10.7	Conventional Ballasted	$57,470,000	$60,590,000	$65,178,000	$34,810,000	$44,991,000	$263,039,000
10.8	Components (rail, ties, etc.)	$62,860,000	$66,272,000	$71,301,000	$38,075,000	$49,210,000	$287,718,000
10.9	Special Track Work	$1,208,000	$1,208,000	$1,208,000	$604,000	$604,000	$4,832,000
10.10	Major Interlocking	$6,286,000	$6,627,000	$7,130,000	$3,807,000	$4,921,000	$28,771,000
10.11	Switch Heaters (power and control)	$9,429,000	$9,940,000	$10,695,000	$5,711,000	$7,381,000	$43,156,000
10.12	Vibration and Noise Dampening	$6,286,000	$6,627,000	$7,130,000	$3,807,000	$4,921,000	$28,771,000
10.13	Other Linear Structures	$12,950,000	$13,653,000	$14,689,000	$7,844,000	$10,138,000	$59,274,000
	Segment Totals	$321,479,000	$335,663,000	$535,840,000	$381,209,000	$328,198,000	$1,902,389,000

Table 109: Economic Impact Multipliers of Track Structures and Tracks for Each Segment

			Final Demand Multipliers			Location Quotient	LQ Multiplier
	Aggregate Industry Name	Industry Code	Output	Earnings	Jobs		
10.1	Construction	230000	1.9525	0.6522	14.9274	0.94	0.94
10.2	Construction	230000	1.9525	0.6522	14.9274	1.14	1
10.3	Construction	230000	1.9525	0.6522	14.9274	1.14	1
10.4	Construction	230000	1.9525	0.6522	14.9274	1.14	1
10.5	Concrete pipe, brick, and block manufacturing	327330	1.9144	0.4985	11.4918	1.03	1
10.6	Concrete pipe, brick, and block manufacturing	327330	1.9144	0.4985	11.4918	1.03	1
10.7	Ground or treated mineral and earth manufacturing	327992	1.6801	0.3481	8.453	6.17	1
10.8	Sawmills and wood preservation	321100	1.4668	0.2702	7.0262	0.21	0.21
10.9	Architectural, engineering, and related services	541300	1.8514	0.634	14.1782	0.3	0.3
10.10	Architectural, engineering, and related services	541300	1.8514	0.634	14.1782	0.78	0.78
10.11	Electronic component manufacturing	334419	1.9238	0.5594	16.4275	0.37	0.37
10.12	Wholesale Trade	420000	1.7263	0.5321	11.6054	1.03	1
10.13	Wholesale Trade	420000	1.7263	0.5321	11.6054	1.03	1

Table 110: Total Output for Track Structures and Tracks for Each Segment

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Component Total
10.1	Grubbing, Cutting, and Filling	$81,056,085	$81,626,215	$402,140,805	$374,563,695	$172,259,313	$1,111,646,113
10.2	Major Bridges	$19,329,750	$38,659,500	$19,329,750	$19,329,750	$57,989,250	$154,638,000
10.3	Minor Bridges	$2,098,938	$0	$0	$2,098,938	$0	$4,197,875
10.4	Road or Railway Crossing Bridges	$52,902,988	$37,273,225	$7,214,488	$18,636,613	$41,480,863	$157,508,175
10.5	Retaining Walls and Systems	$141,992,962	$149,715,652	$241,612,595	$129,007,587	$111,163,465	$773,492,262
10.6	Culverts and Drainage Systems	$21,508,284	$22,676,068	$24,397,114	$13,027,492	$16,837,148	$98,446,106
10.7	Conventional Ballasted	$96,555,347	$101,797,259	$109,505,558	$58,484,281	$75,589,379	$441,931,824
10.8	Components (rail, ties, etc.)	$92,203,048	$97,207,770	$104,584,307	$55,848,410	$72,181,228	$422,024,762
10.9	Special Track Work	$2,236,491	$2,236,491	$2,236,491	$1,118,246	$1,118,246	$8,945,965
10.10	Major Interlocking	$11,637,900	$12,269,228	$13,200,482	$7,048,280	$9,110,739	$53,266,629
10.11	Switch Heaters (power and control)	$18,139,510	$19,122,572	$20,575,041	$10,986,822	$14,199,568	$83,023,513
10.12	Vibration and Noise Dampening	$10,851,522	$11,440,190	$12,308,519	$6,572,024	$8,495,122	$49,667,377
10.13	Other Linear Structures	$22,355,585	$23,569,174	$25,357,621	$13,541,097	$17,501,229	$102,324,706
Anticipated Output per Segment:		$572,868,410	$597,593,344	$982,462,770	$710,263,234	$597,925,549	$3,461,113,307

Table 111: Nevada Output for Track Structures and Tracks for Each Segment

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Component Total
10.1	Grubbing, Cutting, and Filling	$76,192,720	$76,728,642	$378,012,357	$352,089,873	$161,923,754	$1,044,947,346
10.2	Major Bridges	$19,329,750	$38,659,500	$19,329,750	$19,329,750	$57,989,250	$154,638,000
10.3	Minor Bridges	$2,098,938	$0	$0	$2,098,938	$0	$4,197,875
10.4	Road or Railway Crossing Bridges	$52,902,988	$37,273,225	$7,214,488	$18,636,613	$41,480,863	$157,508,175
10.5	Retaining Walls and Systems	$141,992,962	$149,715,652	$241,612,595	$129,007,587	$111,163,465	$773,492,262
10.6	Culverts and Drainage Systems	$21,508,284	$22,676,068	$24,397,114	$13,027,492	$16,837,148	$98,446,106
10.7	Conventional Ballasted	$96,555,347	$101,797,259	$109,505,558	$58,484,281	$75,589,379	$441,931,824
10.8	Components (rail, ties, etc.)	$19,362,640	$20,413,632	$21,962,704	$11,728,166	$15,158,058	$88,625,200
10.9	Special Track Work	$670,947	$670,947	$670,947	$335,474	$335,474	$2,683,789
10.10	Major Interlocking	$9,077,562	$9,569,998	$10,296,376	$5,497,658	$7,106,377	$41,547,971
10.11	Switch Heaters (power and control)	$6,711,619	$7,075,352	$7,612,765	$4,065,124	$5,253,840	$30,718,700
10.12	Vibration and Noise Dampening	$10,851,522	$11,440,190	$12,308,519	$6,572,024	$8,495,122	$49,667,377
Anticipated Output per Segment Benefiting Nevada:		$457,255,279	$476,020,465	$832,923,173	$620,872,980	$501,332,729	$2,888,404,624
Proportion of Total Output Benefitting Nevada:							83.45%

Table 112: Total Earnings for Track Structures and Tracks for Each Segment

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Component Total
10.1	Grubbing, Cutting, and Filling	$27,075,431	$27,265,873	$134,328,416	$125,116,744	$57,540,345	$371,326,809
10.2	Major Bridges	$6,456,780	$12,913,560	$6,456,780	$6,456,780	$19,370,340	$51,654,240
10.3	Minor Bridges	$701,115	$0	$0	$701,115	$0	$1,402,230
10.4	Road or Railway Crossing Bridges	$17,671,359	$12,450,498	$2,409,879	$6,225,249	$13,855,989	$52,612,974
10.5	Retaining Walls and Systems	$36,974,244	$38,985,193	$62,914,688	$33,592,918	$28,946,400	$201,413,442
10.6	Culverts and Drainage Systems	$5,600,648	$5,904,733	$6,352,884	$3,392,293	$4,384,308	$25,634,864
10.7	Conventional Ballasted	$20,005,307	$21,091,379	$22,688,462	$12,117,361	$15,661,367	$91,563,876
10.8	Components (rail, ties, etc.)	$16,984,772	$17,906,694	$19,265,530	$10,287,865	$13,296,542	$77,741,404
10.9	Special Track Work	$765,872	$765,872	$765,872	$382,936	$382,936	$3,063,488
10.10	Major Interlocking	$3,985,324	$4,201,518	$4,520,420	$2,413,638	$3,119,914	$18,240,814
10.11	Switch Heaters (power and control)	$5,274,583	$5,560,436	$5,982,783	$3,194,733	$4,128,931	$24,141,466
10.12	Vibration and Noise Dampening	$3,344,781	$3,526,227	$3,793,873	$2,025,705	$2,618,464	$15,309,049
10.13	Other Linear Structures	$6,890,695	$7,264,761	$7,816,017	$4,173,792	$5,394,430	$31,539,695
Anticipated Worker Earnings per Segment:		$151,730,909	$157,836,744	$277,295,604	$210,081,129	$168,699,965	$965,644,351

Table 113: Nevada Earnings for Track Structures and Tracks for Each Segment

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Component Total
10.1	Grubbing, Cutting, and Filling	$25,450,905	$25,629,921	$126,268,711	$117,609,739	$54,087,924	$349,047,200
10.2	Major Bridges	$6,456,780	$12,913,560	$6,456,780	$6,456,780	$19,370,340	$51,654,240
10.3	Minor Bridges	$701,115	$0	$0	$701,115	$0	$1,402,230
10.4	Road or Railway Crossing Bridges	$17,671,359	$12,450,498	$2,409,879	$6,225,249	$13,855,989	$52,612,974
10.5	Retaining Walls and Systems	$36,974,244	$38,985,193	$62,914,688	$33,592,918	$28,946,400	$201,413,442
10.6	Culverts and Drainage Systems	$5,600,648	$5,904,733	$6,352,884	$3,392,293	$4,384,308	$25,634,864
10.7	Conventional Ballasted	$20,005,307	$21,091,379	$22,688,462	$12,117,361	$15,661,367	$91,563,876
10.8	Components (rail, ties, etc.)	$3,566,802	$3,760,406	$4,045,761	$2,160,452	$2,792,274	$16,325,695
10.9	Special Track Work	$229,762	$229,762	$229,762	$114,881	$114,881	$919,046
10.10	Major Interlocking	$3,108,553	$3,277,184	$3,525,928	$1,882,638	$2,433,533	$14,227,835
10.11	Switch Heaters (power and control)	$1,951,596	$2,057,361	$2,213,630	$1,182,051	$1,527,705	$8,932,343
10.12	Vibration and Noise Dampening	$3,344,781	$3,526,227	$3,793,873	$2,025,705	$2,618,464	$15,309,049
10.13	Other Linear Structures	$6,890,695	$7,264,761	$7,816,017	$4,173,792	$5,394,430	$31,539,695
Anticipated Nevadan Worker Earnings per Segment:		$131,952,545	$137,090,984	$248,716,374	$191,634,973	$151,187,613	$860,582,489
Proportion of Total Earnings going to Nevada Residents:							89.12%

Table 114: Total Jobs for Track Structures and Tracks for Each Segment

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Component Total
10.1	Grubbing, Cutting, and Filling	620	624	3,074	2,864	1,317	8,499
10.2	Major Bridges	148	296	148	148	443	1,182
10.3	Minor Bridges	16	--	--	16	--	32
10.4	Road or Railway Crossing Bridges	404	285	55	142	317	1204
10.5	Retaining Walls and Systems	852	899	1450	774	667	4643
10.6	Culverts and Drainage Systems	129	136	146	78	101	591
10.7	Conventional Ballasted	486	512	551	294	380	2,223
10.8	Components (rail, ties, etc.)	442	466	501	268	346	2,022
10.9	Special Track Work	17	17	17	9	9	69
10.10	Major Interlocking	89	94	101	54	70	408
10.11	Switch Heaters (power and control)	155	163	176	94	121	709
10.12	Vibration and Noise Dampening	73	77	83	44	57	334
10.13	Other Linear Structures	150	158	170	91	118	688
Anticipated Job Creation per Segment:		3,581	3,727	6,473	4,876	3,946	22,604

Table 115: Nevada Jobs for Track Structures and Tracks for Each Segment

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Component Total
10.1	Grubbing, Cutting, and Filling	583	587	2,890	2,692	1,238	7,989
10.2	Major Bridges	148	296	148	148	443	1,182
10.3	Minor Bridges	16	--	--	16	--	32
10.4	Road or Railway Crossing Bridges	404	285	55	142	317	1,204
10.5	Retaining Walls and Systems	852	899	1,450	774	667	4,643
10.6	Culverts and Drainage Systems	129	136	146	78	101	591
10.7	Conventional Ballasted	486	512	551	294	380	2,223
10.8	Components (rail, ties, etc.)	93	98	105	56	73	425
10.9	Special Track Work	5	5	5	3	3	21
10.10	Major Interlocking	70	73	79	42	54	318
10.11	Switch Heaters (power and control)	57	60	65	35	45	262
10.12	Vibration and Noise Dampening	73	77	83	44	57	334
10.13	Other Linear Structures	150	158	170	91	118	688
Anticipated Job Creation in Nevada per Segment:		3,066	3,186	5,748	4,416	3,496	19,912
Proportion of Total Job Creation going to Nevada Residents:							88.09%

B.2 Costs for Stations

Table 116: Station Costs

20.01	Station Buildings: Structures	$24,030,000
20.02	Station Buildings: Service	$6,007,000
20.03	Platforms	$4,806,000
20.04	Truck Loading and Unloading System	$30,000,000
20.05	Fare Collection System	$3,000,000
20.06	Access for Loading Systems	$961,000
20.07	Station Security System	$1,200,000
20.08	Accommodation, Landscaping, Parking Lots	$1,200,000
	Total Cost	$71,204,000

Table 117: Economic Impact Multipliers for Stations

		Final Demand Multipliers					
	Aggregate Industry Name	**Industry Code**	**Output**	**Earnings**	**Jobs**	**Location Quotient**	**LQ Multiplier**
20.01	Construction	230000	1.9525	0.6522	14.9274	1.14	1
20.02	Construction	230000	1.9525	0.6522	14.9274	1.14	1
20.03	Construction	230000	1.9525	0.6522	14.9274	1.14	1
20.04	Architectural, engineering, and related services	541300	1.8514	0.634	14.1782	0.78	0.78
20.05	Electronic component manufacturing	334419	1.9238	0.5594	16.4275	0.37	0.37
20.06	Construction	230000	1.9525	0.6522	14.9274	1.14	1
20.07	Security Services	561600	1.875	0.7804	28.7334	0.99	0.99
20.08	Architectural, engineering, and related services	541300	1.8514	0.634	14.1782	0.78	0.78

Table 118: Total Output for Stations

20.01	Station Buildings: Structures	$46,918,575
0.02	Station Buildings: Service	$11,728,668
20.03	Platforms	$9,383,715
20.04	Truck Loading and Unloading System	$55,542,000
20.05	Fare Collection System	$5,771,400
20.06	Access for Loading Systems	$1,876,353
20.07	Station Security System	$2,250,000
20.08	Accommodation, Landscaping, Parking Lots	$2,221,680
	Total Anticipated Output for Stations:	$6,348,033

Table 119: Nevada Output for Stations

20.01	Station Buildings: Structures	$46,918,575
20.02	Station Buildings: Service	$11,728,668
20.03	Platforms	$9,383,715
20.04	Truck Loading and Unloading System	$43,322,760
20.05	Fare Collection System	$2,135,418
20.06	Access for Loading Systems	$1,876,353
20.07	Station Security System	$2,227,500
20.08	Accommodation, Landscaping, Parking Lots	$1,732,910
	Anticipated Output Benefitting Nevada:	$5,836,763
	Proportion of Total Output Benefitting Nevada:	91.95%

Table 120: Total Earnings for Stations

20.01	Station Buildings: Structures	$15,672,366
20.02	Station Buildings: Service	$3,917,765
20.03	Platforms	$3,134,473
20.04	Truck Loading and Unloading System	$19,020,000
20.05	Fare Collection System	$1,678,200
20.06	Access for Loading Systems	$626,764
20.07	Station Security System	$936,480
20.08	Accommodation, Landscaping, Parking Lots	$760,800
Total Anticipated Worker Earnings:		$45,746,849

Table 121: Nevada Earning for Stations Nevada Earning for Stations

20.01	Station Buildings: Structures	$15,672,366
20.02	Station Buildings: Service	$3,917,765
20.03	Platforms	$3,134,473
20.04	Truck Loading and Unloading System	$14,835,600
20.05	Fare Collection System	$620,934
20.06	Access for Loading Systems	$626,764
20.07	Station Security System	$927,115
20.08	Accommodation, Landscaping, Parking Lots	$593,424
Total Anticipated Worker Earnings		$40,328,442
Proportion of Total Earnings going to Nevada Residents:		88.16%

Table 122: Total Jobs for Stations

20.01	Station Buildings: Structures	359
20.02	Station Buildings: Service	90
20.03	Platforms	72
20.04	Truck Loading and Unloading System	425
20.05	Fare Collection System	49
20.06	Access for Loading Systems	14
20.07	Station Security System	34
20.08	Accommodation, Landscaping, Parking Lots	17
	Total Anticipated Worker Earnings:	1,061

Table 123: Nevada Jobs for Stations

20.01	Station Buildings: Structures	359
20.02	Station Buildings: Service	90
20.03	Platforms	72
20.04	Truck Loading and Unloading System	332
20.05	Fare Collection System	18
20.06	Access for Loading Systems	14
20.07	Station Security System	34
20.08	Accommodation, Landscaping, Parking Lots	13
	Total Anticipated Worker Earnings:	932
	Proportion of Total Job Creation going to Nevada Residents:	87.86%

B.3 Cost for Support Facilities

Table 124: Costs for Support Facilities

30.01	Administration Building	$14,240,000
30.02	Light Maintenance Facility	$160,000,000
30.03	Heavy Maintenance Facility	$140,000,000
30.04	Maintenance Storage	$30,000,000
30.05	Yard and Yard Track	$3,000,000
	Total Cost	$347,240,000

Table 125: Economic Impact Multipliers for Support Facilities

	Aggregate Industry Name	Industry Code	Final Demand Multipliers			Location Quotient	LQ Multiplier
			Output	Earnings	Jobs		
30.01	Construction	230000	1.9525	0.6522	14.9274	1.14	1
30.02	Construction	230000	1.9525	0.6522	14.9274	1.14	1
30.03	Construction	230000	1.9525	0.6522	14.9274	1.14	1
30.04	Construction	230000	1.9525	0.6522	14.9274	1.14	1
30.05	Construction	230000	1.9525	0.6522	14.9274	0.3	0.3

Table 126: Total Output for Support Facilities

30.01	Administration Building	$27,803,600
30.02	Light Maintenance Facility	$312,400,000
30.03	Heavy Maintenance Facility	$273,350,000
30.04	Maintenance Storage	$58,575,000
30.05	Yard and Yard Track	$5,857,500
	Total Anticipated Output	$677,986,100

Table 127: Nevada Output for Support Facilities

30.01	Administration Building	$27,803,600
30.02	Light Maintenance Facility	$312,400,000
30.03	Heavy Maintenance Facility	$273,350,000
30.04	Maintenance Storage	$58,575,000
30.05	Yard and Yard Track	$1,757,250
	Anticipated Output Benefitting Nevada:	$673,885,850
	Proportion of Total Output Benefitting Nevada:	99.40%

Table 128: Total Earning for Support Facilities

30.01	Administration Building	$9,287,328
30.02	Light Maintenance Facility	$104,352,000
30.03	Heavy Maintenance Facility	$91,308,000
30.04	Maintenance Storage	$19,566,000
30.05	Yard and Yard Track	$1,956,600
	Total Anticipated Earnings	$226,469,928

Table 129: Nevada Earnings for Support Facilities

30.01	Administration Building	$9,287,328
30.02	Light Maintenance Facility	$104,352,000
30.03	Heavy Maintenance Facility	$91,308,000
30.04	Maintenance Storage	$19,566,000
30.05	Yard and Yard Track	$586,980
	Anticipated Earnings for Nevada	$225,100,308
	Proportion of Total Earnings going to Nevada Residents:	99.40%

Table 130: Total Jobs for Support Facilities

30.01	Administration Building	213
30.02	Light Maintenance Facility	2,388
30.03	Heavy Maintenance Facility	2,090
30.04	Maintenance Storage	448
30.05	Yard and Yard Track	45
Total Anticipated Job Creation:		5,183

Table 131: Nevada Jobs for Support Facilities

30.01	Administration Building	213
30.02	Light Maintenance Facility	2,388
30.03	Heavy Maintenance Facility	2,090
30.04	Maintenance Storage	448
30.05	Yard and Yard Track	13
Anticipated Nevada Job Creation:		5,152
Proportion of Total Job Creation going to Nevada Residents:		99.40%

B.4 Cost for Land

Table 132: Cost for Land

40.01	Demolition and Site Clearing	$32,050,000
40.02	Site Utilities, Utility Relocation	$320,000,000
40.03	Hazardous Material Removal, Ground Water Treatment	$48,000,000
40.04	Environmental Mitigation	$128,000,000
40.05	Temporary Facilities	$18,000,000
40.06	Real Estate	$50,000,000
40.07	Relocation of Existing Structures	$100,000,000
	Total Costs	$696,050,000

Table 133: Economic Impact Multipliers for Land

	Aggregate Industry Name	Industry Code	Final Demand Multipliers			Location Quotient	LQ Multiplier
			Output	Earnings	Jobs		
40.01	Construction	230000	1.9525	0.6522	14.9274	0.94	0.94
40.02	Construction	230000	1.9525	0.6522	14.9274	1.14	1
40.03	Waste Management and Remediation	562000	1.786	0.4701	10.9639	1.25	1
40.04	Environmental Services	5416A0	1.7611	0.5855	17.0627	1.29	1
40.05	Construction	230000	1.9525	0.6522	14.9274	1.14	1
40.06	Real Estate	531000	1.4378	0.2559	21.4536	1.2	1
40.07	Construction	230000	1.9525	0.6522	14.9274	1.14	1

Table 134: Total Output for Land

40.01	Demolition and Site Clearing	$62,577,625
40.02	Site Utilities, Utility Relocation	$624,800,000
40.03	Hazardous Material Removal, Ground Water Treatment	$85,728,000
40.04	Environmental Mitigation	$225,420,800
40.05	Temporary Facilities	$35,145,000
40.06	Real Estate	$71,890,000
40.07	Relocation of Existing Structures	$195,250,000
	Total Anticipated Output:	$1,300,811,425

Table 135: Nevada Output for Land

40.01	Demolition and Site Clearing	$58,822,968
40.02	Site Utilities, Utility Relocation	$624,800,000
40.03	Hazardous Material Removal, Ground Water Treatment	$85,728,000
40.04	Environmental Mitigation	$225,420,800
40.05	Temporary Facilities	$35,145,000
40.06	Real Estate	$71,890,000
40.07	Relocation of Existing Structures	$195,250,000
	Total Anticipated Output:	$1,297,056,768
	Proportion of Total Output Benefitting Nevada:	99.71%

Table 136: Total Earnings for Land

40.01	Demolition and Site Clearing	$20,903,010
40.02	Site Utilities, Utility Relocation	$208,704,000
40.03	Hazardous Material Removal, Ground Water Treatment	$22,564,800
40.04	Environmental Mitigation	$74,944,000
40.05	Temporary Facilities	$11,739,600
40.06	Real Estate	$12,795,000
40.07	Relocation of Existing Structures	$65,220,000
	Total Anticipated Output:	$1,300,811,425

Table 137: Nevada Earnings for Land

40.01	Demolition and Site Clearing	$19,648,829
40.02	Site Utilities, Utility Relocation	$208,704,000
40.03	Hazardous Material Removal, Ground Water Treatment	$22,564,800
40.04	Environmental Mitigation	$74,944,000
40.05	Temporary Facilities	$11,739,600
40.06	Real Estate	$12,795,000
40.07	Relocation of Existing Structures	$65,220,000
	Total Anticipated Output:	$1,297,056,768
	Proportion of Total Output Benefitting Nevada:	99.71%

Table 138: Total Jobs for Land

40.01	Demolition and Site Clearing	478
40.02	Site Utilities, Utility Relocation	4,777
40.03	Hazardous Material Removal, Ground Water Treatment	526
40.04	Environmental Mitigation	2,184
40.05	Temporary Facilities	269
40.06	Real Estate	1,073
40.07	Relocation of Existing Structures	1,493
	Total Anticipated Output:	10,800

Table 139: Nevada Jobs for Land

40.01	Demolition and Site Clearing	450
40.02	Site Utilities, Utility Relocation	4,777
40.03	Hazardous Material Removal, Ground Water Treatment	526
40.04	Environmental Mitigation	2,184
40.05	Temporary Facilities	269
40.06	Real Estate	1,073
40.07	Relocation of Existing Structures	1,493
	Total Anticipated Output:	10,771
	Proportion of Total Output Benefitting Nevada:	99.73%

B.5 Cost for Communications

Table 140: Cost for Communications

50.01	Wayside Signaling Equipment	$32,000,000
50.02	Signal Power Access & Distribution	$8,000,000
50.03	Onboard Signaling Equipment	$1,000,000
50.04	Traffic Control	$5,000,000
50.05	Communications	$32,000,000
50.06	Grade Crossing Protections	$700,000
50.07	Warning System	$450,000
	Total Costs	$79,150,000

Table 141: Economic Impact Multipliers for Communications

	Aggregate Industry Name	Industry Code	Final Demand Multipliers			Location Quotient	LQ Multiplier
			Output	Earnings	Jobs		
50.01	Electronic component manufacturing	334419	1.9238	0.5594	16.4275	0.37	0.37
50.02	Electronic Power Distribution	2211A0	1.4532	0.3543	6.0271	0.79	0.79
50.03	Electronic component manufacturing	334419	1.9238	0.5594	16.4275	0.37	0.37
50.04	Electronic component manufacturing	334419	1.9238	0.5594	16.4275	0.37	0.37
50.05	Communications Equipment Manufacturing	334290	1.8163	0.4694	12.0223	2.16	1
50.06	Architectural, engineering, and related services	541300	1.8514	0.634	14.1782	0.78	0.78
50.07	Electronic component manufacturing	334419	1.9238	0.5594	16.4275	0.37	0.37

Table 142: Total Output for Communications

50.01	Wayside Signaling Equipment	$61,561,600
50.02	Signal Power Access & Distribution	$11,625,600
50.03	Onboard Signaling Equipment	$1,923,800
50.04	Traffic Control	$9,619,000
50.05	Communications	$58,121,600
50.06	Grade Crossing Protections	$1,295,980
50.07	Warning System	$865,710
	Total Anticipated Output:	$145,013,290

Table 143: Nevada Output for Communications

50.01	Wayside Signaling Equipment	$22,777,792
50.02	Signal Power Access & Distribution	$9,184,224
50.03	Onboard Signaling Equipment	$711,806
50.04	Traffic Control	$3,559,030
50.05	Communications	$58,121,600
50.06	Grade Crossing Protections	$1,010,864
50.07	Warning System	$320,313
	Total Anticipated Output:	$95,685,629
	Proportion of Total Output Benefitting Nevada:	65.98%

Table 144: Total Earnings for Communications

50.01	Wayside Signaling Equipment	$17,900,800
50.02	Signal Power Access & Distribution	$2,834,400
50.03	Onboard Signaling Equipment	$559,400
50.04	Traffic Control	$2,797,000
50.05	Communications	$15,020,800
50.06	Grade Crossing Protections	$443,800
50.07	Warning System	$251,730
	Total Anticipated Output:	$39,807,930

Table 145: Nevada Earnings for Communications

50.01	Wayside Signaling Equipment	$6,623,296
50.02	Signal Power Access & Distribution	$2,239,176
50.03	Onboard Signaling Equipment	$206,978
50.04	Traffic Control	$1,034,890
50.05	Communications	$15,020,800
50.06	Grade Crossing Protections	$346,164
50.07	Warning System	$93,140
	Total Anticipated Output:	$25,564,444
	Proportion of Total Output Benefitting Nevada:	64.22%

Table 146: Total Jobs for Communications

50.01	Wayside Signaling Equipment	526
50.02	Signal Power Access & Distribution	48
50.03	Onboard Signaling Equipment	16
50.04	Traffic Control	82
50.05	Communications	385
50.06	Grade Crossing Protections	10
50.07	Warning System	7
	Total Anticipated Output:	1,074

Table 147: Nevada Jobs for Communications

50.01	Wayside Signaling Equipment	195
50.02	Signal Power Access & Distribution	38
50.03	Onboard Signaling Equipment	6
50.04	Traffic Control	30
50.05	Communications	385
50.06	Grade Crossing Protections	8
50.07	Warning System	3
	Total Anticipated Output:	664
	Proportion of Total Output Benefitting Nevada:	61.82%

B.6 Cost for Diesel Vehicles

Table 148: Cost for Diesel Vehicles

60.01	Vehicle Acquisition: Diesel Multiple Units	$12,000,000
60.02	Vehicle Acquisition: Non-railroad Support	$1,000,000
60.03	Vehicle Acquisition: Railroad Maintenance	$1,000,000
60.04	Spare Parts	$1,000,000
	Total Costs	$15,000,000

Table 149: Economic Impact Multipliers for Diesel Vehicles

	Aggregate Industry Name	Industry Code	Final Demand Multipliers			Location Quotient	LQ Multiplier
			Output	Earnings	Jobs		
60.01	Railroad Rolling Stock Manufacturing	336500	1.5996	0.3632	9.328	0.68	0.68
60.02	Railroad Rolling Stock Manufacturing	336500	1.5996	0.3632	9.328	0.68	0.68
60.03	Railroad Rolling Stock Manufacturing	336500	1.5996	0.3632	9.328	0.68	0.68
60.04	Motor Vehicle Parts Manufacturing	336300	1.7139	0.4048	10.4003	0.94	0.94

Table 150: Total Output for Diesel Vehicles

60.01	Vehicle Acquisition: Diesel Multiple Units	$19,195,200
60.02	Vehicle Acquisition: Non-railroad Support	$1,599,600
60.03	Vehicle Acquisition: Railroad Maintenance	$1,599,600
60.04	Spare Parts	$1,713,900
	Total Anticipated Output:	$24,108,300

Table 151: Nevada Output for Diesel Vehicles

60.01	Vehicle Acquisition: Diesel Multiple Units	$13,052,736
60.02	Vehicle Acquisition: Non-railroad Support	$1,087,728
60.03	Vehicle Acquisition: Railroad Maintenance	$1,087,728
60.04	Spare Parts	$1,611,066
	Total Anticipated Output:	$16,839,258
	Proportion of Total Output Benefitting Nevada:	69.85%

Table 152: Total Earnings for Diesel Vehicles

60.01	Vehicle Acquisition: Diesel Multiple Units	$4,358,400
60.02	Vehicle Acquisition: Non-railroad Support	$363,200
60.03	Vehicle Acquisition: Railroad Maintenance	$363,200
60.04	Spare Parts	$404,800
	Total Anticipated Earnings	$5,489,600

Table 153: Nevada Earnings for Diesel Vehicles

60.01	Vehicle Acquisition: Diesel Multiple Units	$2,963,712
60.02	Vehicle Acquisition: Non-railroad Support	$246,976
60.03	Vehicle Acquisition: Railroad Maintenance	$246,976
60.04	Spare Parts	$380,512
	Total Anticipated Output:	$3,838,176
	Proportion of Total Output Benefitting Nevada:	69.92%

Table 154: Total Jobs for Diesel Vehicles

60.01	Vehicle Acquisition: Diesel Multiple Units	112
60.02	Vehicle Acquisition: Non-railroad Support	9
60.03	Vehicle Acquisition: Railroad Maintenance	9
60.04	Spare Parts	10
	Total Anticipated Output:	141

Table 155: Nevada Jobs for Diesel Vehicles

60.01	Vehicle Acquisition: Diesel Multiple Units	76
60.02	Vehicle Acquisition: Non-railroad Support	6
60.03	Vehicle Acquisition: Railroad Maintenance	6
60.04	Spare Parts	10
	Total Anticipated Output:	99
	Proportion of Total Output Benefitting Nevada:	69.92%

B.7 Cost for Professional Services

Table 156: Cost for Professional Services

70.01	Service Development/Environmental	$31,110,000
70.02	Preliminary Engineering/Environmental	$93,331,000
70.03	Final Design	$217,772,000
70.04	Project Management	$46,665,000
70.05	Construction Administration	$155,552,000
70.06	Professional Liability and Insurance	$62,221,000
70.07	Legal: Permits and Review Fees	$31,110,000
70.08	Surveys, Testing, and Investigations	$31,110,000
70.09	Engineering Inspection	$31,110,000
70.10	Start Up	$5,000,000
	Total Costs	$704,981,000

Table 157: Economic Impact Multipliers for Professional Services

	Aggregate Industry Name	Industry Code	Final Demand Multipliers			Location Quotient	LQ Multiplier
			Output	Earnings	Jobs		
70.01	Research and Development Services	541700	1.936	0.6996	13.5944	1.01	1
70.02	Architectural, Engineering, and Related Services	541300	1.8514	0.634	14.1782	0.76	0.76
70.03	Specialized Design Services	541400	1.721	0.5499	18.8307	0.78	0.78
70.04	Management Consulting Services	541610	1.8129	0.6374	15.6662	1.25	1
70.05	Administrative Services	561100	1.9764	0.7768	17.4676	0.52	0.52
70.06	Insurance Agencies and Related Activities	524200	1.9195	0.6168	17.0884	0.25	0.25
70.07	Legal Services	54110	1.9158	0.8207	16.0132	0.94	0.94
70.08	Architectural, Engineering, and Related Services	541300	1.8514	0.634	14.1782	0.76	0.76
70.09	Architectural, Engineering, and Related Services	541300	1.8514	0.634	14.1782	0.76	0.76
70.10	Business Support Services	561400	1.8265	0.6073	21.5974	0.76	0.76

Table 158: Total Output for Professional Services

70.01	Service Development/Environmental	$60,228,960
70.02	Preliminary Engineering/Environmental	$172,793,013
70.03	Final Design	$374,785,612
70.04	Project Management	$84,598,979
70.05	Construction Administration	$307,432,973
70.06	Professional Liability and Insurance	$119,433,210
70.07	Legal: Permits and Review Fees	$59,600,538
70.08	Surveys, Testing, and Investigations	$57,597,054
70.09	Engineering Inspection	$57,597,054
70.10	Start Up	$9,132,500
	Total Anticipated Output:	$1,303,199,892

Table 159: Nevada Output for Professional Services

70.01	Service Development/Environmental	$60,228,960
70.02	Preliminary Engineering/Environmental	$131,322,690
70.03	Final Design	$292,332,777
70.04	Project Management	$84,598,979
70.05	Construction Administration	$159,865,146
70.06	Professional Liability and Insurance	$29,858,302
70.07	Legal: Permits and Review Fees	$56,024,506
70.08	Surveys, Testing, and Investigations	$43,773,761
70.09	Engineering Inspection	$43,773,761
70.10	Start Up	$6,940,700
	Anticipated Output Benefitting Nevada:	$908,719,582
	Proportion of Total Output Benefitting Nevada:	69.73%

Table 160: Total Earnings for Professional Services

70.01	Service Development/Environmental	$21,764,556
70.02	Preliminary Engineering/Environmental	$59,171,854
70.03	Final Design	$119,752,823
70.04	Project Management	$29,744,271
70.05	Construction Administration	$120,832,794
70.06	Professional Liability and Insurance	$38,377,913
70.07	Legal: Permits and Review Fees	$25,531,977
70.08	Surveys, Testing, and Investigations	$19,723,740
70.09	Engineering Inspection	$19,723,740
70.10	Start Up	$3,036,500
	Total Anticipated Earnings:	$457,660,167

Table 161: Nevada Earnings for Professional Services

70.01	Service Development/Environmental	$21,764,556
70.02	Preliminary Engineering/Environmental	$44,970,609
70.03	Final Design	$93,407,202
70.04	Project Management	$29,744,271
70.05	Construction Administration	$62,833,053
70.06	Professional Liability and Insurance	$9,594,478
70.07	Legal: Permits and Review Fees	$24,000,058
70.08	Surveys, Testing, and Investigations	$14,990,042
70.09	Engineering Inspection	$14,990,042
70.10	Start Up	$2,307,740
	Total Anticipated Earnings:	$318,602,052
Proportion of Total Earnings Benefitting Nevada:		69.62%

Table 162: Total Jobs for Professional Services

70.01	Service Development/Environmental	423
70.02	Preliminary Engineering/Environmental	1,323
70.03	Final Design	4,101
70.04	Project Management	731
70.05	Construction Administration	2,717
70.06	Professional Liability and Insurance	1,063
70.07	Legal: Permits and Review Fees	498
70.08	Surveys, Testing, and Investigations	441
70.09	Engineering Inspection	441
70.10	Start Up	108
	Total Anticipated Jobs:	11,847

Table 163: Nevada Jobs for Professional Services

70.01	Service Development/Environmental	423
70.02	Preliminary Engineering/Environmental	1,006
70.03	Final Design	3,199
70.04	Project Management	731
70.05	Construction Administration	1,413
70.06	Professional Liability and Insurance	266
70.07	Legal: Permits and Review Fees	468
70.08	Surveys, Testing, and Investigations	335
70.09	Engineering Inspection	335
70.10	Start Up	82
	Total Anticipated Jobs:	8,258
	Proportion of Total Jobs Benefitting Nevada:	69.71%

B.8 Cost for Operations

Table 164: Total Cost for Operations

1	Annual Utilities	$8,657,000
2	Annual Fuel	$6,727,000
3	Annual Operator	$328,000
4	Annual Administrative Maintenance	$1,443,000
5	Annual Track Maintenance	$26,304,000
6	Annual Engine Maintenance	$750,000
	Annual Operations and Maintenance:	$44,209,000
	Total Cost over 40 Years:	$1,768,360,000

Table 165: Economic Impact Multipliers for Operations

	Aggregate Industry Name	Industry Code	Final Demand Multipliers			Location Quotient	LQ Multiplier
			Output	Earnings	Jobs		
1	Facilities Support Services	561200	1.8464	0.6329	17.0707	1.55	1
2	Oil and Gas Extraction	211000	1.7337	0.4076	8.6752	1.05	1
3	Rail Transportation	482000	1.8101	0.4321	8.5106	0.3	0.3
4	Building Services	561700	1.8071	0.5998	27.2603	1.55	1
5	Rail Transportation	482000	1.8101	0.4321	8.5106	0.3	0.3
6	Rail Transportation	482000	1.8101	0.4321	8.5106	0.68	0.68

Table 166: Total Output for Operations

1	Annual Utilities	$15,984,285
2	Annual Fuel	$11,662,600
3	Annual Operator	$593,713
4	Annual Administrative Maintenance	$2,607,645
5	Annual Track Maintenance	$47,612,870
6	Annual Engine Maintenance	$1,357,575
Annual Operations and Maintenance:		$79,818,688

Table 167: Nevada Output for Operations

1	Annual Utilities	$15,984,285
2	Annual Fuel	$11,662,600
3	Annual Operator	$178,114
4	Annual Administrative Maintenance	$2,607,645
5	Annual Track Maintenance	$14,283,861
6	Annual Engine Maintenance	$923,151
Annual Operations and Maintenance:		$45,639,656
Proportion of Total Output:		57.18%

Table 168: Total Earnings for Operations

1	Annual Utilities	$5,479,015
2	Annual Fuel	$2,741,925
3	Annual Operator	$141,729
4	Annual Administrative Maintenance	$865,511
5	Annual Track Maintenance	$11,365,958
6	Annual Engine Maintenance	$324,075
Annual Operations and Maintenance:		$20,918,214

Table 169: Nevada Earnings for Operations

1	Annual Utilities	$5,479,015
2	Annual Fuel	$2,741,925
3	Annual Operator	$42,519
4	Annual Administrative Maintenance	$865,511
5	Annual Track Maintenance	$3,409,788
6	Annual Engine Maintenance	$220,371
Annual Operations and Maintenance:		$12,759,129
Proportion of Total Earnings:		61.00%

Table 170: Total Jobs for Operations

1	Annual Utilities	148
2	Annual Fuel	58
3	Annual Operator	3
4	Annual Administrative Maintenance	39
5	Annual Track Maintenance	224
6	Annual Engine Maintenance	6
1	Annual Utilities	148
Annual Operations and Maintenance:		479

Table 171: Nevada Jobs for Operations

1	Annual Utilities	148
2	Annual Fuel	58
3	Annual Operator	1
4	Annual Administrative Maintenance	39
5	Annual Track Maintenance	67
6	Annual Engine Maintenance	4
Annual Operations and Maintenance:		318
Proportion of Total Jobs:		66.42%

B.9 Economic Impact of Combined Total Costs

Table 172: Combined Total Costs

Phase One: Construction								
	Initial Investment/ Final Demand Change		**Total**			**Nevada**		
			Output	**Earnings**	**Jobs**	**Output**	**Earnings**	**Jobs**
1	Track	$1,902,389,000	$3,461,113,307	$965,644,351	22,604	$2,990,729,331	$860,582,489	19,912
2	Stations	$71,204,000	$135,692,390	$45,746,849	1,061	$119,325,898	$40,328,442	932
3	Support	$347,240,000	$677,986,100	$226,469,928	5,183	$673,885,850	$225,100,308	5,152
4	Land	$696,050,000	$1,300,811,425	$416,870,410	10,800	$1,297,056,768	$415,616,229	10,771
5	Communications	$79,150,000	$145,013,290	$39,807,930	1,074	$95,685,629	$25,564,444	664
6	Vehicles	$15,000,000	$24,108,300	$5,489,600	141	$16,839,258	$3,838,176	99
7	Professional Services	$704,981,000	$1,303,199,892	$457,660,167	11,847	$908,719,582	$318,602,052	8,258
	Totals	$3,816,014,000	$7,047,924,704	$2,157,689,235	52,709	$6,102,242,316	$1,889,632,140	45,788
Proportion of Total Benefitting Nevada:						86.58%	87.58%	86.87%
Phase Two: Operations								
		Initial Investment/ Final Demand Change	**Total**			**Nevada**		
	Annual		**Output**	**Earnings**	**Jobs**	**Output**	**Earnings**	**Jobs**
1	Utilities	$8,657,000	$15,984,285	$5,479,015	148	$15,984,285	$5,479,015	148
2	Fuel	$6,727,000	$11,662,600	$2,741,925	58	$11,662,600	$2,741,925	58
3	Operator	$328,000	$593,713	$141,729	3	$178,114	$42,519	1
4	Administrative Maintenance	$1,443,000	$2,607,645	$865,511	39	$2,607,645	$865,511	39
5	Track Maintenance	$26,304,000	$47,612,870	$11,365,958	224	$14,283,861	$3,409,788	67
6	Engine Maintenance	$750,000	$1,357,575	$324,075	6	$923,151	$220,371	4
	Totals	$44,209,000	$79,818,688	$20,918,213	478	$45,639,656	$12,759,128	318
Proportion of Total Benefitting Nevada:						57.18%	61.00%	66.41%
For 40 years:						$1,825,586,234	$510,365,134	318