The 4th ASEAN Civil Engineering Conference

November 22-23, 2011 - Yogyakarta, Indonesia

Editors
Istiarto
Henricus Priyosulistyo
Budi Santoso Wignyosukarto
Sigit Priyanto

Organized by: AUN/SEED-Net

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PROCEEDINGS

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Organized by:
Department of Civil and Environmental Engineering, Universitas Gadjah Mada (CEE-UGM)
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Supported by:
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Route Alternative for Yogyakarta’s Railway Development: Design Choice and Possibilities

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Abstract: The rail services between Yogyakarta and Magelang was closed in 1976. Currently, the Ministry of Transportation is reviewing reactivated possibilities of the services. This paper is aimed to provide some alternative routes between Yogyakarta-Magelang using MCA (Multi Criteria Analysis). MCA's key feature is its ability to offer a number of ways of aggregating the data on individual criteria to provide indicators of the overall performance's options. Three alternative routes are decided based on their specific goals. The first route: crossing along the old track; the second route: connecting busy area between Yogyakarta-Magelang; and the last route: heading straight to Borobudur Temple. Each route was analyzed by MCA method and compared each other by scoring and weighting. For quantitative criteria (construction cost, operational cost, acquisition, and railway length), scoring and weighting were given based on calculation using Autocad Civil 3D or simple Microsoft Excel, and for qualitative criteria (demand, accessibility, landscape, social effect, and others), scoring and weighting were given based on scale 1–5. The results show that the third route has the lowest cost, but quite weak in qualitative criteria. Then, the chosen route is the second route, with the best qualitative assessment and also cheap in quantitative assessment.

Keyword: Multi Criteria Analysis, Yogyakarta-Magelang track, alternative route

INTRODUCTION

1 Background
The railway transport is the best solution to all transportation problems so far. It's eco friendly, regarding its low emission, loads better number of passengers, lower cost, reliable (related to its safety) etc. Yogyakarta – Magelang track used to serve the Yogyakarta – Magelang – Secang – Temanggung – Kuran route, but the services was closed in 1976. Currently, the Ministry of Transportation is reviewing the possibilities of its services by doing the detailed engineering design and provides socialization to the people.

2 Problems Description
a. Which route and operation design is the best?
   What we need to plan a route?

3 Scope and limitation
   The research conducted only at Yogyakarta – Magelang track
   This research mainly analyzing about the cost, other factors is less considered

4 Objective
   To decide the best route and operation design, mainly based on cost and other factors

b. To serve as guidelines in planning the route

1.5 Benefits
a. Wider economic impact goes along the new track
b. Reducing barriers to travel
c. Reducing negative impact of transportation
d. A suitable guideline for giving railways alternative route

2 LITERATURE REVIEW
Re-activation of an old railway and make it as a part of national railway network is a complex process that needs a complex analysis. Therefore, these criteria are important to be considered:

2.1 Construction Cost
One of the detailed findings of the review of current practices is that there is an inconsistency of how Base Estimates are prepared. In particular, the reviewed procedures describe how the estimation are come up from direct and indirect costs, but in actual fact are often estimated at “all up” rates which contain a spread allowance (often by percentage uplift) for Contractor’s Indirect Costs and Margins in the unit rate.

Construction Costs in an estimate should be structured in one of two ways:
a. by using ‘all up’ rates that include all construction costs and margin as a spread allowance (often by percentage uplift) across all rates or
b. by separating out the construction’s costs into direct costs, indirect costs and margin.

2.2 Operating Cost
Operating costs could be split into two groups. The expenses of the first group depends on traffic volume, the second doesn’t. These expenses are called dependent and conditionally constant.

a. The dependent expenses are the salaries of locomotive and train crews, fuel and electricity expenses, the maintenance of rolling-stock, etc.

b. The conditionally constant expenses include salary of management personal of railway departments, maintenance of buildings, constructions and communication facilities.

2.3 Geometric Design
The routes upon which a train is travel and the track is constructed are called as alignment (PT KAI, 1986; IRCG, 2004). Road alignment is less complicated than railway alignment because of the following reason:

a. The railway operator has no control over horizontal movement, such as steering
b. The available power for moving the mass is less than other modes, such as air or road modes

Alignment is defined in two kinds:

1. Horizontal Alignment
Physically defined as the place where the track goes (XY plane).

2. Vertical Alignment
Defined as the elevation, rise and fall (Z component)

2.4 Area Coverage
Crucial thing when analyzing the accessibility are reflecting at its impact on people. The old network coverage must be defined by the majority people groups, considering their needs are expressed through the travel demand and the following market

There are potentially many hundreds of combinations of people groups, time of day, trip purpose and travel behavior preferences which could be relevant to the analysis. It is not practical to look at these entire but rather to concentrate on those sections of society or those trip purposes that demonstrate the key impacts. The importance part is to optimize the choice of population sectors, geographical coverage, spatial detail, and trip purposes to reflect policy issues, which are sensitive locally. To ensure that social exclusion issues are considered properly analysis should consider access to:

- work for all people;
- learning for unemployed people;
- health for all people; and
- food shops for all people.

The new route should offer the best performance related to the area coverage. It must have better accessibility than the old one, less boundaries, and other.

2.5 The Market
Target of passenger are:

1. Employment
   Employment is the first target to reach, both from Magelang and Yogyakarta

2. Tourist
   The alternative route should support the tourism industry by bringing the visitor/tourist

3. Student
   Student also the potential target passenger, in this case, student from Magelang who taking an education in Yogyakarta

2.6 Forecasting Demand
The demand for travel is the key of this analysis and the first thing should be considered. UK-TRL (1980) notes that the forecasting demand is highly need to be as accurate as possible, and it can be carried out by:

a. Good understanding of existing local social economic condition
b. Transparency and logic forecast
c. Validate the output
d. Complete data trend

2.7 Accessibility
Transit services accessibility to another public services (post office, health center, shops, bank etc) are highly required. The transit services distance and its reaching time by walking or cycling can significantly affecting the transit’s level of service at all.

If walking and cycling to the transit services have not considered under the transit’s analysis, the worst that can happen is the transit services have no public general acceptance and stopping the services at the end.
Lack of access by walking, cycling, etc. is sometimes also called severance. However, transport investment can improve access by walking and cycling rather than simply mitigate problems, so it is more meaningful to measure changes in access rather than reductions in severance.

BASIC THEORY

Construction Cost Items
Construction cost including:

- Land Acquisition
- Earthwork
- Cut and fill volume calculation
- Material Preparation
- Consist of: Crushed rock ballast preparation and transportation
- Preparation Works
- Consist of: workers building and warehouse construction, stakes measurement and installation, workers building destruction, mobilization and demobilization of tools, and also documentation
- Ballast Works
- Consist of: Ballast works, Listing works
- Railroad Construction Works
- Consist of: Concrete sleeper installation, thermite rail welding, new spoor setting, switcher installation, and also switch over works
- Special Works
- Consist of: Asphalting, site clearance, and Soft built drawing

Operating Cost Items
- Vehicle Ownership Costs
  - Locomotive
  - Freight cars
  - coaches
- Vehicle Maintenance Costs
  - Locomotive maintenance (unit cost/km or unit cost/fuel used)
  - Freight Cars (unit cost/km or unit cost/car load)
- Transportation Costs
  - Train fuel
  - Train crew wages
  - Loco crew wages
  - Shunting
  - Station operation
  - Billing
  - Others

3.3 Geometric Design

Figure 1. Railway Cross Section

<table>
<thead>
<tr>
<th>Table 1. Cross Section Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Section</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
</tbody>
</table>

4 METHODOLOGY

Figure 2. Research Location

Yogyakarta:
Area: 32.5 km²
Population (2011) - Total 430,735 ppl
Density: 13,253.4 ppl/km²

Magelang:
Area: 18.12 km²
Total Population: 120,000 (2003)
Density: 6,623 ppl/km²

4.1 Multi Criteria Analysis

Common method used to compare the input and output for product’s decision-valuation before MCA is called CEA (Cost Effectiveness Analysis) and CBA (Cost Benefit Analysis). Both methods use the cost (money) as main criteria. MCA is a method to compares the input-output that is not only seen from cost /money factors, but also from other factors that effecting the decision-valuation (DCLG, 2009).
Decision-making order of execution are:

- **Identifying objectives**
The purpose of decision making should be clear and specified, measurable and realistic, etc. a good decision- judgment should consist of few level of, which are: immediate objective to be achieved, medium-term objective, main objective.

- **Identifying options for achieving the objectives**
After the objectives have been made, the next stage is decide how many option available to make the decision-judgment.

- **Analysis of the options**
Next stage is to analyze the available option. Generally, the government always chooses the financial factors to analyze the available option to make the decision-judgment.

- **Making choices**
Making choices is the final stages to make decision judgment. Final decision made by related parties according to political interest.

- **Feedback**
A good decision is a decision which refine the previous decision. This judgment is analyzed so that we can predict the possible mistake to improve the quality of decision-judgment in the future.

MCA offers a number of ways of aggregating the data on individual criteria to provide indicators of the overall performance of options. A key feature of MCA is its emphasis on the judgment of the decision making team, in establishing objectives and criteria, estimating relative importance weights and, to some extent, in judging the contribution of each option to each performance criterion. The stages consist of:

1. **Scoring**
Scoring criteria for each option based on the results of the calculation or assessment criteria.

2. **Weighting**
Weighting is done by following ways:

a. The best score (for example in terms of route length criteria, then the best score given to the shortest route. Best score given weight = 10)
b. Then do the weighting of each criterion, by means of score each criteria, compared with the best score and then multiplied by the weighting score of the best.

**Stages of analysis:**

1. **Deciding 3 alternative route**
The alternative route is deciding with different goal. The first route was the old route, used as a comparison. The second route connecting the areas between Yogyakarta – Magelang, to serve worker, trader, students, etc. And the last heading straight to Borobudur Temple, with the main goal to serve tourist from Yogyakarta to Borobudur.

2. **Plotting each route on Map Source and Google Earth to get contour data**
Plotting route on Map Source to get better view on every location, then view in Google Earth. Google Earth already has contour data, so we could get contour data on our route easily and quickly.

3. **Inserting each route on Autocad Civil 3D**
Autocad Civil 3D is the best solution in planning a route. With this software we could get route’s length, alignment vertical, alignment horizontal, cross section, and also cut and fill volume.

4. **Calculating construction cost and also operating cost**
Construction Costs include the volume of work obtained from each route and multiplying by the unit price that has been analyzed (the calculation will be attached to the next chapter). Operating cost obtained from replacement cost for locomotive, freight cars, coaches, vehicle maintenance, and also transportation needs (fuel, crew wages, etc.)

5. **MCA analysis**
**Stages:**
**Scoring**
Scoring criteria for each option based on the results of the calculation or assessment criteria.

**Weighting**
Weighting is done by following ways:
a. The best score (for example in terms of route length criteria, then the best score given to the shortest route. Best score given weight = 10)
b. Then do the weighting of each criterion, by means of score each criteria, compared with the best score and then multiplied by the weighting score of the best.

6. **Decision making**
Qualitative and quantitative criteria will be compared and with proper analysis, the best route will be decided.
ALTERNATIVE ROUTE ANALYSIS

Alternative Route

Three alternative route was decided with its each goal listed below:

Route 1
Passing along the old track, starting from Yogyakarta - Sleman - Muntilan - Pabelan - Blendo - Blabak - Mertojoyudan - Magelang Kota - Kebonpolo - Seang - Parakan - Temanggung.

Route 2
The second route connecting the busy areas between Yogyakarta - Magelang. Therefore, the target passengers are workers, students, traders and consumers. Based on the goal, this route mainly taking about the issues of accessibility, and doesn't need a super straight track. As long as the route could accommodate most people demands, this route is firmly accepted.

This route passes through the busy areas, such as:
- Yogyakarta
- Sleman
- Sleman
- Muntilan
- Pabelan
- Blendo
- Blabak
- Mertojoyudan
- Magelang Kota
- Kebonpolo
- Seang
- Parakan
- Temanggung

Route 3
Alternative 3 heading straight to Borobudur Temple (crossing through Yogyakarta - Trihanggo - Seyegan - Margokaton - Banyurejo - Bloko - Banjaroyo - Candirejo - Tuksono - Borobudur) as the main attraction of Magelang. So that, building the track as straight as possible is a major concern.

5.2 Cost Estimation

Earthwork
Earthwork consist of two kinds, cut and fill. Theoretically, cut are cost less than fill, because cut doesn't require any additional material (soil). But one thing must be considered was, the fill requires better performance of heavy equipment. The best solution is to make the land as flat as possible by balancing the volume of cut and fill at a reasonable cost.

After plotting in Autocad Civil 3D, the number of excavation volume on the third route was very large. That's because the third route paying no attention to other than straight to Borobudur, so that, although the distance was very short than other alternative route, the third route crossing mountains area, and provide excavation volume that make no sense.

The two other routes have an appropriate and balance cut and fill volume associated with their length. The first route, which is through the old track, has the longest length, because the route is not stopped at Magelang, but expanding until Temanggung. And the second route, connecting busy areas between Yogyakarta and Magelang, hoping that this route achieving the target, enhance railway's use in our people activities.
Table 2. Earthwork Detail

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Cut</th>
<th>Cost/m³</th>
<th>Cost</th>
<th>Fill</th>
<th>Cost</th>
<th>Cost/ km</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROUTE 1</td>
<td>79.696</td>
<td>20.97.105</td>
<td>37600</td>
<td>78.85 M</td>
<td>19.03.105</td>
<td>38700</td>
<td>73.65 M</td>
</tr>
<tr>
<td>ROUTE 2</td>
<td>51.655</td>
<td>11.09.105</td>
<td>37600</td>
<td>41.7 M</td>
<td>10.9.105</td>
<td>38700</td>
<td>41.26 M</td>
</tr>
<tr>
<td>ROUTE 3</td>
<td>29.234</td>
<td>15.94.105</td>
<td>37600</td>
<td>59.95 M</td>
<td>5.76.105</td>
<td>38700</td>
<td>22.27 M</td>
</tr>
</tbody>
</table>

Construction Stages

Stages:

1. Material Preparation
   Material procurement work consists of providing crushed rocks for ballast with 2-6 cm dimension, transportation to bring the crushed rocks, and also cost for unloading and installing crushed rocks on site.

2. Preparation
   Preparation work consist of:
   a. Workers building and warehouse construction
      Workers building are planned with dimension 18 m² and 5 cm floor thickness. Assuming that the workers building is built around the site of work and after work is completed, the building dismantled and rebuilt in the next place where the next job held on.
   b. Stakes measurement and installation
      Stakes measurement and installation costs consisting of the needs for timber class III, nail, carpenter, head of carpenter, worker, and foreman
   c. Workers building destruction
      The cost only to pay workers to demolish the workers building
   d. Mobilization and de-mobilization of tools
      The costs of mobilization and de-mobilization of tools consist of cost for foreman and worker salary and also material
   e. Documentation

3. Ballast works
   The calculation of ballast works cost includes worker and foreman wages to put the crushed rocks as the ballast and for listing with HTT, MTT, SSP until reach normal velocity.

4. Railroad construction works
   Consist of:
   a. Concrete sleeper preparation cost for worker
   b. Thermite Rail Welding

Consist of cost for supporting material (oxygen, LPG, gasoline, oil, duster, plastic tent, hand millstone, oxygen regulator, and LPG regulator), welding material (thermite welding material), tools (hammer pin, chisel wedge, welding goggles, gloves, steel brush, apron, shovel, wrench, crowbar, tarpon key, stopwatch, welding shoes, jackbeam and pen puller), rent machine (grinding machine, hand grinding machine and manual welding machine), wages (for supervisor, welder, grinder, and worker) and other cost (transportation, and operational safety)

   c. Spoer setting
      Spoer setting cost only coming from wages for worker and foreman

   d. Switcher installation
      Switcher installation costs including transportation from warehouse consist of:
      - Picking from warehouse to job site (worker and foreman wages and material)
      - Loading unloading switcher
      - Material transportation
      - Switcher setting preparation

   e. Switch over works

5. Special works
   a. Asphalting
      Asphalting required to make railroad parallel with roads. Asphalting costs consist of: grinding cost, and asphalting with hotmix

   b. Site clearance
      Site clearance is necessary, because of the land function maybe not compatible with the project.

   c. Soft drawing

5.3 Construction Cost

Route 1: Rp78.583.974.058
Route 2: Rp50.162.289.356
Route 3: Rp28.503.558.742
4.4 Operating Cost

Operating costs could be split into two groups. The expenses of the first group depend on traffic volume, and the second doesn’t. These expenses are called dependent and conditionally constant.

The dependent expenses are the salaries of locomotive and train crews, fuel and electricity expenses, the maintenance of rolling-stock, etc.

<table>
<thead>
<tr>
<th>Cost type</th>
<th>Route 1</th>
<th>Route 2</th>
<th>Route 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Ownership Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locomotive</td>
<td>Replacement Cost</td>
<td>Replacement Cost</td>
<td>Replacement Cost</td>
</tr>
<tr>
<td>Freight Cars</td>
<td>Replacement Cost</td>
<td>Replacement Cost</td>
<td>Replacement Cost</td>
</tr>
<tr>
<td>Coaches</td>
<td>Unit cost/loc unit - km</td>
<td>Unit cost/litre of fuel used</td>
<td>Unit cost/car - km</td>
</tr>
<tr>
<td>Vehicle Maintenance Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locomotive</td>
<td>Unit cost/loc unit - km</td>
<td>Unit cost/litre of fuel used</td>
<td>Unit cost/car - km</td>
</tr>
<tr>
<td>Freight Cars</td>
<td>Unit cost/loc unit - km</td>
<td>Unit cost/litre of fuel used</td>
<td>Unit cost/car - km</td>
</tr>
<tr>
<td>Transportation Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train Fuel</td>
<td>Unit cost</td>
<td>Actual by cost centre</td>
<td>Actual by cost centre</td>
</tr>
<tr>
<td>Train Crew Wages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loco Crew Wages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shunting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Station Operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Billing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.5 Land Acquisition

Land acquisition based on the prevailing land prices in the area. In the first route and second, because the region through a strategic area, the land acquisition costs are assumed higher than the cost of land acquisition in the third route.

Table 4 MCA’s Performance Matrix

<table>
<thead>
<tr>
<th>No</th>
<th>Criteria</th>
<th>Route 1</th>
<th>Route 2</th>
<th>Route 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Quantitative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Railway Length</td>
<td>79.70</td>
<td>3.67</td>
<td>51.66</td>
</tr>
<tr>
<td></td>
<td>Construction Cost</td>
<td>78583974057.72</td>
<td>3.63</td>
<td>50162289355.75</td>
</tr>
<tr>
<td></td>
<td>Earth Work</td>
<td>152,500,000,000</td>
<td>5.39</td>
<td>829,557,500,000</td>
</tr>
<tr>
<td></td>
<td>Land Acquisition</td>
<td>225,000,000,000</td>
<td>4.00</td>
<td>135,000,000,000,000</td>
</tr>
<tr>
<td>2</td>
<td>Qualitative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demand</td>
<td>Good</td>
<td>4.00</td>
<td>Very Good</td>
</tr>
<tr>
<td></td>
<td>Accessibility</td>
<td>Fine</td>
<td>3.00</td>
<td>Very Good</td>
</tr>
<tr>
<td></td>
<td>Land Availability</td>
<td>Enough</td>
<td>2.00</td>
<td>Enough</td>
</tr>
<tr>
<td></td>
<td>Social Impact</td>
<td>Good</td>
<td>4.00</td>
<td>Very Good</td>
</tr>
<tr>
<td></td>
<td>Landscape</td>
<td>Fine</td>
<td>3.00</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Crossing Productive Area</td>
<td>Good</td>
<td>4.00</td>
<td>Very Good</td>
</tr>
<tr>
<td></td>
<td>Crossing Dense Population Area</td>
<td>Good</td>
<td>4.00</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

Quantitative Analysis: 16.69  27.920462  40

Qualitative Analysis: 24.00  31  23
5.6 Decision Making

In the quantitative assessment, the third route is superior to others because it has the shortest route with the lowest cost. However, one factor should be considered that good services are service which has the best ability to accommodate users’ needs and also well accepted by them. One way to measure whether the service is desirable or not, could be seen from the qualitative assessment. Meanwhile, from the MCA’s performance matrix, it could be known that the best route qualitative assessment is the second route. The second route also has the second lowest cost after the third route, therefore, it can be considered as an eligible route to be selected.

6 CONCLUSIONS

From analysis we could conclude as follow:

a. The shortest route was the third route
b. The lowest cost for construction also obtained from route number 3
c. The second route has the highest value on qualitative assessment
d. The chosen route after cost analysis, demand analysis, and other factor was the second route.

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