Traction Cost Comparisons

for

Coal Haulage Railway

in Indonesia

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- Lifelong interest in railways;
- Webmaster for the 5AT Project;
- Currently living in China.

Introduction

- Paper presents cost comparisons between traction options for a <u>**planned**</u> coal-haulage railway forming part of a $500 million coal export project in Indonesia.
- Similar to earlier studies, but with one important difference – a project planner that <u>**wants**</u> to use steam traction.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Introduction (continued)

Paper presents cost comparisons between:

- diesel traction,
- electric traction,
- “modern” steam, and
- “old” steam (viz: Chinese QJ locos)

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Introduction (continued)

- Costs comparisons largely based on **Chinese** data;
- Costs are broken down into:
  - Capital/depreciation Costs;
  - Maintenance Costs;
  - Labour Costs;
  - Water Costs;
  - Fuel/Power Costs.
- Excludes infrastructure costs – e.g. fuelling, servicing and maintenance facilities.

Introduction (concluded)

Summary of Findings

- For this particular project (with cheap coal and low-cost labour), steam costs appear to be about 50% of diesel and 70% of electric.
- Modern steam appears to offer the lowest overall costs (per tonne hauled).
- Substantial increases in fuel and labour costs would be needed to change that conclusion.

Railway Outline

- A **planned** railway (no certainty that it will be built);
- Railway budget $160 million;
- Approx 90 km length over near-level terrain;
- Haulage: 20 million tonnes of coal per annum (mtpa) :
- No connections to existing tracks hence no gauge constraints;
- Project planners favour the use of steam to utilize cheap coal from mine.

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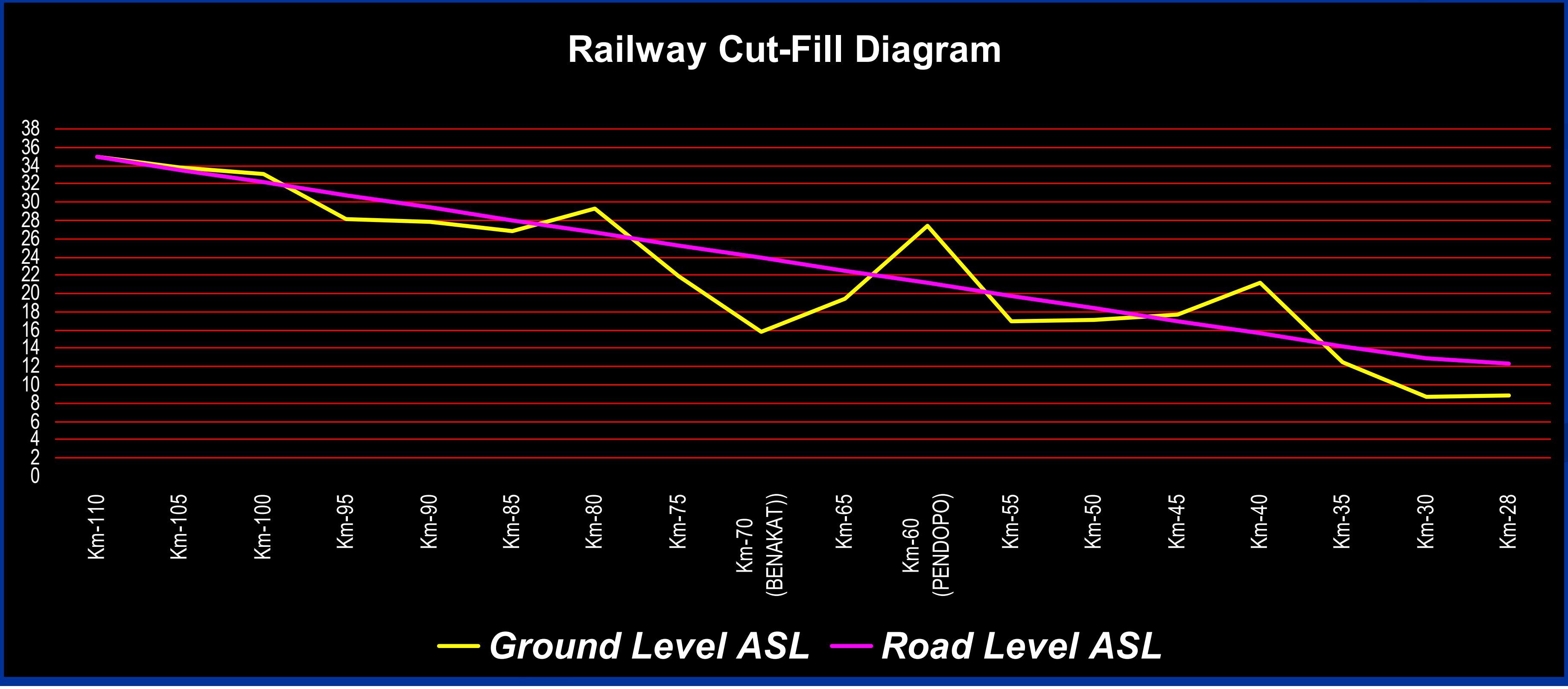
for
Indonesian Coal Haulage Railway

Railway Cross-Section

- 23 metre fall in 90 km = avg grade -0.025%
- No major earthwork
- Cut/fill volume: ~10^6 m^3.



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for
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An Obvious Choice for Steam Traction (was)

2200 kW QJ Type from China

In 2003 fully reconditioned QJs cost $150,000 ex-works

In 2005 they cost around $250,000 ex-works

In late 2006 they are becoming hard to source.

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for
Indonesian Coal Haulage Railway

QJ Locomotive

Performance Data – 1

Vital Statistics for Chinese QJ Steam Locomotives			
1	Weight of Loco in working order (t)		133.8
2	Wheel Arrangement		2-10-2
3	Axle Loads	Leading Axle (t)	13.40
		Driving Axle (t)	20.10
		Trailing Axle (t)	19.90
4	Tender	Weight in working order (t)	119.70
		Weight empty (t)	48.2
		Coal Capacity (t)	21.5
		Water Capacity (t)	50
5	Gross Weight of Loco and Tender in working order (t)		254.73
6	Total Length of Loco and Tender (m)		29.181
10	Working Pressure of Boiler (kPa)		1500
7	Design Speed (kph)		85
8	Nominal Wheel-rim Power at 70 kph (kW)		2191.8
9	Starting Tractive Effort (kN)		326.2

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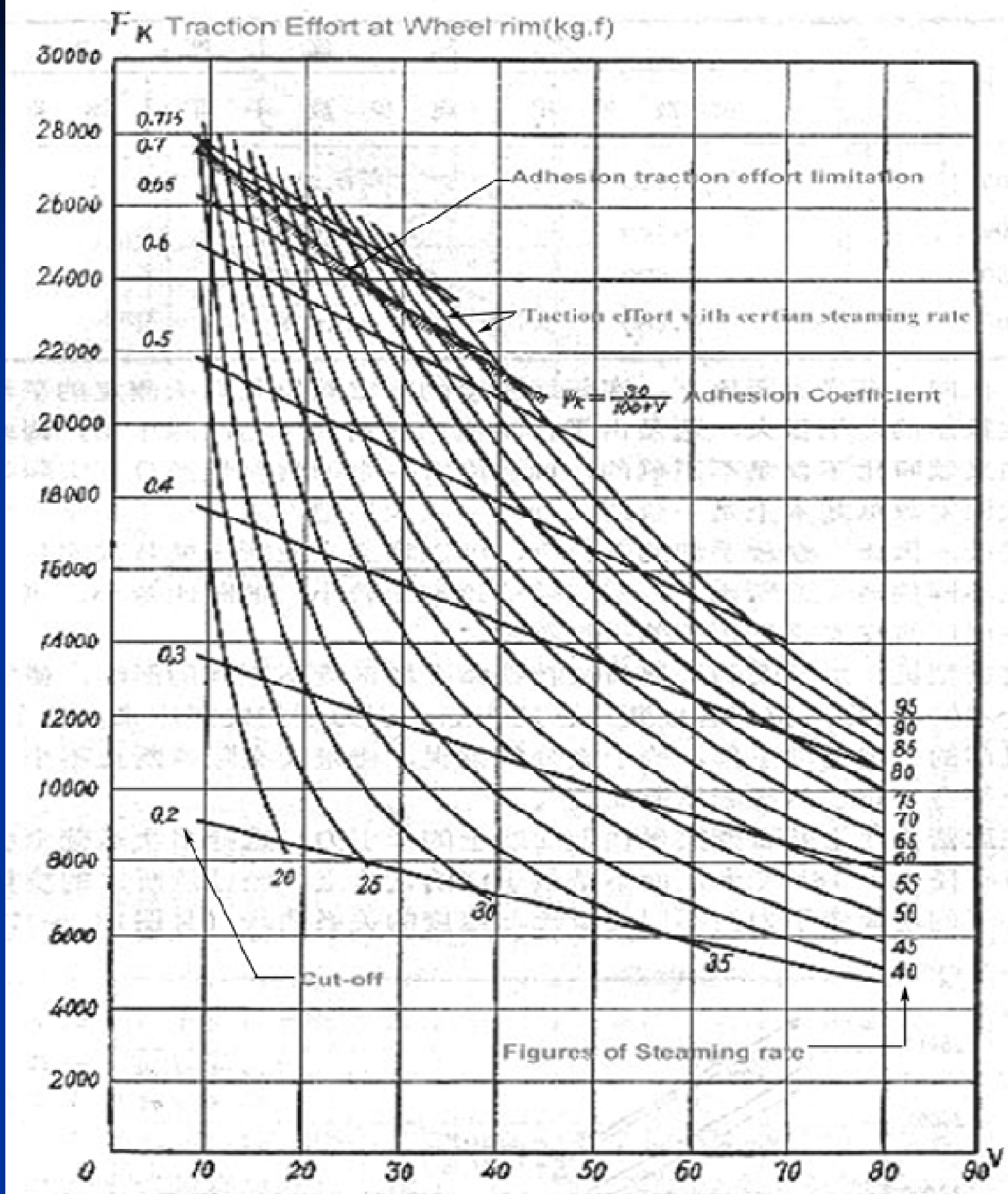
for
Indonesian Coal Haulage Railway

QJ Locomotive

Performance Data – 2

Relationship between speed, wheel-rim tractive force, cut-off and steam consumption



The curves of traction effort at wheel rim to different steaming rate, cutoff and speed (V)

图17 轮周牵引力F_K按不同遮断比、不同供汽率与速度的关系曲线

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for
Indonesian Coal Haulage Railway

QJ Performance Data – 3
Starting and Rolling Resistance Formulae

(ex China National Railways)

- QJ Starting Resistance = 8N/kN
- Wagon Starting Resistance = 3.5N/kN
- QJ Rolling Resistance =
  $W \times [(0.70 + 0.0243\ V + 0.000673\ V^2) + 1/Grad + 600/Rad]$
- Wagon Rolling Resistance =
  $W \times [(0.92 + 0.0048\ V + 0.000125\ V^2) + 1/Grad + 600/Rad \times L/C)]$

Where: R = rolling resistance in Newtons; W = weight in kN
V = speed in kph; Grad = Gradient in %; T= Train Length
Rad = Track curvature radius in metres; C= Curve Length

Note – these equations give lower values than similar formulae from other countries

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for
Indonesian Coal Haulage Railway

QJ Performance 4 – Spreadsheet Calculations

Microsoft Excel - Indonesia Power Estimate Rev 3d.xls

Track Data						
Gradient %	Grade 1 in ...	Grade Angle	Curve Radius	Curvature	Curve Length m	Length Factor
0.00	Flat	0	1000	0.001	1000	1.000

Wagon Data							
Individual Wagons			Train				
Tare Wt	Gross Wt	Length	No	Tare Wt	Gross Wt	Net Wt	Length
23	93	14.7	43	989	3999	3010	633.734

Loco Mass Ton	Total Train Mass Ton
225	4224

Speed Kph	QJ Traction and Power Limits*		QJ + 6 axle tender + Wagons with								
			Roller Bearings			Plain Bearings			Empties		
	Power kW	Traction kN	Power kW	Traction kN	Check	Power kW	Traction kN	Check	Power kW	Traction kN	Check
0	0	295	0	180		0	238		0	73	
5		280		64							
10	750	270	183	66		197	71		90	33	
15		260		68							
20	1389	250	387	70		413	74		197	35	
25		240		72							
30	1875	225	623	75		668	80		333	40	
35		220		78							
40	2333	210	901	81		979	88		512	46	
45		200		85							
50	2500	180	1231	89		1363	98		746	54	
55		160		93							
60	2583	155	1623	97		1837	110		1049	63	
65		140		102							
70	2625	135	2088	107		2419	124		1434	74	
75		125		113							
80	2667	120	2636	119		3128	141	Overload	1913	86	

* Figures taken from performance graph supplied by Wang Li Jie - see below

Acceleration and distance estimates for Roller Bearing stock							
Accel'n m/s/s	kmh	Speed (m/s)	time (s)	cumul've time (s)	cumul've time (min)	dist (m)	dist km
0.0273	0	0.00	0	0	0.0	0	0.00
0.0510	5	1.39	27	27	0.5	18.9	0.02
0.0483	10	2.78	28	55	0.9	58.2	0.06
0.0455	15	4.17	30	85	1.4	102.8	0.10
0.0427	20	5.56	31	116	1.9	153.1	0.15
0.0398	25	6.94	34	150	2.5	210.6	0.21
0.0356	30	8.33	37	187	3.1	281.7	0.28
0.0337	35	9.72	40	227	3.8	362.2	0.36
0.0305	40	11.11	43	270	4.5	450.7	0.45
0.0273	45	12.50	48	318	5.3	567.1	0.57
0.0216	50	13.89	57	375	6.3	748.9	0.75
0.0159	55	15.28	74	449	7.5	1079.1	1.08
0.0136	60	16.67	94	543	9.1	1501.7	1.50
0.0089	65	18.06	123	666	11.1	2135.2	2.14
0.0065	70	19.44	179	845	14.1	3364.4	3.36
0.0029	75	20.83	295	1141	19.0	5943.3	5.94
0.0003	80	22.22	869	2009	33.5	18700.9	18.70

Const speed on bal of line =	60	kmh			
Total line length =	90	km	Braking dist (est) =	2	km
Av spd for braking dist (est) =	30	kmh	BrakingTime =	0.067	h
l line length at chosen speed=	86.50	km	Balance line time =	1.442	h
Total time for line =	1.659	h	Av speed	54.2	kmh

Number of Wagons	Full of Empty	Gross Train Wt Tonnes	Assumed Speed kph	Calculated TE kN	Calculated TE kg	Steaming Rate from Graph	Heating Surface m2	Kg/hr	Journey Time Hrs	Total Water Tonnes
83	Full	6806	50	148	15,087	75	255.3	19148	1.8	34
66	Full	5412	60	134	13,660	75	255.3	19148	1.5	29
55	Full	4510	60	113	11,552	65	255.3	16595	1.5	25
50	Full	4100	70	114	11,621	75	255.3	19148	1.3	25
50	Full	4100	60	104	10,601	62	255.3	15829	1.5	24
50	Full	4100	50	95	9,684	45	255.3	11489	1.8	21

Acceleration and Speed

General Calcs / QJ + 4 axle tender / QJ + 6 axle tender

QJ Performance Estimates (from spreadsheet):

Max running speed with 4000 tonne gross (3000 tonne net) on straight track:

Gradient		Speed
0	0	79 kph
0.1%	1 in 1000	60 kph
0.25%	1 in 400	45 kph
0.5%	1 in 200	Overloaded*

*Note – Dave Wardale cites an instance where a GPCS-fitted QJ hauled 4100 tonnes up a 0.7% gradient at a steady 25 kph

– see "Red Devil and Other Tales from the Age of Steam" p. 467 .

Estimating Loco Fleet Numbers

Assumptions:

- Train size of 3000 tonnes net (4000 gross) for steam;
- "Haulage Capacity Factor" used to estimate electric and diesel train sizes compared to QJs.
- Trains average 50 kph over the 90 km route;
- Trains are loaded at 6000 tph and unloaded (two at a time) at 3000 tph each;
- Railway operating 320 days per year at 75% efficiency;
- Spare locos to be added according to maintenance and servicing requirements, and to cover breakdowns;
- Double track railway assumed for this calculation.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Loco Fleet Numbers (continued)

Traction Type	Electric (New)	Diesel (New)	Modern Steam	QJ Steam
Haulage Capacity Factor (QJ=1)	1.75	1.50	1.00	1.00
Net Train Capacity (tonnes)	5.250	4,500	3,000	3,000
Return Journeys per day*	16	19	28	28
Average Train Speed both ways (kph)	50	50	50	50
Train Travel Time (mins)	108	108	108	108
Train Load Time at 6000 tph (mins)	53	45	30	30
Train Unload Time at 3000 tph (mins)	105	90	60	60
Minimum Train Cycle Time (mins)	373	351	306	306
Assumed Train Cycle Time (hours)	7.0	6.5	5.5	5.5
Locos required to haul trains	**5**	**6**	**7**	**7**
Number of Locos being serviced	0	0	1	1
Number of Locos under Maintenance	1	1	1	1
Standby Loco Requirements	1	1	1	2
Total Estimated Loco Requirement	**7**	**8**	**10**	**11**
Total Locos Assumed	**7**	**8**	**11**	**12**

** Daily train haulage capacity: 83,300 tpd, based on operating 320 days per year at 75% efficiency*

Estimating Fuel Consumption

<u>Steam:</u>

- Apply highest recorded Chinese consumption figure to QJ steam;
- Verify using loco thermal efficiency and coal calorific value;
- Assume “Modern Steam” consumption is 67% of QJ.

<u>Diesel</u>

- Apply low-average Chinese consumption figure.

<u>Electric</u>

- See later slide.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Fuel Consumption (continued)

Comparative figures - Steam vs. Diesel from China Rail.

Years	Available locos per day (Sets)		Train Gross Ton-kilometers (10^6 t-km)		Loco Failures per 10^6 t-km		Av. Fuel Consumption per 10^6 t-km (tonne)		Unit Price of Fuel ($US/tonne)*		Fuel Cost of Traction $US/$10^6$ t-km	
	Steam	**Diesel**	**Steam**	**Diesel**	**Steam**	**Diesel**	**Steam**	**Diesel**	**Steam**	**Diesel**	**Steam**	**Diesel**
1987	5,317	3,282	770,009	750,090	3.0	11.0	11.09	2.59	24	367	267	951
1995	3,061	6,224	268,998	1,435,365	3.4	16.8	13.74	2.43	24	367	331	893
1999	1,013	7,825	32,475	1,682,046	0	13.1	**20.66**	2.62	24	367	497	962
2003	-	8,585	-	1,384,996	-	7.0	-	**2.54**	24	367	-	993

Fuel Consumption Rates shown in Red are used in estimating loco operating costs – see next slide

The above figures were supplied by China National Railways in Mar 2004.
Note: The are taken from official statistics of the operation department of China's National Railway, as published by State authorities.
* Figures do not include contemporary fuel costs; 2003 costs are used for comparative purposes (converted at RMB 8.3 per USD).

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Fuel Consumption (continued)

Estimating QJ Coal Consumption based on Thermal Efficiency etc

Assumptions:

Thermal efficiency	7%
Coal calorific value	4000 kcal/kg (NAR)*
Conversion rate	860 kcal per kWh
Power required to haul 4000 gross tonnes at 50kph on level track	1250 kW (based on QJ performance curves)
Power required to haul 1000 tare tonnes at 50kph on level track	400 kW (based on QJ performance curves)

*Note: The coal available from the mine is expected to have a calorific value of no more than 4000 kcal/kg NAR

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Fuel Consumption (continued)

Estimating QJ Coal Consumption based on Thermal Efficiency (continued)

Loco energy consumption	= 860 ÷ 7%	12,285 kCal per kWh output
Coal consumption	= 12,285 ÷ 4000	3.1 kg of coal per kWh output
Av power output for loaded train	from spreadsheet	1250 kW
Av power output for empty train	from spreadsheet	400 kW
Journey time (90km at 50kph)	= 90 ÷ 50	1.8 hours
Energy Consumed Loaded Train	=1250 x 1.8	2250 kWh one way
Coal Required Loaded Train	= 3.1 x 2250	7.0 tonnes one way
Tonne-km travelled (loaded)	= 4000 x 90	0.36 million tonne-km
Coal Consumption (loaded)	= 7.0 ÷ 0.36	19.4 tonnes per million tonne-km
Energy Consumed Empty Train	= 400 x 1.8	720 kWh one way
Coal Required Empty Train	= 3.1 x 720	2.2 tonnes one way
Tonne-km travelled (empty)	= 1000 x 90	0.09 million tonne-km
Coal Consumption (empty)	= 2.2 ÷ 0.09	24.4 tonnes per million tonne-km
Average coal consumption	**= (7.0+2.2) ÷ (.36+.09)**	**20.4 tonnes per 10^6 tonne-km**

Note: if a calorific value of 6500 kcal/kg is used, then the coal consumption of the loaded train is 11.8 tonnes per 10^6 t-km, which approximates the best Chinese figure

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Fuel Consumption (continued)

Fuel Consumption Rates used for Indonesian Cost Estimates

Diesel	Modern Steam	QJ Steam
2.50 $t/10^6$ t-km	**14.0** $t/10^6$ t-km	**21** $t/10^6$ t-km

Notes – 1: 21 $t/10^6$ t-km is more than the highest of the Chinese coal consumption figures;
2: 14 $t/10^6$ t-km assumes that modern steam will be 50% more efficient than QJ traction.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Fuel/Electric Power Consumption and Cost Estimates

Additional figures from China

2001 Av Cost for Main Line Electrification	>3.4 m RMB per km	**>$425,000 per km**
2001 Power Consumption – Electric	**11,310 kW-h per 10^6 t-km**	
2005 Cost – Electric Power	0.65 RMB/kW-h	**8.1 cents per kW-h**
2006 Cost – Electric Power (Indonesia)	(received 7th Dec)	7~9 cents per kW-h

Notes: (1) Figures in Red are used in next slide;
(2) Figure in **yellow** is used in Capital Cost estimate.
(3) The cost of main-line electrification applies to a single track (including stations sidings etc)

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Fuel Consumption estimates for hauling 20 million tonnes of coal per year (one way) over 90 km railway based on China National Railway's data:

Traction Type	Electric (New Build)	Diesel (New Build)	Modern Steam (New Build)	Recondition ed QJ Steam
Total Loaded (Gross) Tonne-km ($x10^6$)	2,391	2,391	2,391	2,391
Total Empty Tonne-km ($x10^6$)	591	591	591	591
Total Tonne-km ($x10^6$)	2,982	2,982	2,982	2,982
Consumption t or kWh per 10^6t-km	11310	2.5	14	21
Total Consumption - tons or kWh/year	33.7m	7,457	41,760	62,640
Fuel/Power Cost per tonne or kWh	$0.08	$700*	$20	$20
Total Fuel Cost per Year	**$2.70m**	**$5.22m**	**$0.84m**	**$1.25m**

Notes: *Diesel fuel price as quoted in Indonesia in March 2006
Coal cost figure as quoted by project planners in March 2006 (actual cost may be lower)
Cost estimates in Yellow are carried forward to Summary.

Estimating Maintenance Costs

Process:

- Adopt Chinese cost data for Major and Intermediate Overhauls and for Routine Maintenance;
- Apply to estimated Indonesian loco fleet mileages.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Maintenance Costs (continued)

Traction Type	Electric (New Build)	Diesel (New Build)	Modern Steam (New Build)	Recon'd QJ Steam
Major Overhaul Cost	$250,000	$200,000	$100,000	$100,000
Major Overhaul Intervals	1.2 m km	700,000 km	400,000 km	250,000 km
Light Overhauls per Major Overhaul	3	3	2	2
Cost per Light Overhaul	$65000	$50,000	$50,000	$50,000
Routine Maintenance Period	40,000 km	30,000 km	40,000 km	30,000 km
Routine Maintenance Cost	$12,000	$10,000	$5,000	$5,000
Train Capacity (net tonnes)	5,250	4,500	3,000	3,000
Number of Train Kilometres per year	685,714	800,000	1,200,000	1,200,000
Av. Travel per year per loco (km)	97,959	100,000	109,091	100,000
Annual Major Maint Cost per loco	$20,408	$28,571	$27,273	$40,000
Annual Intermdt Maint Costs per loco	$10,612	$14,286	$13,636	$20,000
Annual Regular Maint Costs per loco	$29,388	$33,333	$13,636	$16,667
Annual Maintenance Costs	**$422,857**	**$609,524**	**$600,000**	**$920,000**

Notes -
1: The above cost estimates do not include maintenance of electrical infrastructure. These could add substantially to the costs of electric traction.

2: Figures in Yellow carried forward to Summary

Estimating Water Consumption

(Steam Only)

Process:

- Estimated from QJ steam consumption (from spreadsheet);
- Apply to total number of round trips;
- Assume 20% reduction for modern steam.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Water Consumption (continued)

Traction Type	Electric (New)	Diesel (New)	Modern Steam	QJ Steam Reconditiond
Water consumption – tonnes per round trip (from spreadsheet)	-	-	30[1]	36
Number of round trips per year	-	-	6,667	6,667
Total water consumed	-	-	200,000	240,000
Water Cost - assumed per tonne	-	-	$0.5[2]	$0.5[2]
Water Treatment Cost – per tonne	-	-	$1.9[3]	$1.9[3]
Total Water Costs (per year)	**-**	**-**	**$480,000**	**$576,000**

Notes – 1: “Modern steam” locos should use substantially less water than standard QJs.

2: The cost of water is likely to be less than 50 cents per tonne.

3: Water treatment cost figures supplied by Martyn Bane

4: Figures in Yellow carried forward to Summary.

Estimating Labour Costs

Process:

- Assume 2-man operation for steam;
- Assume 1-man operation for diesel and electric;
- Adopt "best guesses" for servicing crew numbers;
- Apply "best guess" for annual labour costs.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Estimating Labour Costs (continued)

Traction Type	Electric (New)	Diesel (New)	Modern Steam	QJ Steam Reconditiond
Shifts per day	3	3	3	3
Loco Crew per loco	1	1	2	2
Total Loco Crew	21	24	60	72
Servicing Crew per shift	6[1]	2	5	5
Total Servicing Crew	18	6	15	15
Wage Rate per year[2]	$5,000	$5,000	$5,000	$5,000
Wages per Year	**$195,000**	**$150,000**	**$405,000**	**$435,000**

Notes: 1. Electrical servicing crew includes a ‘guestimate’ as to the number of people that will be needed to keep the electrical system operating
2. Assumed salary rates are slightly higher than the figure supplied from Indonesia

Estimating Capital/Depreciation Costs

Process:

- Adopt Chinese capital cost data;
- Apply to estimated loco fleet numbers;
- Assumed life-expectancy for each loco type;
- Include infrastructure costs for electric traction;
- Include development costs for modern steam traction.

Estimating Capital/Depreciation Costs (continued)

Traction Type	Electric (New Build)	Diesel (New Build)	Modern Steam (New Build)	Reconditiond QJ Steam
Development/Infrastructure Costs	90km x **$425,000** = $38.25 m*		Assumed **$6.0m** development	
Purchase Cost	$1.0 m	$1.0 m	$2.0 m	$0.4 m
No Locos Needed	7	8	11	12
Total Investment	$45.25 m	$8.0 m	$28.0 m	$4.8 m
Life Expectancy (assumed)	25 years	25 years	25 years	10 years
Annualized Cap Cost	**$1.81 m**	**$0.32 m**	**$1.12 m**	**$0.48 m**

Note: *The given cost of electrification applies to single tracks (including stations, yards etc). Thus the cost should be doubled for a two-track railway. However because this particular railway is likely to be a single track railway, the single track cost is used.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Final Cost Comparison

between four locomotive types
to handle 20 million tonnes per year over 90 km railway:

Traction Type	Electric (New Build)	Diesel (New Build)	Modern Steam (New Build)	Recondition QJ Steam
Annualized Cap Cost	$1.81 m	$0.32 m	$1.12 m	$0.48 m
Maintenance Cost	$0.42 m	$0.61 m	$0.60 m	$0.92 m
Fuel/Power Cost	$2.70 m	$5.22 m	$0.84 m	$1.25 m
Water Cost	-	-	$0.48 m	$0.58 m
Labour Cost	$0.20 m	$0.15 m	$0.41 m	$0.44 m
Total Cost per Year	$5.12 m	$6.30 m	$3.44 m	$3.66 m
Cost per Tonne hauled	**$0.26**	**$0.31**	**$0.17**	**$0.18**
Cost per Million Tonne-km	**$2,848**	**$3,500**	**$1,911**	**$2.035**

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Alternative Scenario 1
Removing "Anti-Steam" Biases – viz:

- Using calculated fleet size requirements (removing steam's "loading");
- Increasing life expectancy of steam options
  30 years for modern steam and 15 years for QJs;
- Assume modern steam coal consumption = 50% of QJ;
- Reducing water costs to $1.80 per tonne;
- Reducing labour costs from $5000 per annum to $3500;

…… produces the following "bottom-line" figures

Traction Type	Electric (New Build)	Diesel (New Build)	Modern Steam (New Build)	Recondition QJ Steam
Cost per Tonne hauled	$0.25	$0.31	$0.14	$0.16
Cost per Million Tonne-km	$2,814	$3,474	$1,508	$1,676

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Alternative Scenario 2
Higher Coal and Labour Costs:

- increasing the cost of coal to $50 per tonne;
- increasing the cost of major overhauls (for steam) to $150,000 and intermediate overhauls to $75,000;
- increasing labour costs to $10,000 per annum;
- using the original water cost of water of $2.4 per tonne;
- using the original depreciation periods;

…. produces the following "bottom-line" figures:

Traction Type	Electric (New Build)	Diesel (New Build)	Modern Steam (New Build)	Recondition QJ Steam
Cost per Tonne hauled	$0.27	$0.32	$0.27	$0.33
Cost per Million Tonne-km	$2,955	$3,583	$2,995	$3,639

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Alternative Scenario – Higher Coal Throughput:

- Doubling the coal throughput to 40 million tonnes per year, and using cost and other figures from original calculation still does not reduce electric traction to that of steam:

Traction Type	Electric (New Build)	Diesel (New Build)	Modern Steam (New Build)	Recondition QJ Steam
Cost per Tonne hauled	$0.21	$0.31	$0.15	$0.17
Cost per Million Tonne-km	$2,368	$3,446	$1,701	$1,936

Note: 40 million tonnes per year throughput would almost certainly require twin track operation which would double the electrical infrastructure cost. This extra cost increases the electric cost to 25 cents per tonne.

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

Environmental Considerations

- Coal burning Steam locos will generate more
  CO_2 than diesels.
- Notwithstanding, total carbon emissions produced from burning locally available coal may well be less than those from drilling, extracting, transporting, processing and burning of oil for diesel locomotives.
- Indonesia is not a party to Kyoto: environmental costs are not yet “real” costs.

Cautionary Note

- Capital cost of traction represents a relatively small component of total railway costs – $0.15 per tonne operating cost differential of is very small compared to total cost of moving coal from mine to port (over $5 per tonne).
- Diminishing availability of QJ locomotives plus the lead-time needed to develop a “modern steam” alternative may force the adoption of diesel or electric traction.

Commercial Opportunities

- If a suitable and proven “modern steam” design were available, then it should be the preferred choice for this and similar railways.
- There must be many similar coal haulage operations in the developing world where modern steam could be competitive.
- If a market can be quantified, it may be possible to develop a business plan to justify the investment in developing new steam designs for coal haulage.

Window of Opportunity

- How should we respond if a firm request comes in for a modern steam alternative to QJ or diesel traction?
- If the call comes, will we be ready for it and can we deliver in time?
- The opportunity may not come again.

Finally –

What might a "modern steam" coal haulage loco look like?

Traction Cost Comparisons
for
Indonesian Coal Haulage Railway

An 8AT, perhaps?

Courtesy of Robin Barnes!

But that's another story!

South Sumatra
Coal Transportation Project

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The Railway System

Copy of paper and slide show will be made available at www.5AT.co.uk

End

11 Dec 2006