Route Selection and Design of a Coal Shuttle Railroad: Experiences of a Recent Railroad Engineering Graduate

C. Tyler Dick, P.E.
HDR Engineering Inc.

University of Illinois W.W. Hay Railroad Engineering Seminar
February 1, 2008
Outline

- Project Background and Overview
- Route and Alignment Selection
  - Comparison techniques
- Detailed Alignment Design
  - Snags and solutions
- Construction
  - Expecting the unexpected
Coal and Power in Texas

- Texas Lignite mined locally for electrical generation
- Several plants use short-haul railroads to transport lignite
- Oak Grove project currently under construction will use an 11-mile railroad
Oak Grove Project

- Twin Oak Reservoir
- Oak Grove Steam Electric Station (SES)
  - Two lignite-fired generation units, 1600 MW
  - Unit 1 online late 2009, Unit 2 in 2010
- Kosse Lignite Mine
- Oak Grove Railroad
- Owner: Luminant Energy (formerly TXU)
Oak Grove Railroad

- Deliver lignite from Kosse Mine to Oak Grove SES on dedicated rail line
- Approximately 9 million tons per year
- Two 40-car trains, push-pull operation
- Limited lignite storage at plant
  - needs to be highly reliable system
- Self contained with maintenance facility
Project Area

- Kosse
- Kosse Mine Loader
- SH7
- UPRR Ennis Subdivision
- Existing spur to SES
- Oak Grove SES

1 MILE
The Challenge – HDR Tasks

- Oak Grove 11-Mile Railroad
  - Railroad route/alignment study
  - Environmental permitting
  - Detailed design of preferred alignment and mine site yard facilities
  - Bidding and general construction support

- Oak Grove SES Plant Site
  - Design reconfigured plant site trackage
    - Lignite unloading
    - Future bottom ash and flyash operations
Project Timeline

- Route/alignment study: June ‘05 - Jan ‘06
- Environmental permitting: Oct ‘05 – May ‘06
- Detailed design: May ‘06 – May ‘07
- Earthwork construction: Jan ‘07 – Jan ‘08
- Bridge construction: Jul ‘07 – Dec ‘07
- Trackwork construction: Jan ’08 – Fall ’08
- In-Service for “first-fire”: Early 2009
Route/Alignment Study

- Develop three possible routes meeting design criteria
  - 40mph operation
  - 1 percent grades desirable
  - 12 MGT annual traffic
- Evaluate routes and select preferred alternative
- Develop feasible alignment along preferred route alternative
Possible Routes

Possible Routes include:

- **A**
  - Existing spur to SES
- **B**
  - SH7
- **C**
  - Kosse Mine Loader

**Oak Grove SES**
Which is preferred?

- “Minimize length, curves and grades” – Wellington & AREMA

How to compare “curviness”?
- Tightest degree curve
- Total degrees central angle = \( S \) delta
- “Curve Index” = \( S \) delta \( \times \) degree

How to compare “hilliness”?
- Ruling grade
- Rise and Fall = \( S \) length \( \times \) |grade|
- “Grade Index” = \( S \) length \( \times \) grade \( \times \) grade
Need for “Curve Index”

Tightest Curve = 3 degrees  Total Central Angle = 360 degrees
“Curve Index” = 1080

Tightest Curve = 3 degrees  Total Central Angle = 360 degrees
“Curve Index” = 540
Need for “Grade Index”

Ruling Grade = 1.0%  Rise and Fall = 30 feet  “Grade Index” = 30

Ruling Grade = 1.0%  Rise and Fall = 30 feet  “Grade Index” = 20
## Route Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Construction (mi)</td>
<td>9.05</td>
<td>8.98</td>
<td>9.58</td>
</tr>
<tr>
<td>Total Route Length (mi)</td>
<td>12.55</td>
<td><strong>12.48</strong></td>
<td>13.08</td>
</tr>
<tr>
<td><strong>Curvature</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Degrees</td>
<td><strong>144</strong></td>
<td>158</td>
<td>258</td>
</tr>
<tr>
<td>Curve Index</td>
<td>285</td>
<td>357</td>
<td>598</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruling Grade</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Rise and Fall</td>
<td><strong>127</strong></td>
<td>146</td>
<td>148</td>
</tr>
<tr>
<td>Grade Index</td>
<td>93</td>
<td>118</td>
<td>109</td>
</tr>
<tr>
<td><strong>Bridges and Drainage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>River Crossings</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Stream/Creek Crossings</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Culverts (lf)</td>
<td>3188</td>
<td>3318</td>
<td><strong>2657</strong></td>
</tr>
<tr>
<td><strong>Road Crossings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Separations</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Grade Crossings</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td><strong>Property Owners</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parcels Crossed / ROW (ac)</td>
<td>9 / 148</td>
<td>7 / 116</td>
<td><strong>0 / 0</strong></td>
</tr>
</tbody>
</table>
Matrix Analysis Approach

- Allows for comparison of alignments relative to multiple decision criteria
- Alignments judged in five evaluation categories
- Categories subdivided into several criterion
- Double weight scoring system
  - Criterion scores weighted to determine category score
  - Category scores weighted to determine overall score for the alignment
Evaluation Categories

- Cost Effectiveness: 30%
- Operational Efficiency, Mobility and Safety Effects: 25%
- Social and Economic Effects: 20%
- Environmental Effects: 15%
- Public and Agency Support: 10%
Sample Criterion

Operational Efficiency, Mobility and Safety Effects (25%)

- Public Safety: 15%
- Railroad Freight Safety: 15%
- Grade Crossings Added: 10%
- Grade Crossing Level of Service: 10%
- Operational Efficiency: 50%

Cost Effectiveness (30%)

- Ease of Implementation: 15%
- Roadway Maint.: 10%
- Railroad Ops & Maintenance Cost: 25%
- Total Cost: 50%
## Scoring Results

<table>
<thead>
<tr>
<th>Category</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency, Mobility and Safety</td>
<td>88</td>
<td>88</td>
<td>75</td>
</tr>
<tr>
<td>Cost-Effectiveness</td>
<td>98</td>
<td>98</td>
<td>110</td>
</tr>
<tr>
<td>Social and Economic Effects</td>
<td>56</td>
<td>56</td>
<td>90</td>
</tr>
<tr>
<td>Environmental Effects</td>
<td>49</td>
<td>57</td>
<td>51</td>
</tr>
<tr>
<td>Public and Agency Support</td>
<td>27</td>
<td>27</td>
<td>37</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>316</td>
<td>325</td>
<td>362</td>
</tr>
</tbody>
</table>
Preferred Alignment

- Alternative C selected as preferred alignment for detailed design

Deciding factors:
- Minimizes right-of-way impacts
- Ease of implementation
- Public support
- Cost of construction
- Shorter alignments had environmental and/or access and constructability issues
Route Study Learning Points

- Beyond Wellington: need to consider range of environmental and social factors, not just engineering geometry and cost
- Curve Index and Grade Index are tools to quickly compare efficiency of alternatives
- Matrix analysis approach can weight various criteria relative to their importance and allow for easy comparisons between alternatives
Detailed Design

- Develop detailed design package for preferred alignment
  - Planset covering all construction tasks
  - Standard details
  - Specifications for earthwork, track and bridge
- Designed with MicroStation and Bentley InRail SelectCAD
Detailed Design Workflow

- Aerial survey – 1000’ strip – 1’ contours
- Geotechnical field investigation
- Track design
  - Horizontal and vertical geometry
  - Subgrade, earthwork and basic drainage
  - Culverts and special ditches
  - Roadway crossings and signage
- Bridge design (by HDR bridge group)
Snag: Aerial Survey and Vegetation

- Aerial survey conducted in January 2006 to generate design topo
- Vegetation obscured many stream channels
- Culverts designed to topo don’t match GPS stream traces used for Corps permit!!!
Solution:

Aerial Survey and Vegetation

- Tried to incorporate GPS traces into aerial topo date but some differences too great
- Conduct ground survey at key jurisdictional water crossings
- Replaced aerial topo with ground survey data then redesigned earthwork and culverts
Snag: Horizontal Obstructions

- Unmarked pioneer graves and abandoned well near working alignment
- Fortunately outside limits of cut/fill construction
- Alternative solutions if needed:
  - Steepen side slopes
  - Retaining walls
  - Realignment
Crossing Streams & Floodplains

- Bridges at Duck Creek and Pool Branch, both in FEMA designated floodplains
- Railroad must create “no rise” in floodplain – HEC-RAS analysis
- How to set profile across bridge?
  - Too high = costly fill and tall bridge bents
  - Too low = interferes with flood flows and unnecessary grades
Top of Rail Elevation over Bridges

- Baseline: 100-year water surface elevation from FEMA flood maps
- Add 2’ of freeboard to structure low chord to clear debris during flood
- Add structure depth approx = span/12
- Add allowance for deck, ballast, track
- Total is 7 feet above flood elevation
- Use to set low point of sag curve over Duck Creek
Duck Creek Bridge – 170’
Duck Creek
5-10’x10’ Relief Culvert
Snag: Mine Loader Elevation

- Confused top of subgrade with top of rail elevation at mine loader
- Loader designed and parts fabricated
- Need to lower railroad 3 feet at loader
- Grades allowed redesign for clearance
- Added 3 feet of climb for loaded train starting from stop up the ruling grade!
Solution: Train Performance Calculation

- Change in elevation at loader negated previous operations analysis by Canac
- Volunteered to run analysis
- Went back to U of I grad school spreadsheet for train acceleration

<table>
<thead>
<tr>
<th>Speed</th>
<th>TE</th>
<th>R</th>
<th>F’a</th>
<th>F’a bar</th>
<th>L step</th>
<th>T step</th>
<th>L tot (ft)</th>
<th>T tot (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100880</td>
<td>62581</td>
<td>7.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100880</td>
<td>62818</td>
<td>7.39</td>
<td>7.42</td>
<td>28</td>
<td>13</td>
<td>28</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>100880</td>
<td>63059</td>
<td>7.35</td>
<td>7.37</td>
<td>47</td>
<td>13</td>
<td>76</td>
<td>26</td>
</tr>
<tr>
<td>etc...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Train Performance Calculation: SD50 and Loaded 40-car Train

- Accelerating from rest at loading station

![Graph showing train performance with speed and distance from loading station](image)
Used Locomotive Shopping

“We’re up here at NRE in Mt. Vernon looking at used SD50s and wanted your opinion…”

- Advised client on features to look for such as traction control, de-rating etc.
- Use ALL of your railroad knowledge to assist client: value-added service!
Detailed Design Learning

Points

- Ground survey is still important
- Leave room for expansion in yards and industrial track designs
- You can’t miss everything, but miss the expensive things
- Bridge basics help set efficient profiles
- Use full rail knowledge of operations to optimize design and aid client
Bidding and Construction

- Detailed design yielded 230-sheet planset

- Bidding also required:
  - Specifications (track, earthwork, bridge)
  - Material breakdowns and bid tabulations

- Construction phase also entailed advising owner on suitability of materials procured by the contractor
Material Lead Times

- Time to procure materials can hamper fast-track projects
  - Timber ties – 9 to 12 months
  - Rail – 6 months
  - Special trackwork – 6 to 8 months
  - Ballast – wait for break in Class 1 production schedule
- Price volatility and fuel charges hamper getting a fixed price from suppliers
Snag: UPRR Connection and CWR Train

- Facing point turnout at UPRR removed

- Contractors to use 1600’ CWR strings
- CWR train: ramp & threader cars, two locos
- Can’t bring 1850’ train into plant!
Solution:
On-Site Rail Welding Plant
Construction Progress: Earthwork and Subgrade
Construction Progress: Duck Creek Bridge
Construction Progress: Subballast
Trackwork Progress:
Tie Layout
Trackwork Progress: Plating
Trackwork Progress: Threading Rail and Spiking
Trackwork Progress:
Skeleton Track
Summary

- Can find oneself designing a “whole new railroad” a few years out of school
- Modern alignment study considers many more factors than just rail geometry and cost
- Rail design is more than just track
- Expect the unexpected and be creative!