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Mr John Hall
Chief Executive Officer
Queensland Competition Authority
GPO Box 2257
BRISBANE QLD 4001

Date: 24 September 2012

Dear Mr Hall

QR Network Electric Traction Services Draft Amending Access Undertaking (DAAU)

In July 2012, the Queensland Competition Authority (QCA) submitted a draft determination rejecting QR Network's DAAU for sustainable electric traction. In response, we would like to submit this report for your consideration.

Arup (Pty) Ltd has been approached by QR Network to undertake detailed analysis to demonstrate, through the use of independent studies, that electric traction offers the lowest possible cost supply chain solution for heavy haul rail transport networks.

This report provides a thorough assessment of the two traction types – electric and diesel-electric, paying particular attention to pertinent technical studies comparing the relative technical and/or operational efficiencies.

Arup has conducted this study utilising South Africa as a case study, being main producers of heavy-haul electrified lines.

We have attached an electronic version of the report for your review and have sent it to the rail@qca.or.au email address. Two hard copy versions will be forwarded to your offices by courier.

Please do not hesitate to contact the undersigned should you require any further information.

Yours sincerely.

[redacted]

Friedel Mulke
Railway Specialist

Queensland Rail National Network

Report on the Relative Comparison of the Technical and Operational Efficiencies between Electric and Diesel-Electric Traction

QR/REP/01/09-2012

Job number 60074817

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		Signature			

		Signature			

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Abbreviations

ABB	Asea Brown Boveri & Cie
AC	Alternating Current
BAW	Barloworld
BEC	Beaufort Wes
CO_2 kg/kWh	Kilogram per Kilowatt- hour (Carbon)
CPT	Cape Town
CQCN	Central Queensland Coal Network
CSR	China South Railway
DC	Direct Current
ELN	East London
EMD	Electro-Motive Diesel
EMDA	Electro-Motive Diesel Africa
GE	General Electric
GFB	General Freight Business
GGK	Grootegeluk
GM SA	General Motors South Africa
GTKM	Gross Ton Kilometer
Hz	Hertz
kg/l	Kilogram per litre (diesel fuel)
kg/ton	Kilogram per ton (coal)
Km	Kilometer
KMP	Kaapmuiden
Kph	Kilometer per hour
Kva	Kilo Volt Ampere
lb/ton	Pounds per Ton
LCC	Life Cycle Cost
LPG	Liquid Petroleum Gas
MJ/kg	Mega Joules per kilogram
mtpa	million tons per annum
NG D	New Generation Diesel-Electric
NG E	New Generation Electric
NOx	Nitrogen Oxides
CO_2	Carbon di-oxide
OEM	Original Equipment Manufacturer
OG D	Old Generation Diesel-Electric
OG E	Old Generation Electric
OHTE	Overhead Track Equipment
OOS	Out of Service
PHR	Port Shepstone
PHW	Phalaborwa
PLK	Polokwane

PRASA	Passenger Rail Agency of South Africa
PRSC	Progress Rail Services Corp
PRZ	Pyramid South
QCA	Queensland Competition Authority
QRN	Queensland Rail Network
QRNN	Queensland Rail National Network
RBQ	Richards Bay
RRL	Railroad Logistics (Grindrod)
RSD	Rolling Stock Dorbyl
SPR	Springfontein
TAT	Turnaround Time
TRE	Transnet Rail Engineering
TZB	Thabazimbi
UCW	Union Carriage & Wagon
US$/ton	US dollar per ton
WICTRA.	WICTRA as manufacturer

1 Introduction

1.1 Background

QRN Network is the owner of the Central Queensland Coal Network (CQCN), comprising the Goonyella, Blackwater, Newlands and Moura systems. It is currently responsible, under the terms of an undertaking given to the Queensland Competition Authority (QCA), for providing, maintaining and managing regulated access to those networks.

The Goonyella and Blackwater railroad systems form part of the QRN Network and are equipped with overhead electrical power supply systems as well as the associated infrastructure necessary for the operation of electric locomotives. Regulated access to the electrical infrastructure is currently provided by QRN Network. The systems were electrified in the 1980s, and the electrical capacity has been expanded since that time by QRN Network. Most recently, QRN Network upgraded four feeder stations in the Blackwater system with support from the user base and following the regulator's approval of the expenditure as prudent.

Goonyella operates on the basis of 100% utilisation by electric locomotives, whereas Blackwater operates as a hybrid system, where both electric and diesel locomotives operate.

1.2 Access pricing for Electric Locomotives

Under the current regulatory framework, access seekers on the QRN Network are given a choice as to whether to operate diesel or electric locomotives (or both).

The QCA supports the access seeker choice in the sense of requiring QRN Network to maintain two Regulatory Asset Bases: one comprising the electrical infrastructure, and the other comprising the track infrastructure.

The QCA also determines QRN Network's Maximum Allowable Revenue for both track access and electrical access charges.

This tariff structure enables an operator that does not wish to run electric trains, to avoid contributing to the cost of QRN Network's electric infrastructure. This has an adverse impact on the cost competitiveness of electric locomotives relative to diesel locomotives in circumstances where a falling electric utilisation rate contributes to higher average prices for access to the electrical infrastructure. By permitting this sort of bypass to occur, the tariff structure increases the risk to QRN Network that it will fail to recover the efficiently incurred costs of providing access to the electric infrastructure.

1.3 QRN Network's Regulatory Proposal

In December 2011, QRN Network lodged a regulatory proposal with the QCA that was directed at mitigating the asset stranding risk that had arisen in the Blackwater system.

On 31 July 2012, the QCA rejected QRN Network's submission for a number of reasons, including the assertion that it may provide additional incentive for users of the Central Queensland Coal Network (CQCN) to select electric traction as their preferred traction choice. Further, in so doing, the QCA report claims that competition in the supply of electric traction is weaker than that of diesel and this will lead to weaker competitive outcomes, stagnant technological development and will weaken productivity gains over time.

1.4 Making the Case

QRN Network is concerned that the QCA's conclusions do not adequately recognise the potential value and viability of electric traction in Queensland.

QRN Network is therefore proposing to assertively make the case for the competitive supply of electric locomotives and the operational efficiency of electric traction.

QRN Network has approached Arup (South Africa) to assist them with making the case to QCA, demonstrating the viability of electric locomotives in comparison to diesel locomotives.

2 Our Understanding of the Brief

2.1 Information Required

QRN Network is seeking assistance in responding to claims from the Queensland Competition Authority (QCA) and are interested in demonstrating, through independent studies, that electric traction offers the lowest possible cost supply chain solution for heavy haul rail transport networks.

QRN Network is also seeking support to make the case to the regulator that the predominant use of electric locomotives on an electrified system is more efficient than hybrid operations on an electrified network.

QRN Network requires information that may assist in supporting the case for electric traction, namely:

Definition of the market structure in the supply of electric traction locomotives and how it compares to the market structure in the supply of diesel traction locomotives.

The following aspects are particularly relevant:

- Who are the main producers of heavy-haul locomotives (both diesel and electric) in South Africa;
- The extent of international trade in those locomotives:
    - ✓ Are they readily or typically produced in one country and sold in another?;
    - ✓ How high are the transport costs?; and
    - ✓ Are there regulatory impediments to importing locomotives to Australia and if so is this a significant barrier to trade? (do domestic producers ultimately have to compete with producers overseas?)
- Is there a second-hand market for electric and/or diesel locomotives – how large is it – do Australian purchasers make use of it – how relevant would it be to potential purchasers of locomotives for the Queensland coal system?

- o Provide technical studies comparing the relative technical and/or operational efficiency of electric traction and the technological development opportunities available to electric traction; and
- o Demonstrate the potential impacts on supply chain efficiency from allowing the use of multiple traction types on a single shared network (i.e. allowing the energy distribution infrastructure to be duplicated across diesel refuelling and overhead power systems).

2.2 Objectives

The following Objectives for this Project Report have been formulated: (refer to Section A1.4.3 to Section A1.4.6 in Appendix A)

2.2.1 Objective 1

Determine at which traffic demand level (million tons per annum [mtpa]) would the systemic cost (US $ /ton) favour electric traction to diesel-electric traction, that is, at what activity level does it become less competitive.

2.2.2 Objective 2

Illustrate the systemic cost performance differential between new and old generation traction models for both electric and diesel-electric.

2.2.3 Objective 3

Illustrate the impact of the availability, or not, of the primary electrical energy supply.

2.2.4 Objective 4

Illustrate the systemic cost impact of running diesel-electric traction where electric traction equipment (OHTE – overhead traction equipment) already exists.

3 The Deliverables

In addition to delivering the outcomes to the abovementioned objectives Arup undertook to provide QRN Network with the following deliverables concerning the requests set out above.

Technical and Operational Efficiency comparatives:

a. Technical studies comparing the relative technical and/or operational efficiency of electric traction;

b. The technological development opportunities available to electric traction;

c. The potential impacts on supply chain efficiency from allowing the use of multiple traction types on a single shared network (i.e. allowing diesel-electric and electric locomotives on a network system designed for electrical traction);

d. The potential impacts of peak oil production and dislocation of the oil supply chain on supply chain efficiency.

The South African Locomotive Industry:

e. The main producers of heavy haul locomotives for the South African Market (South Africa and neighbouring States).

f. The supply of electric traction locomotives and how it compares to the market structure in the supply of diesel traction locomotives to the South African railway networks.

g. The extent of trade of these locomotives as well as locomotives imported from OEM (original equipment manufacturer) suppliers on other continents.

h. The general comparative performance results of a study of Cap-gauge (1 067 mm) locomotives of old and new generation models; including and excluding the impact on the primary electrical network.

i. A statement concerning direct environmental impact by electrical and diesel.

j. The compilation of a report.

4 The Methodology

The Technical and Operational Efficiency comparatives will be undertaken as follows:

- The relative technical and operational efficiency of electric traction to that of diesel traction will be compiled.

- The technological development opportunities available for electric traction in comparison to that of diesel traction will be demonstrated.

- The potential impacts on supply chain efficiency (operations) from allowing the use of multiple traction types on a single shared network will be highlighted and discussed.

- An overview addressing the Southern African Locomotive Industry will be compiled and will include:

  - Identifying the main producers of heavy haul locomotives for the South African Market (South Africa and neighbouring States).

  - The supply of electric traction locomotives and how it compares to the market structure in the supply of diesel traction locomotives to the South African railway networks will be highlighted.

  - The extent of trade of these locomotives as well as locomotives imported from OEM supplies on other continents.

  - The general comparative performance results of a study of Cap-gauge (1 067 mm) locomotives of old and new generation models; including and excluding the impact on the primary electrical network, will be demonstrated.

- We will briefly collate the Transnet locomotive program, plus the PRASA order and what local OEM's in South Africa are pushing into Africa and on local mines.

- We will demonstrate by means of six (6) general alignments, for various traffic volumes, various distances (to match QRNN networks), various speeds, old and new South African locomotive characteristics, South Africa energy costs run (simulation) to determine the U$D/ton comparison between diesel/electric with and without primary supply.

- We will do a locomotive Life Cycle Costing (LCC) per ton comparative analysis based on South African costs.

- We will obtain information on future locomotive developments e.g. alternative fuels, biogas, nuclear, hybrids, fuel cells, etc.

- We will compare the emission status of one (1) litre of fuel versus the equivalent mass of coal from a mine/well to locomotive consumption.

- A statement concerning the direct Environmental Impact by electric and diesel traction will be made.

  This statement will only address the information at hand and will exclude the input of extensive on-site investigations and surveys (Desk top approach).

5 Results

5.1 Deliverable a

Technical studies comparing the relative technical and/or operational efficiency of electric traction.

What is applicable and relevant in South Africa may not be so in Australia hence this deliverable is addressed generically with qualifications related to the Rail Network specific conditions.

Aspect	Electric Traction	Diesel-electric Traction	Qualification
Altitude	Not applicable.	Results in loss of power due to	At what altitude are the specific operations and

Aspect	Electric Traction	Diesel-electric Traction	Qualification
		density of air.	what are the prevailing climatic conditions?
Tunnels	Additional space must be allowed for OHTE equipment increasing infrastructural LCC.	Long tunnels result in oxygen starvation with associated loss of power and potential stalling	Are there any tunnels on QRNN? Of what length and what is the train consist configuration operated through the tunnels?
Maximum locomotive speed.	Balancing speed is higher and improves the TAT	Locomotive system design fixes balancing speed which is normally lower than electric traction, increasing the TAT (and systemic LCC)	Is the rail alignment optimised for the intended traction type?
Flexibility of operations	Confined to the availability of OHTE	Not applicable. Flexible. Independent of OHTE layout	Has the environment an element of anti-social behaviour that affects OHTE such as cable theft?
Energy efficiency	Perceived to be more efficient but ambiguous in what is included.	Known, published and given	From whence is the calculation started?
Carbon foot print	Basic calculations as per deliverable I shows an advantage	Basic calculations as per deliverable I shows a dis-advantage	Has the efficiency of energy conversion been included? This could reverse the outcome dependent upon the specific situation under consideration.
Load Haul capacity	A 6000 hp ABB locomotive dispatches at 37% adhesion.	A 4000 hp EMD locomotive dispatches at 43% adhesion.	Load haul is a function of the optimisation accuracy between alignment and locomotive characteristics. Hence is the systemic design

Aspect	Electric Traction	Diesel-electric Traction	Qualification
			optimised to which traction type if any?
Energy saving during braking – regenerative braking	Is very receptive to this technology as the current collection is part of the locomotive design.	Traditionally has been dynamic in nature, that is, will be dissipated through a resistance bank cooled by blowers – no subsequent use.	Does the traction substation which receives the energy transfer it to the grid or is it dissipated within the substation? Is the train schedule so optimised that crossing trains can share power?
Maintenance costs	Maintenance intervention periods are longer	New generation locomotives have significantly changed service intervals. Long range fuel tanks also reduce down time.	This is a function of the environment and statutory requirements. Oil degradation in a transformer is as important as that within a diesel engine. Generally using a maintenance plan based upon 2 million km and detailed in tables 2 and 3 below it is observed that the availability of electric locomotives would be 93% versus the 89% for diesel-electric over a 30 year period. (See Table 2 and Table 3 in this regard)
Mission reliability – the ability to reach the end point with the complete load even though it may be delayed.	A function of the availability of the OHTE and reliability of input power – voltage drops result in reduced tractive effort performance.	The additional tractive effort, although at lower speed, allows cutting out defective traction motors but retain capacity to reach the end point.	To what requirement of Mission Reliability was the systemic design optimised to?

Table 1 Qualifications related to Rail Network Conditions

Table 1 above is not definitive in that one rail network environment is not necessarily comparable to another rail network environment. The specific rail network environment must be considered and the boundaries of influencing variables be evaluated for that specific rail network environment for a deterministic study.

Maintenance Intervention	A	B	C	D	E	F	G
Every x weeks	1	16	32	64	336	672	1344
Over 30 years repeat intervention	1680	53	26	21	3	1	1
Duration [h]	2	6	8	12	24	32	40
Total OOS time [h] / intervention	3360	318	208	252	72	32	40
Total OOS time [h]	4282						
Availability	89%						

Table 2 Diesel-electric Locomotive Maintenance Plan

Maintenance Intervention	A	B	C	D	E	F	G	H
Every x years	0.089	0.5	1	2	4	7	8	16
Every y weeks	5	28	56	112	224	392	448	896
Over 30 years repeat intervention	336	60	30	15	7	4	3	1
Duration [h]	2	5	10	18	36	16	180	250
Total OOS time [h] / intervention	672	300	300	270	252	64	540	250
Total OOS time [h]	2648							
Availability	93%							

Table 3 Electric Locomotive Maintenance Plan.

A fundamental understanding prerequisite for comparison of energy efficiency applicable to different traction types is the selection of the analysis point of origin.

Consider the representation in Figure 1 below as a comparative model.

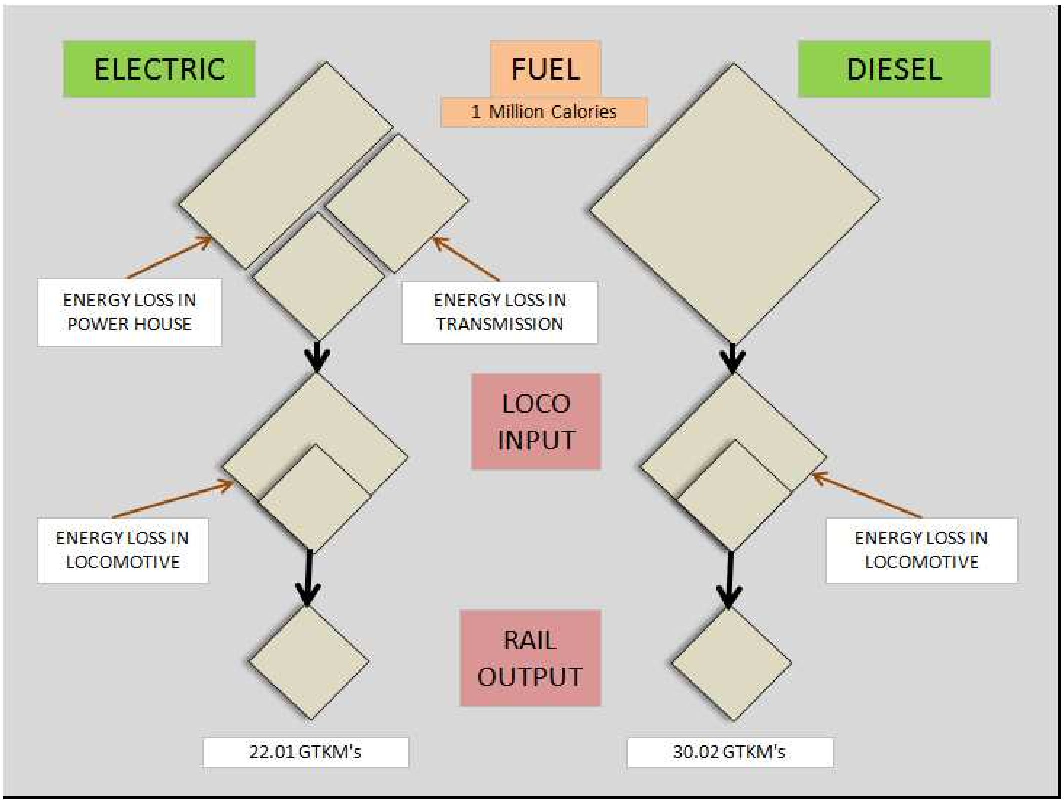


Figure 1 Diagram showing the Energy Efficiency of Electric vs Diesel Traction

The relative proportion of each component shown above is a function of the rail network environment under consideration. The local values relevant for the rail network environment must be taken into consideration including the cost differential between electricity and fuel.

5.2 Deliverable b

The technological development opportunities available to electric traction.

The question of technology development is not restrained to a specific traction type. A qualitative synopsis as demonstrated below in Table 4 could put matters into perspective:-

Technology	Electric Traction	Diesel-electric Traction	Comment
Regenerative power	Utilising traction motor "braking" to feed back into the National power grid	The reciprocal which GE is investigating is a hybrid solution of storing same braking effort into some sort of energy storage	The power network must be susceptible to accommodating the regenerative energy. Volumetric space on a diesel-electric locomotive

Technology	Electric Traction	Diesel-electric Traction	Comment
		device.	could limit the advantage of stored energy.
Alternative fuels / hybrid applications	The primary source, power station, could diversify into any alternative energy source such as fuel cells, solar, wind and/or hydro.	EMD has announced its development of a LPG gas engine. GE have a hybrid engine/battery locomotive operational. Both GE and EMD have indicated that bio gas is under consideration.	The advantage of this development is a function of the downstream efficiency of operations to provide the energy where it is used.
A National perspective	What is the state of power generation in the local circumstance	What is the real cost driver to pursue diesel? Is it company returns or National logistic competitiveness in commodity markets?	Are the statutory requirements a function of industry acceptance or what is good for the macro economics of Australia?
Systemic design	An electric locomotive is totally dependent upon the integrity/ reliability of its source of energy.	The performance of a diesel-electric is a function of the level of optimisation to the operating environment.	Is the local network and its operations optimised to the benefit of the logistic chain cost?

Table 4 Technological Development Opportunities

5.3 Deliverable c

The potential impacts on supply chain efficiency from allowing the use of multiple traction types on a single shared network (i.e. allowing the energy distribution infrastructure to be duplicated across diesel refuelling and overhead power systems).

The discussion that follows is based upon the study recorded in appendix A. The fundamental question that must be answered is:-

"in a network design where the decision was made to electrify and this legacy is now passed onto an environment whereby there is choice of traction power - who is responsible to recoup the infrastructure investment that has already been incurred"?

In the case of an organisation being put in managerial control thereof then legislation should follow suit. There is no need to deprive organisations of their freedom of choice but they must acknowledge their commitment to the legacy and this could only be done in a tariff structure that accepts this commitment and acts accordingly. At the end of the day to who's benefit is it, the economy of Australia, or the bottom line returns of singular companies which could, because of their approach, perpetuate a declining international competitive edge?

The resolution of this aspect is beyond organisations not directly involved.

What could be considered within the analysis of a generic environment as described in the study of appendix A, is the following:-

- Perpetuation of a non-contributory tariff structure (e.g. diesel traction on an electrified rail network) implies that for new generation locomotives a diesel-electric option would benefit the "company" where its traffic demand level ranges between 10 to 15 mpta;

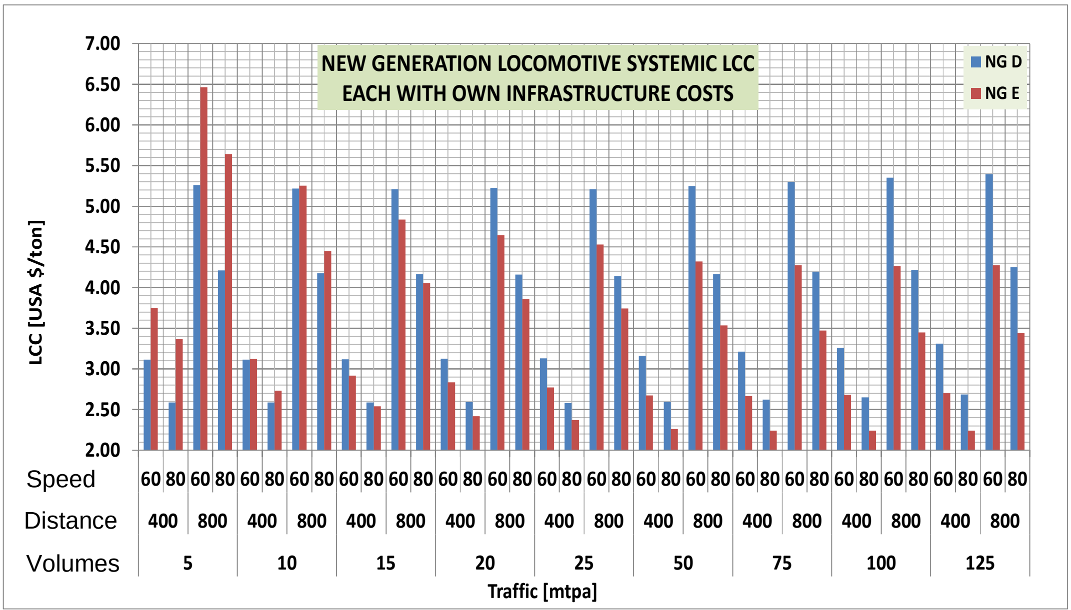


Figure 2 New Generation Locomotive Systemic LCC each with own Infrastructure Costs

- Where-as in a differential cost structure, whereby network users contribute towards the legacy of OHTE investment, they would be responsible to contribute as from inception. However as long as there is a company perspective and not a National perspective this argument will perpetuate.

- In Figure 3 below, the LCC of diesel-electric traction exceeds that of electric traction as from "inception" to the 10 mtpa activity level.

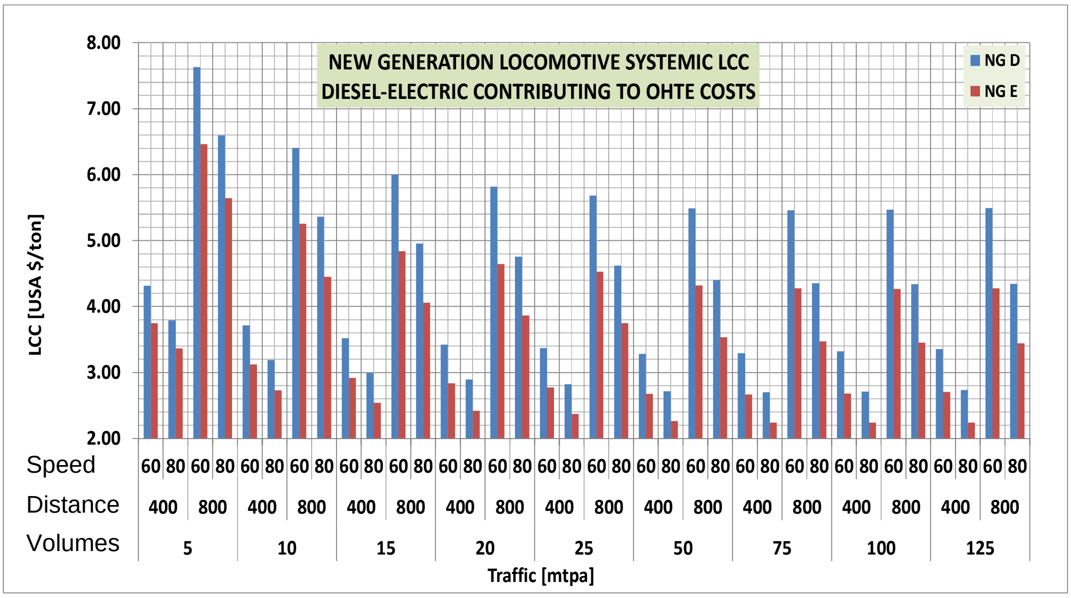


Figure 3 New Generation Locomotive Systemic LCC Diesel-electric contributing to own OHTE Costs

In the case where a railway line has a fixed capacity and is electrified, should diesel-electric traction proliferate and continuously absorb more of the capacity of the line, the LCC for electric traction would increase to the detriment of the logistic chain cost. This aspect is illustrated in Figure 4 below

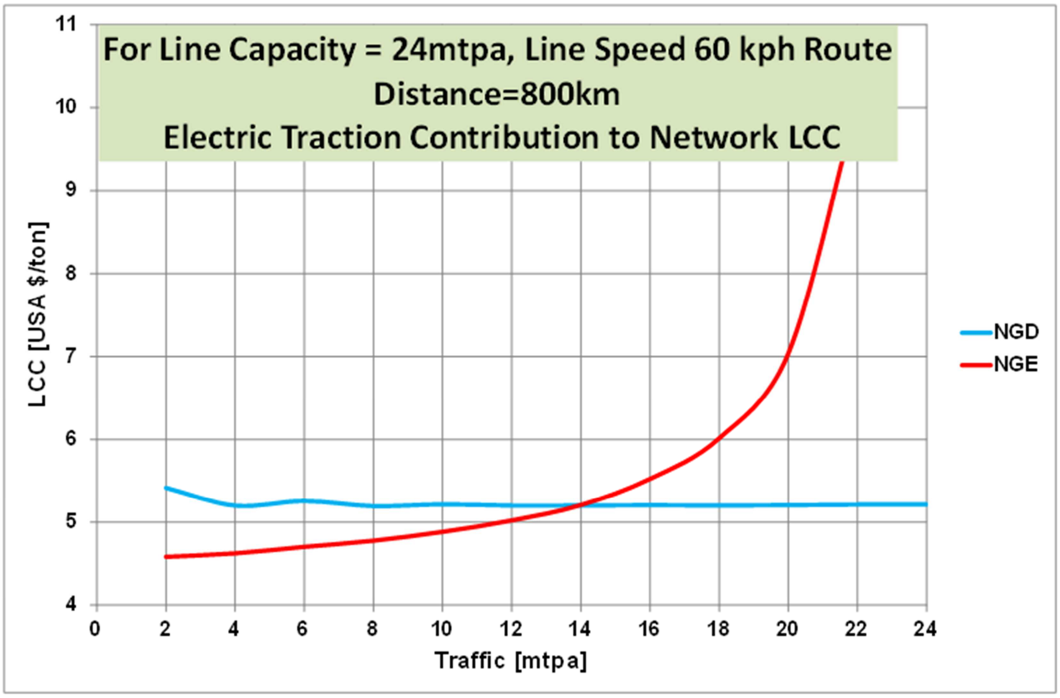


Figure 4 Electric Traction Contribution to Network LCC

With reference to Figure 4; as the diesel-electric traction claims more capacity on the line, the contribution the electric traction makes towards the network LCC increases. For an activity level as from 14 mtpa onwards, electric traction pays an increasing premium towards covering the fixed cost of the network.

5.4 Deliverable d

The potential impacts of peak oil production and dislocation of the oil supply chain on supply chain efficiency.

This aspect is a localised imperative. South Africa is dependent upon a net oil import supply chain. A number of alternative technologies have been implemented such as oil from coal and tapping into gas reserves.

Development of wind energy farms and other forms of energy harnessing were undertaken during the last decade with the intent of reducing increased demand upon oil imports.

Globally oil reserves are being re-estimated annually; the validity thereof not being the subject matter of this report. The dependency of a railway system upon local conditions, political standing and supply of oil, needs be determined within the local operational environment of the diesel-electric locomotives in order to determine the rail network specific outcomes.

5.5 Deliverable e

The main producers of heavy haul locomotives for the South African Market (South Africa and neighbouring States) will be identified.

5.5.1 Electric Locomotives

The South African electrical locomotive fleet has over the years had the suppliers and manufacturers shown in Table 5 below:-

Supplier	Manufacturer
50 C/S Group	Dorbyl
Alstom	General Motors South Africa
BBC-Siemens	Metropolitan-Vickers Werkspoor Robert Stephenson & Hawthorns
CSR	North British
English Electric	Siemens
General Electric Company (GEC)	Swiss Locomotive & Machine Works
General Motors	Transnet Rail Engineering
Henschel	Union Carriage & Wagon (UCW)
Hitachi	Vulcan
Metropolitan-Vickers	WICTRA
Mitsui / Toshiba	
Siemens	
Swiss Locomotive & Machine Works	
Toshiba	

Table 5 List of Locomotive Suppliers and Manufacturers of Electric Locomotives

All the above mentioned suppliers are international. Local manufacturers include Dorbyl, General Motors SA (no longer exists) Transnet Rail Engineering, UCW and WICTRA.

Recent locomotive orders have been awarded to:-

- Mitsui / Toshiba (186 locomotives) as suppliers and Union Carriage & Wagon (UCW) as manufacturer;

- CSR (China South Railway) (95 locomotives) as supplier and WICTRA as manufacturer. WICTRA is a new entrant as manufacturer in South Africa.

The impact of WICTRA having been awarded the latest contract, could have severe implications for UCW.

5.5.2 Diesel-electric Locomotives

The diesel-electric fleet provisioning is as shown in Table 6 below:-

Supplier	Manufacturer
General Electric	GE
General Motors-EMD	EMD
	RSD
	GM SA
	Transnet Rail Engineering
	RRL Grindrod Ltd

Table 6 List of Locomotive Suppliers and Manufacturers of Diesel-Electric Locomotives

Currently there is a tender out to the industry for the supply of 495 diesel-electric locomotives to Transnet. Both GE and EMD have formed alliances within South Africa for the manufacture of diesel-electric locomotives.

GE has teamed up with Transnet Rail Engineering and has completed the refurbishing of 100 of the class 43-000 locomotives.

Industrial brands group Barloworld (BAW) and Electro-Motive Diesel, Inc. (EMD), a subsidiary of Progress Rail Services Corp., a Caterpillar company, have formed a joint venture - Electro-Motive Diesel Africa.

The new joint venture will provide rail and transit customers with industry-leading locomotive products and services, including access to cutting-edge diesel and emissions technology.

Effective as from June 2012, Electro-Motive Diesel Africa will offer services and solutions to rail customers in South Africa and neighbouring countries, leveraging EMD's and Barloworld's existing resources in the region.

RLL Grindrod specialises in the refurbishment of diesel-electric locomotives to an "as new" condition using refurbished sub systems imported from EMD in the USA. The primary market is local mining houses and the Africa market.

5.6 Deliverable f

The supply of electric traction locomotives and how it compares to the market structure in the supply of diesel traction locomotives to the South African railway networks will be highlighted.

The South African rail network is described as follows[1]:-

- Network
  - 30 400 km of track
  - 20 953 route km
  - Core network: 12 801 route km
- Network Electrification:
  - 50kV AC (861km),
  - 25 kV AC (2309km)
  - 3kV DC (4935km)
  - Diesel (11974km)
- Axle loading:
  - Main lines at 22t / axle
  - Coal & ore lines 30t /axle (coal line operated at 26 ton/axle)
- The network composition in South Africa illustrating the current and future electrified lines is shown in Figure 5 below.

[1] Transnet 2009 National Investment Plan Road Show Presentation

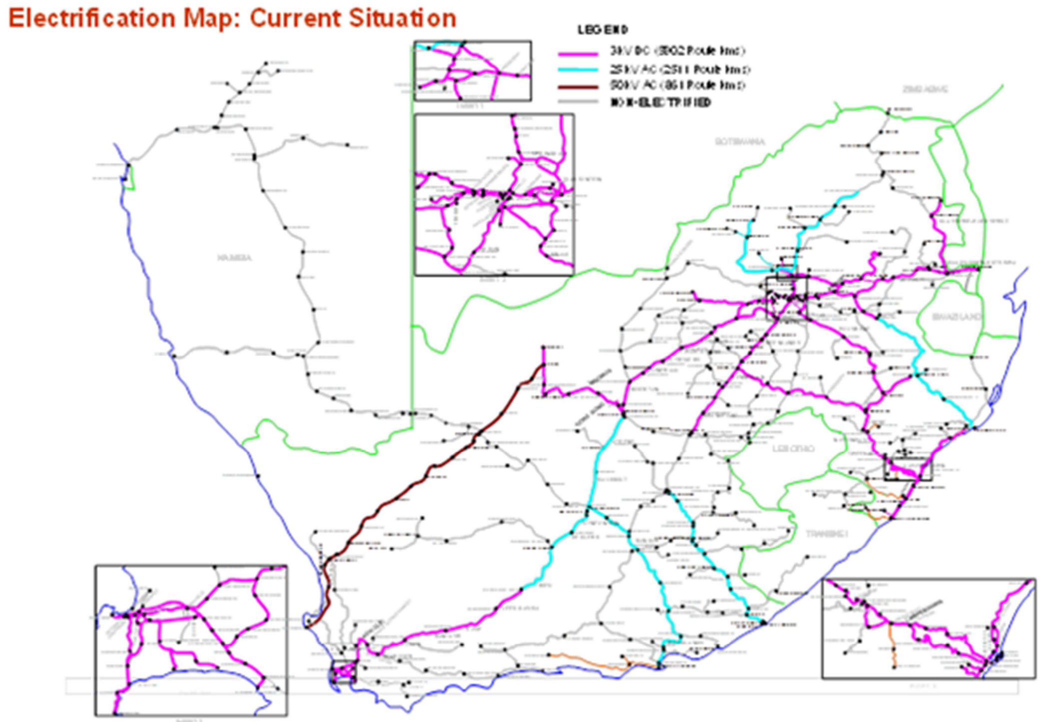


Figure 5 Current Electrified Railway lines in South Africa

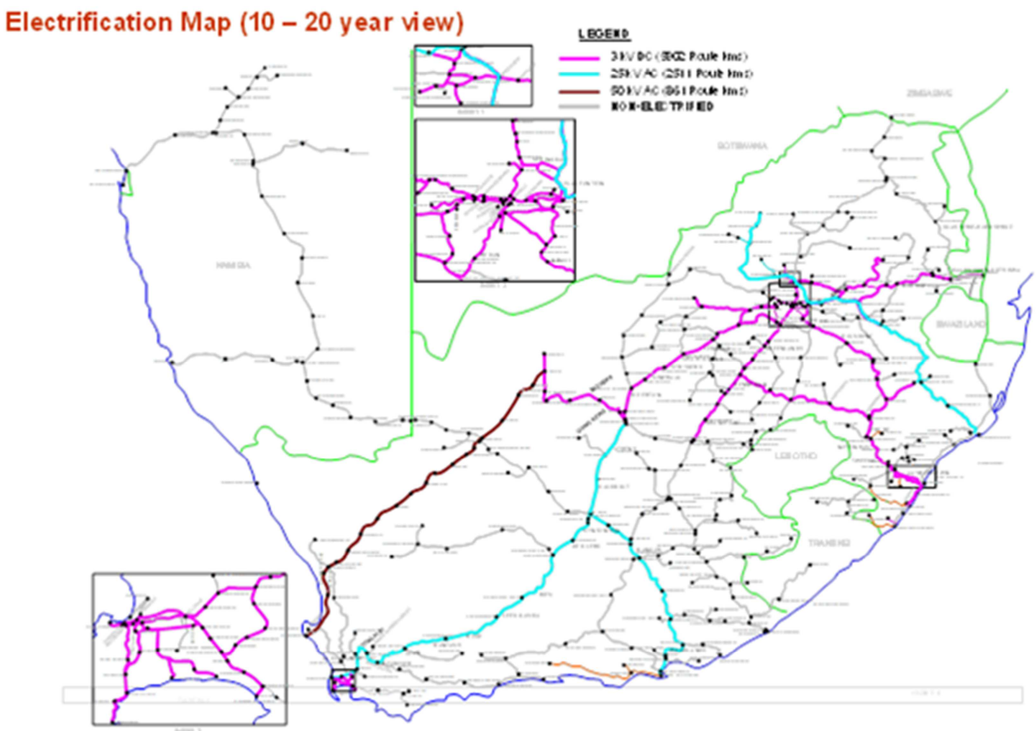


Figure 6 Future Electrified Railway lines in South Africa

The evolution into the future entails:-

- Diesel-electric traction deployment. The decision is based upon:-
  - Traffic demand on the line section. The rule of thumb used by Transnet is where traffic demand < 10mtpa diesel-electric traction would be deployed;
  - Cross border arrangements with neighbouring countries which enables the bordering countries from entering South Africa with their own traction power (diesel-electric) and proceeding to some destination within South Africa. The change over at the border post is eliminated resulting in a more effective service;
- The standardisation on 25 kVA 50 Hz OHTE in areas where it is appropriate.

Figure 7 and Table 7 below show where dieselising and electrification of rail networks in South Africa are planned. The fundamental decision being that there is no intention of moving away from electrification where the activity level exceeds 10 mtpa.

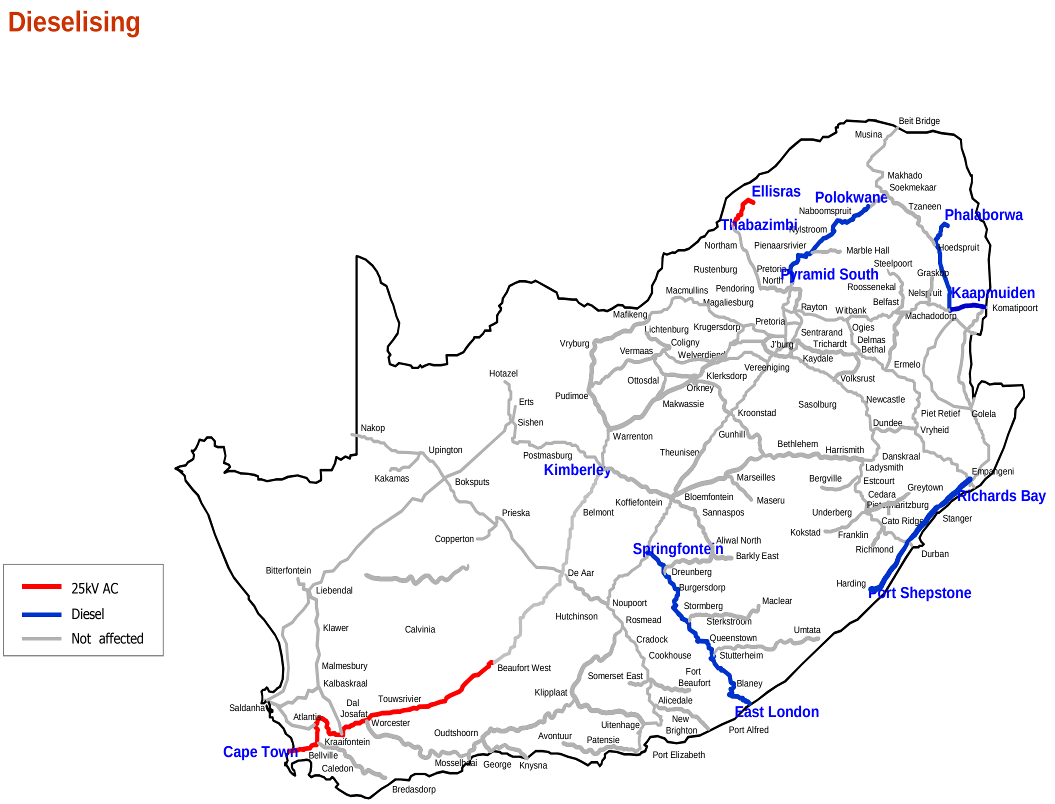
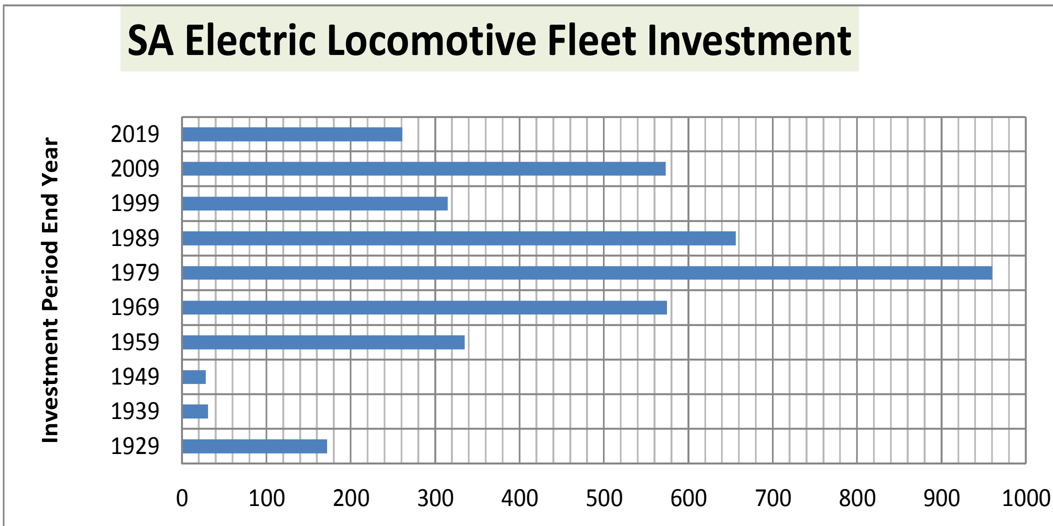


Figure 7 Planned Dieselisation and Electrification Routes in South Africa

	SECTION	CURRENT TRACTION	NEW TRACTION
1	PLK – PRZ	AC	Diesel
2	GGK – TZB	Diesel	AC
3	PHW – KMP	DC	Diesel
4	RBQ – PHR	DC	Diesel
5	SPR – ELN	AC	Diesel
	BEC - CPT	AC & DC	AC

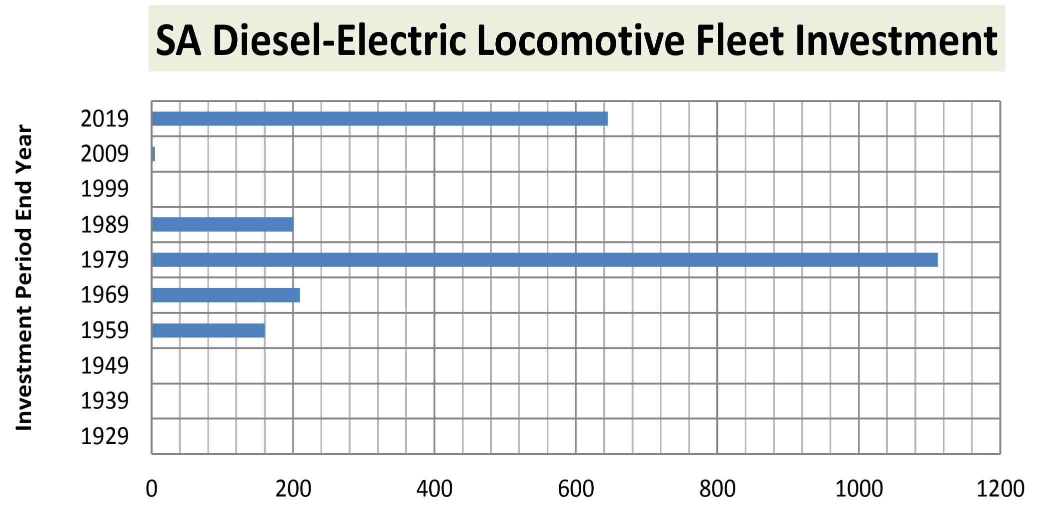
Table 7 Planned Changes of Traction on Rail Network sections in South Africa

The South African locomotive fleet was originally steam driven as from 1859, with the last investment in steam traction in 1981. The first electric locomotives were acquired by the South African Railways & Harbours (SAR&H) in 1929. Figure 8 and Figure 9 illustrate South Africa's investment in electric traction over the years. The introduction of the diesel-electric fleet only featured in 1959, 30 years after the first electric locomotive was introduced, subsequent to the decision to cease all steam operations.



	1929	1939	1949	1959	1969	1979	1989	1999	2009	2019
Number Off	172	31	28	335	575	960	656	315	573	261

Figure 8 SA Electric Locomotive Fleet Investment



	1929	1939	1949	1959	1969	1979	1989	1999	2009	2019
Number off	0	0	0	160	210	1112	201	0	5	645

Figure 9 SA Diesel- Electric Locomotive Fleet Investment

The locomotive fleets (both electric and diesel-electric), which have been replaced and/or complemented recently, are deployed on the heavy haul lines and are designated to operate the present traffic demand of 60 and 73 mtpa respectively.

The current age profile of the total locomotive fleet in South Africa is shown in Figure 10 below.

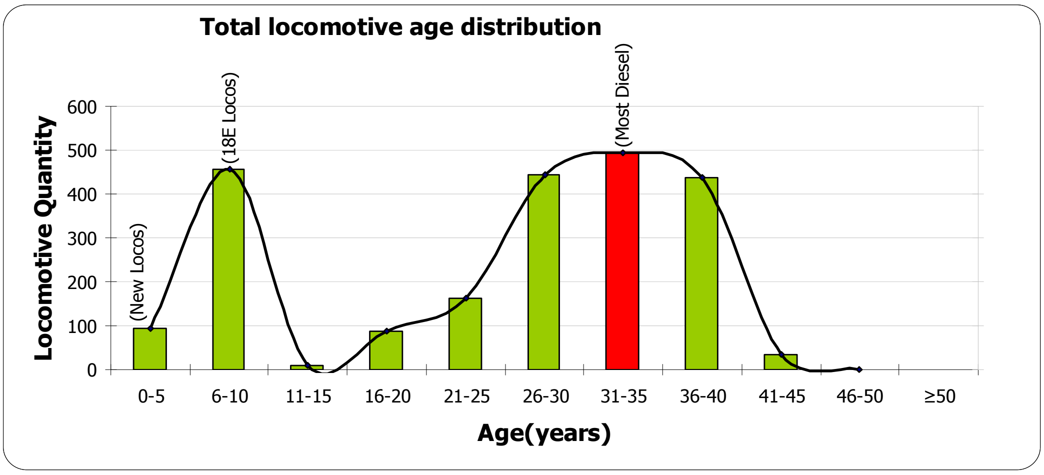


Figure 10 Total Locomotive Age distribution in South Africa

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[2] 2011_01_11 Locomotive Fleet Plan Exco Presentation

The age profile and the expansion expectations on the ore and coal lines to activity levels of of 80mtpa and 92mtpa respectively, signify that significant investment will be required.

Based upon the infrastructure plans discussed above, Transnet in South Africa is not considering decreasing its dependence upon electric traction.

5.7 Deliverable g

The extent of trade of these locomotives as well as locomotives imported from OEM supplies on other continents will be reflected in our Report.

Paragraph 5.6 above addressed the local locomotive demand in South Africa. The prerequisite in the latest tenders for locomotives, irrespective of type, require at least a 60% local content. Hence, the technology would need to be imported whilst the majority of the manufacturing and assembly will need to occur within South Africa. There are no unusual impediments to the importing of new technology. However importation of pre-owned equipment would be scrutinised very closely by South African authorities and will invariably only succeed if such importation of locomotives is destined for export again.

RRL Grindrod has been successful in the importation of pre-owned locomotives from Australia.

To date, operators in South Africa have not indulged in the procurement of pre-owned electric locomotives and there is no indication that this would be the course of action in the near future.

The African market North of South Africa has a potential use mainly for diesel-electric locomotives. The availability of funds (unless a mining house is procuring and/or leasing locomotives) is an issue in these countries. The demand over the next 24 months is projected as follows:-

- Congo Brazzaville 30 locomotives;
    - Exarro 20 locomotives; and
    - Congo itself 10 locomotives;
- Democratic Republic of Congo 35 locomotives; and
- Mozambique 19 locomotives.

The estimated demand for the next 5 – 10 years will be in the order of 400 – 600 locomotives.

5.8 Deliverable h

The general comparative performance results of a study of Cap-gauge (1 067 mm) locomotives of old and new generation models; including and excluding the impact on the primary electrical network, will be demonstrated.

The discussion that follows refers to the study to be found in Appendix A. All results from this study are available in Excel format and can be forwarded on request.

The Objectives (see Section 2.2 above) have been discussed below and is addressed in Appendix A; Sections A1.4.3 to A1.4.6.

5.8.1 Objective 1

Determine at which traffic demand level (million tons per annum [mtpa]) would the systemic cost (US $ /ton) favour electric traction to diesel-electric traction, that is at what activity level does it become less competitive.

Statements 1 to 4 in Appendix A explain the impact of the multiple of variables upon the systemic LCC.

Considering a specific environment described by a route distance =400km, alignment=A, line speed=80kph and loco consist of 4. The breakeven point within a generic analysis occurs at ~5mtpa for electric versus old generation diesel-electric traction and at ~12,5mtpa versus the new generation diesel-electric traction as shown in Figure 11 below

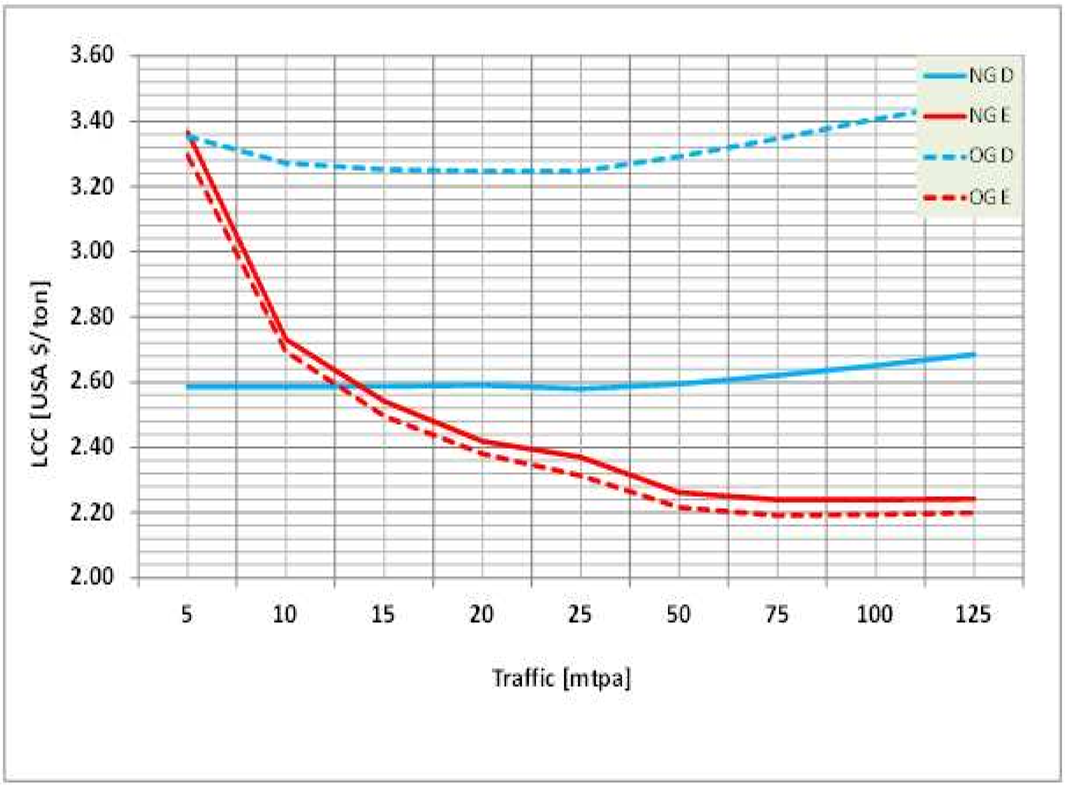

Figure 11 LCC versus Traffic Volumes

The result in Appendix A is for a generic simulation. To determine its applicability and/or relevance to QRN Network, requires the application of the local "Australian" cost drivers, alignment and train handling techniques.

5.8.2 Objective 2

Illustrate the systemic cost performance differential between new and old generation traction models for both electric and diesel-electric.

Figure 12 below, for its specific rail network environment, illustrates that a definitive LCC exists between new and old generation locomotives. However the extent to which it is a differential is a function of the local environment needs to be localised with specific route alignment information of QRN Network.

It is apparent though that a definite differential exist between new and old traction models for both electric and diesel-electric.

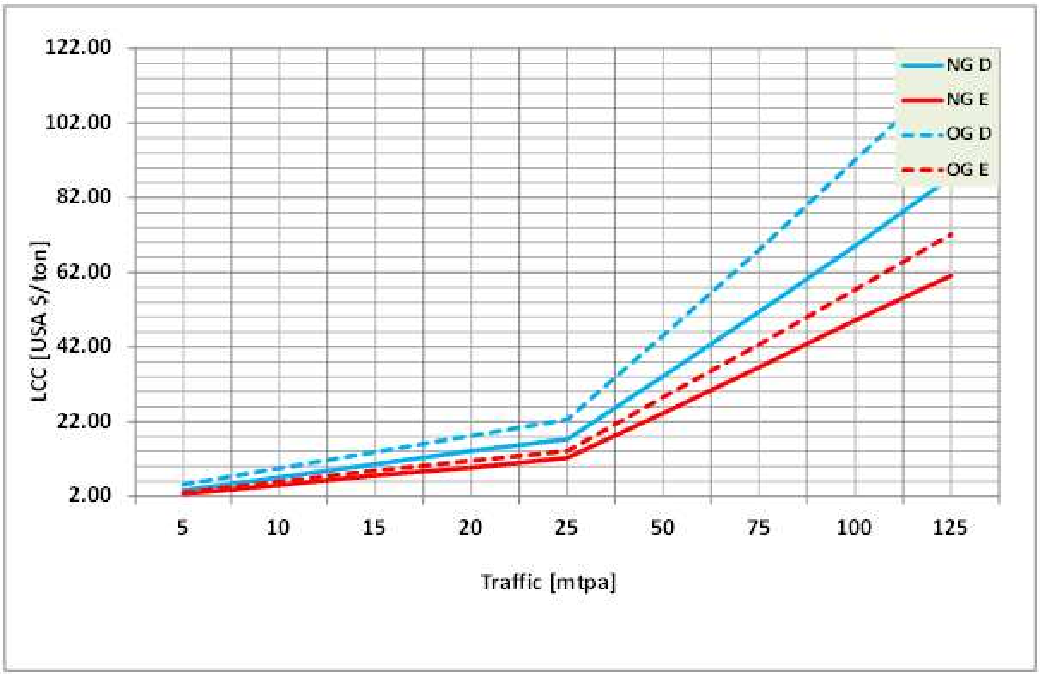

Figure 12 The Systemic Cost Performance Differential between old and new generation Traction

The extent of the differential could be an operational and technical efficiency improvement in the case of diesel-electric traction of ~32% for the new generation over the old generation diesel-electric traction versus a ~17% for electric traction, measured at a traffic level of 50mtpa.

5.8.3 Objective 3

Illustrate the impact of the existence or not of the primary electrical energy supply.

In Objective 1 a break-even point of ~12.5 mtpa was shown to exist for a specific rail network environment. The analysis assumed the existence of the primary electrical network for the supply of electrical energy. If such a network needs to be established as part of the service then the break-even point would significantly move as shown in Figure 13 below.

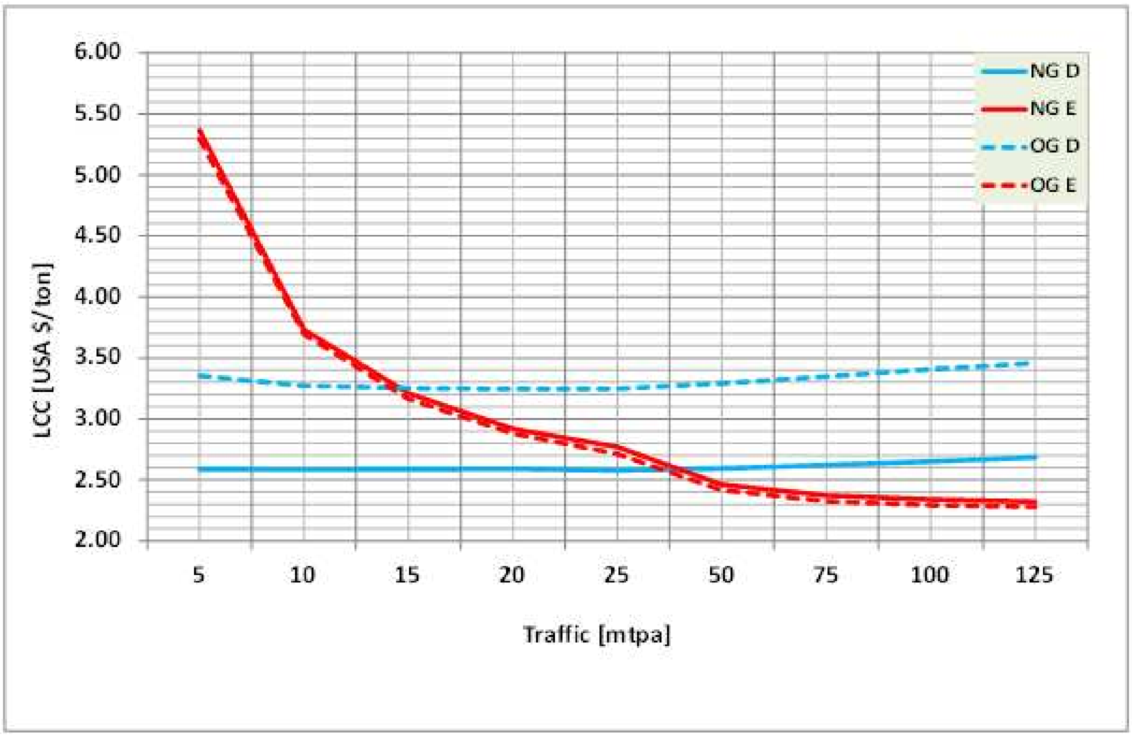

Figure 13 Impact of the existence of primary electrical energy supply

It is clear from Figure 13 that a breakeven point within a generic analysis exists and increases to ~14mtpa for electric versus old generation diesel-electric traction and at ~37,5mtpa for the new generation diesel-electric traction.

5.8.4 Objective 4

The systemic cost impact of running diesel-electric traction where electric traction equipment (OHTE – overhead traction equipment) already exists.

Refer to paragraph 5.3, deliverable c for the response.

5.9 Deliverable i

A statement concerning direct environmental impact by electrical and diesel traction will be made.

The environmental impacts which are not common to either traction type is carbon emissions and noise.

Considering the accepted energy[3] content (MJ/kg), CO_2 emissions (kg/ton) for coal and (kg/l) for diesel fuel, as listed in the table below, and a conversion factor of 1MJ = 0.2778kWh, the CO_2 emissions per ton of traffic could be ascertained.

[3] Energy Information Administration USA

Table 8 below illustrates the impact of CO_2 emissions for a locomotive consist of 4, alignment A, line speed of 80kph and route distance of 400km.

Coal	**Energy Content [MJ/kg]**		**CO_2 Emissions [lb/ton]**	**CO_2 Emissions [kg/ton]**	**CO_2 Emis-sions [kg/l]**	**CO_2 Emissions [kg/kWh]**		
	From	**To**				**From**	**To**	**Ave-rage**
Bitumous	24	35	4931	2.4655		0.213	0.311	0.262
Anthracite	26	33	5685	2.8425		0.266	0.338	0.302
Liginite	10	20	2791	1.3955		0.050	0.100	0.075
Sub Bitumous	20	21	3716	1.858		0.134	0.140	0.137
Diesel	36.4	36.4			2.7			

Table 8 CO_2 Emissions of types of Coal

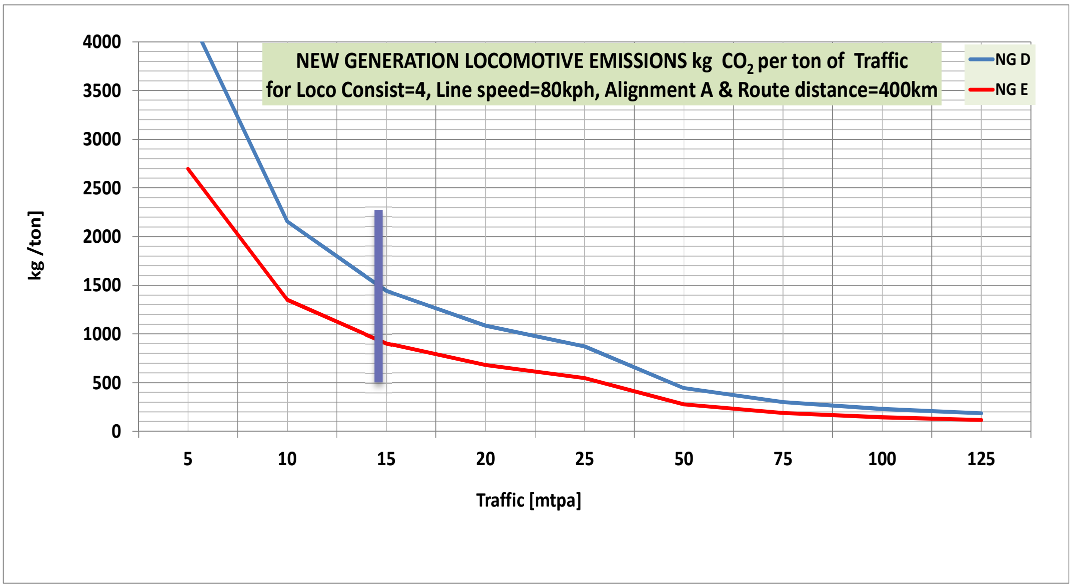

Figure 14 New Generation Locomotive Emissions kg CO_2 per ton of Traffic

At the breakeven point of ~12,5 mtpa traffic demand electric traction produces ~39% less CO_2 emissions than diesel-electric traction. Electric traction is clearly more environmental friendly. Technologies for the reduction of NOx emissions are currently being developed for both diesel and coal applications with the aim of near zero emission levels, hence there is very little differential in the two energy sources.

Noise generated by a locomotive is contradictory from a safety perspective. A noisy locomotive alerts any persons adjacent to the rail reserve that a train is eminent. This aspect is important in a densely populated area. Electric traction is renowned to be more "quiet" hence increasing risk of unawareness of approaching trains.

6 Conclusions

The following conclusions are made concerning the Results (Section 5 above) of the deliverables "a" to "i":

Deliverable	Conclusions
a	Table 1 above is not definitive in that one rail network environment is not necessarily comparable to another rail network environment. The specific rail network environment must be considered and the boundaries of influencing variables be evaluated for that specific rail network environment for a deterministic study.
b	Technological development opportunities exist for both electric and diesel-electric traction; the difference being that the development being applied to the diesel-electric locomotives whereas in the case of electric locomotives, the development will primarily be applied to the power stations.
c	In the situation where a line has a fixed capacity and is electrified, should diesel-electric traction proliferate and continuously absorb more of the capacity of the line, the LCC for electric traction would increase to the detriment of the logistic chain cost.
d	Globally oil reserves are being re-estimated annually. The dependency of a railway system upon local conditions and supply of oil need be determined within the local operational environment of the diesel-electric locomotives in order to determine the rail network specific outcomes.
e	The manufacturers of locomotives in South Africa are WICTRA and UCW for electric locomotives and TRE (Transnet Rail Engineering) for Diesel-electric.
f	The locomotive orders currently in the SA market place is:- • 186 electric locomotives of which ~150 have already been

Deliverable	Conclusions
	delivered, produced by UCW for the coal and ore lines; • 95 electric locomotives, for general freight application, just awarded to WICTRA and supplied by CSR; • 495 diesel-electric locomotives tender which still has to be awarded. The capacity of the plants and the quantities involved for the SA market implies that the plants, especially UCW, would have spare capacity in the near future. RRL Grindrod who specialises in refurbished “as new” locomotives for the African and mining market has an order book for at least 24 months. The commuter transport company, PRASA, has a total fleet renewal tender in the market place which would result in additional facilities for commuter rolling stock being required. This tender should be awarded in December 2012. The age profile and the expansion expectations on the ore and coal lines to activity levels of of 80mtpa and 92mtpa respectively, indicate that significant investment will be required. Based upon the infrastructure plans discussed above, Transnet in South Africa is not considering decreasing its dependence upon electric traction.
g	South Africa has to date been a net importer of locomotives excluding such locomotives which have been destined for the African market and 20 units which were delivered to Brazil. A stipulation in the latest tenders for locomotives, irrespective of type, requires at least a 60% local content. Hence the technology would need to be imported whilst the majority of the manufacturing and assembly must occur within South Africa.
h	1. From the observations of the results in Figure 21 below it is apparent that a breakeven point does exist resulting in electrical traction being a more viable alternative than diesel-electric traction measured by LCC and provided the primary power source already exists. The exact position of the breakeven point is a function of which variable is being considered. The value of the analysis is that it is indicative that a breakeven point exists. The continued use of diesel-traction

Deliverable	Conclusions
	beyond this breakeven point results in a cost which would impede the competitive export of the commodity on that specific logistic chain. The impediment is further increased should the required OHTE already exist. 2. From Section A1.4.4 below it is apparent that a performance improvement has been realised as follows:- o NGD versus OGD an improvement of 32%; o NGE versus OGE an improvement of 17%; and o NGE versus NGD an improvement of 40%. (The above is based upon an activity level of 50mtpa) 3. From Section A1.4.5 below it is evident that in the case of the primary electrical power source being existent the benefits of electric traction over diesel electric traction is realised sooner at an activity level of 5 versus 14 mtpa for the old generation traction and 12,5 versus 37,5mtpa for new generation traction. 4. From Section A1.4.6 below it is evident that the hybrid traction scenario operating on a network is not beneficial to the LCC of the rail logistic chain. Rather it is considered to be an impediment to the cost competitiveness of the network.
i	At the breakeven point of ~12,5 mtpa traffic demand, electric traction produces ~39% less CO_2 emissions than diesel-electric traction. Electric traction is clearly more environmentally friendly. Technologies for the reduction of NOx emissions are currently being developed for both diesel and coal applications with the aim of near zero emission levels, hence there is very little differential in the two energy sources. To date the experience has been that the noise envelope of an electric locomotive is less than that of a diesel-electric locomotive. Noise is advantageous from a safety perspective in that is provides warning of an approaching train. However excessive noise is irritating to the environment (extent is determined by the actual operating environment and local legislation in this regard) as well as operators and/or maintainers of diesel-electric locomotives.

7 Recommendations

The opinion of the authors of this report is that:-

- There is a case to be made for a tariff structure alignment that accommodates a legacy of infrastructure investment to which the accountable body had no previous right of veto.
- The extent of such an alignment could only be determined by an in depth analysis of the actual environment to which it applies.

The following recommendations are to be considered:-

- Based upon conclusion "h1" above a detailed simulation of the existing route specific environment with its associated tractive effort characteristics, alignment and cost factors should be conducted in order to determine the breakeven point for QRNN purposes;
- An in depth analysis of the driving cost factors should be included in the above analysis in order to ensure that the cost factors are representative of the application of best practice and to identify the potential for improvement on the cost factors; and
- QRNN should be granted the opportunity to avail them of such a detail analysis in order to reconstruct the tariff structure for industry. What is of cardinal importance is that the analysis must be conducted with a cost to Australia emphasis and not maximum return to a specific industry and/or individual group.

Appendix A

Comparative Systemic Cost Using Electric versus Diesel Electric Traction

A1 Comparative Systemic Cost: Electric vs Diesel-Electric traction

Contents

A1.1 Abbreviations

ABB	Asea Brown Boveri & Cie
AC	Alternating Current
BAW	Barloworld
BEC	Beaufort Wes
CO_2 kg/kWh	Kilogram per Kilowatt- hour (Carbon)
CPT	Cape Town
CQCN	Central Queensland Coal Network
CSR	China South Railway
DC	Direct Current
ELN	East London
EMD	Electro-Motive Diesel
EMDA	Electro-Motive Diesel Africa
GE	General Electric
GFB	General Freight Business
GGK	Grootegeluk
GM SA	General Motors South Africa
GTKM	Gross Ton Kilometre
Hz	Hertz
kg/l	Kilogram per litre (diesel fuel)
kg/ton	Kilogram per ton (coal)
Km	Kilometer
KMP	Kaapmuiden
Kph	Kilometer per hour
Kva	Kilo Volt Ampere
lb/ton	Pounds per Ton
LCC	Life Cycle Cost
LPG	Liquid Petroleum Gas
MJ/kg	Mega Joules per kilogram
mtpa	million tons per annum
NG D	New Generation Diesel-Electric
NG E	New Generation Electric
NOx	Nitrogen Oxides
O_2	Oxygen
OEM	Original Equipment Manufacturer
OG D	Old Generation Diesel-Electric
OG E	Old Generation Electric
OHTE	Overhead Track Equipment
OOS	Out of Service
PHR	Port Shepstone
PHW	Phalaborwa
PLK	Polokwane
PRASA	Passenger Rail Agency of South Africa

PRSC	Progress Rail Services Corp
PRZ	Pyramid South
QCA	Queensland Competition Authority
QRN	Queensland Rail Network
QRNN	Queensland Rail National Network
RBQ	Richards Bay
RRL	Railroad Logistics (Grindrod)
RSD	Rolling Stock Dorbyl
SPR	Springfontein
TAT	Turnaround Time
TRE	Transnet Rail Engineering
TZB	Thabazimbi
UCW	Union Carriage & Wagon
US$/ton	US dollar per ton
WICTRA.	WICTRA as manufacturer

A1.2 Introduction

A1.2.1 Purpose

The aim of this Appendix to this report is to illustrate the impact that the utilisation of diesel-electric and electrical traction has on the systemic cost of transporting coal.

A1.2.2 Objectives

The following objectives (see Section 2.2 above) are addressed:-

1. Determine at which traffic demand level (million tons per annum [mtpa]) would the systemic cost (US $ /ton) favour electric traction to diesel-electric traction, that is at what activity level does the latter traction type become less competitive;

2. Illustrate the systemic cost performance differential between new and old generation traction models for both electric and diesel-electric;

3. Illustrate the impact of the presence or not of the primary electrical energy supply; and

4. Illustrate the systemic cost impact of running diesel-electric traction where electric traction equipment (OHTE – overhead traction equipment) already exists.

A1.2.3 Qualification

The report and its findings are qualified as follows:-

1. The report is a comparative report; not absolutely applicable to a specific rail network and operational practices and therefore all common cost components are excluded from the analysis;

2. The input data used in the analysis are based on South African historic costs, experience and cost drivers;

3. The analysis is based upon generic alignments which are defined within the report and are indicative of typical alignments found in South Africa. The generic alignment does therefore not represent any specific line in South Africa;

4. The report is not intended to be used for any deterministic commercial purpose other than a qualitative comparison between diesel-electric traction versus electric traction.

A1.3 Methodology

A1.3.1 Scope

The analysis is conducted upon a range of the variables namely:

- Alignments designated as A, B, C, D, E, and F of which the characteristics are shown in Section A1.3.4.1 and Table 12 below;
- Traffic demand levels of 5, 10, 15, 20, 25, 50,75,100 and 125 mtpa;
- Route distances of 100, 200, 400, 600, 800 ,1000 and 1200km; and
- Line speeds of 50, 60, 70, 80 and 90 kph.

The traction types considered are the locomotives used and/or intended to be used on the coal line to Richards Bay in South Africa. The characteristics of the locomotives are listed below.

For the purpose of this report the locomotives have been designated as:-

- OGD – old generation diesel-electric, class 34-800;
- NGD – new generation diesel-electric, class 43-000;
- OGE – old generation electric, class 7E3; and
- NGE – new generation electric, class 19E

A1.3.1.1 Diesel Traction

ASPECT	OGD	NGD
Picture		
Power type	Diesel-electric	Diesel-electric
Designer	Electro-Motive Diesel	General Electric
Builder	General Motors South Africa	34-001 to 34-010 GE 34-011 to 34-100 TRE[1]

ASPECT	OGD	NGD
Model	EMD GT26MC	GE C30ACi
Build date	1978-1980	2010-2011
Total production	59	100
UIC classification	Co+Co interlinked bogies	Co+Co interlinked bogies
Gauge	3 ft 6 in (1,067 mm) Cape gauge	3 ft 6 in (1,067 mm) CAP gauge
Wheel diameter	3.632 m (11 ft 11.0 in) wheelbase	1,041 mm (41.0 in) new 965 mm (38.0 in) worn
Locomotive weight	113,100 kg (111.3 long tons) maximum	126,000 kg (124 long tons)
Fuel type	Fuel oil	Fuel oil
Fuel capacity	6,230 litres (1,650 USgal)	7,000 litres (1,800 USgal)
Engine type	EMD 16-645E3 2 stroke V16	Diesel
Aspiration	EMD E16 turbocharger	Electronic fuel-injection system
Traction motors	**Upgraded** Six EMD D31 DC 4 pole * 545A 1 hour * 520A continuous at 21 km/h (13 mph)	Six GE 3-phase AC induction
Top speed	100 km/h (62 mph)	100 km/h (62 mph)
Power output	2,342 kW (3,141 hp) starting 2,171 kW (2,911 hp) continuous	3,300 hp (2,500 kW) GHP 3,000 hp (2,200 kW) THP
Tractive effort	306 kN (69,000 lbf) starting 245 kN (55,000 lbf) continuous at 26 km/h (16 mph)	548 kN (123,000 lbf) starting 460 kN (100,000 lbf) continuous at 14.8 km/h (9.2 mph)
Locomotive brakes	28-LAV-1 with vigilance control	Dynamic braking

ASPECT	OGD	NGD
	Dynamic brake	
Locomotive brakeforce	peak effort: 188 kN (42,000 lbf) at 28 km/h (17 mph)	Peak effort 288 kN (65,000 lbf)

Table 9 Specifications for Diesel-Electric Locomotives

A1.3.1.2 Electric Traction

ASPECT	OGE	NGE
Picture		
Power type	Electric 25 kVA 50 Hz	Dual voltage 25kVA 50 Hz and 3000V dc
Designer	Hitachi	Mitsui
Builder	Dorbyl	UCW Partnership
Model	Hitachi 7E3	Mitsui 19E
Build date	1983-1984	2007-2011
Total production	60	110
UIC classification	Co-Co	Bo-Bo
Gauge	3 ft 6 in (1,067 mm) Cape gauge	3 ft 6 in (1,067 mm) Cape gauge
Wheel diameter	1,220 mm (48.0 in)	25,570 kg (25.17 long tons) mass per pair
Locomotive weight	123,500 kg (121.5 long tons)	104,000 kg (102 long tons) permissible

ASPECT	OGE	NGE
Current collection method	Pantographs	Pantograph
Traction motors	Six HS 1054 GR	-
Transmission	16/94 Gear ratio	-
Top speed	100 km/h (62 mph)	120 km/h (75 mph) operating 132 km/h (82 mph) by design
Power output	**Per motor:** 525 kW (704 hp) 1 hour 500 kW (670 hp) continuous **Total:** 3,150 kW (4,220 hp) 1 hour 3,000 kW (4,000 hp) continuous	3,000 kW (4,000 hp) continuous
Tractive effort	450 kN (100,000 lbf) starting 319 kN (72,000 lbf) 1 hour 300 kN (67,000 lbf) continuous [1]	392 kN (88,000 lbf) starting 300 kN (67,000 lbf) cont.
Locomotive brakes	Rheostatic [2][3]	Regenerative and Rheostatic
Locomotive brakeforce	210 kN	288 kN

Table 10 Specifications for Electric Locomotives

A1.3.2 Process

The process followed in the analysis is as depicted in Figure 15 below.

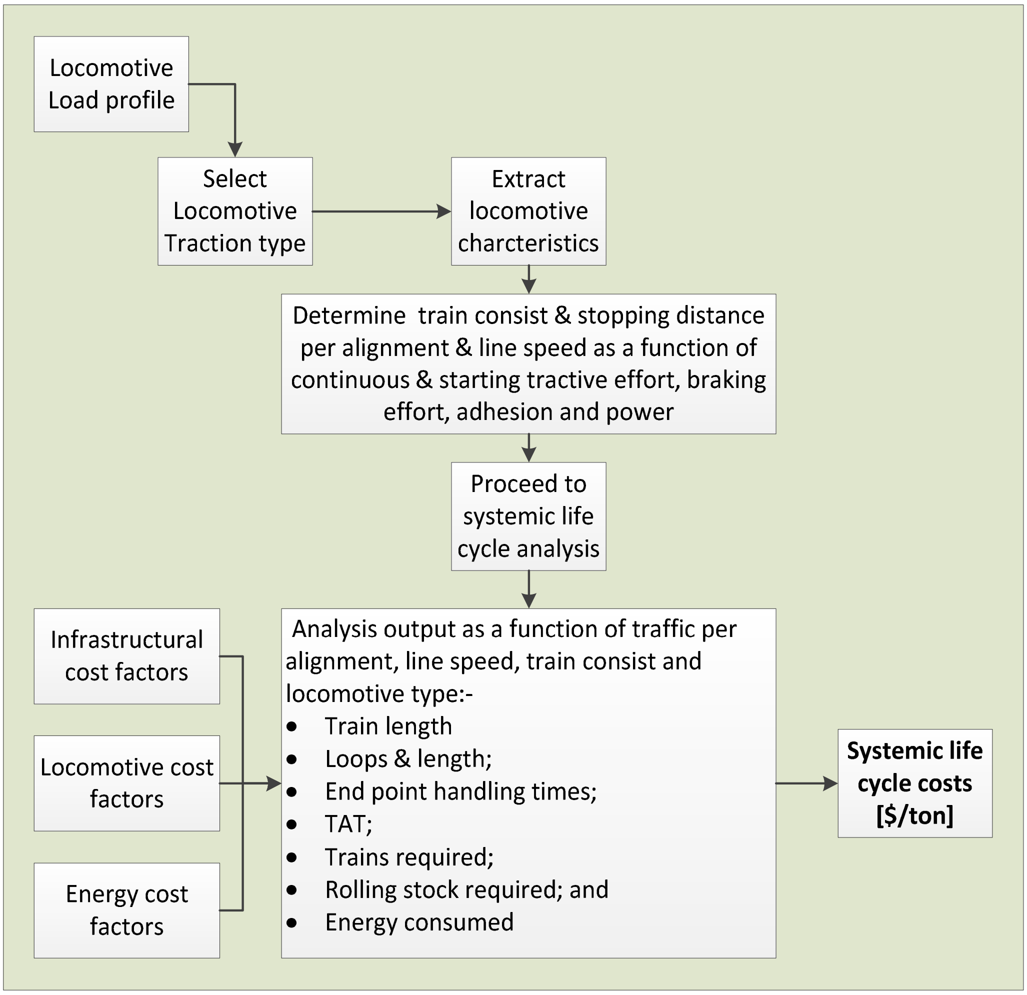

Figure 15 Process Flow for determining Life Cycle Costs

The results are reflected in appropriate tables and/or graphical figures to substantiate the findings per objective.

A1.3.3 Assumptions

The following assumptions are applicable to the analysis:-

- Only a gondola type wagon is considered;
- Only 1 in 12 turn outs are considered;
- Locomotives' preparation time is ignored;
- Yards have 4 lines each;
- There are only 2 yards at each end point;
- Material costs are included in maintenance costs;
- Electrical power feeder sub is available;

- Permanent way, train control, signalling & communications are assumed to be common to both environments hence the costs are excluded from the analysis;

- The electrification power supply is assumed to be 25kVA 50 Hz;

- The gauge is CAP gauge (1 067 mm); and

- The differential in balancing speed (the minimum speed at which the locomotive would operate continuously) is compensated for by decreasing the diesel-electric tractive effort to the speed at which the electric locomotive balance speed is as shown in Figure 16 below. This would not be required in a real time simulation where the train handling determines the position on the tractive effort curve. This is necessary to compensate for Turnaround Time (TAT) when negotiating long inclines.

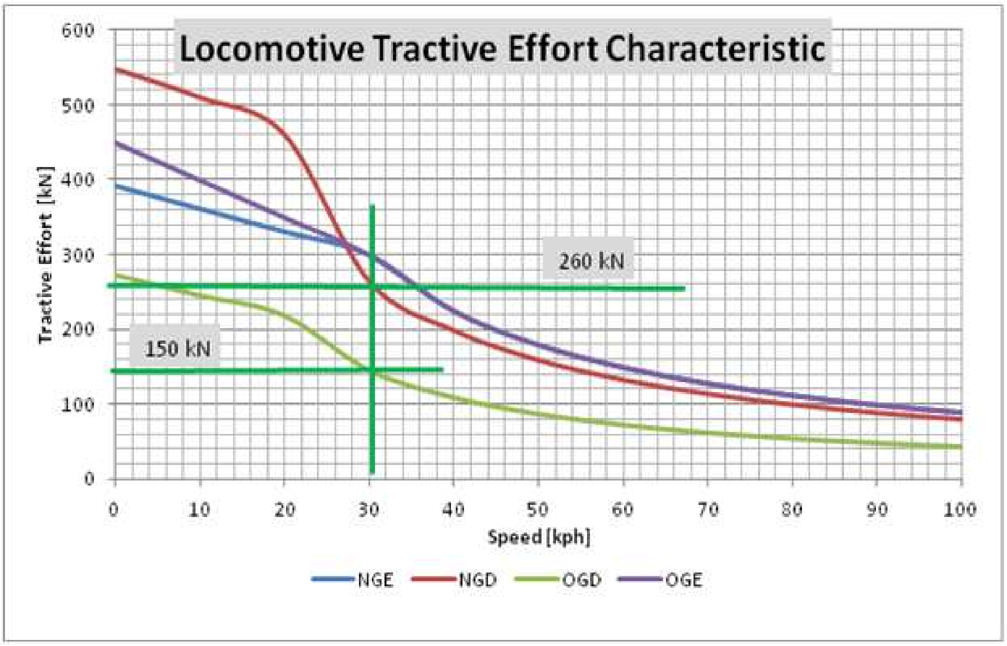

Figure 16 Locomotive Tractive Effort Characteristic

- The energy consumption of the locomotives is based on an aggregate rate applicable across the full duty cycle of the locomotive. The aggregate is determined using an acceptable medium level duty cycle for the locomotive where it has been determined that a locomotive would spend a certain percentage factor of the running time in certain notches as shown in Table 11 below:-

		Weighted Average			
Notch	**Factor**	**OG D**	**NG D**	**OGE**	**NGE**
8	0.17	67.7	101.2	510	629
7	0.04	15.9	20.0	105	129.5
6	0.04	16.3	16.9	90	111
5	0.04	16.9	12.0	75	92.5
4	0.04	17.9	9.1	60	74
3	0.04	2.6	6.9	45	55.5
2	0.04	2.9	3.8	30	37
1	0.04	1.2	1.8	15	18.5
0.2	0.46	6.9	4.9	34.5	42.55
-1	0.09	40.4	20.5	67.5	83.25
Aggregate Value		**188.7**	**197.2**	**1032**	**1272.8**

Table 11 Energy Consumption of Locomotives

- The generic analysis precludes the advantages of incorporating train handling techniques, such as momentum swing, which would make greater use of the available tractive effort and limit the time in the lower speed ranges. It further precludes the optimisation of the alignment to the specific characteristics of the locomotive fleet. This is only possible in a real time detailed simulation of locomotive performance whilst optimizing the alignment to ensure the most efficient operations of the holistic railway system.

A1.3.4 Variables

A1.3.4.1 Alignment

The alignment options considered for simulation and train consist compilation purposes, are described in Table 12 below:-

Alignment	Up gradient	Down gradient	Curve radius	Alignment Classification [N/kJ]	Clarification
A	200	150	1200	0.5	State of the art heavy haul line
B	125	100	800	0.8	Economy class heavy haul line
C	100	100	600	0.9	Upgraded main line
D	80	80	400	1.1	Average Main line
E	60	60	200	1.6	Improved branch line
F	50	50	100	2.1	Branch line environment

Table 12 Alignment Options Used in Simulation

A1.3.4.2 Locomotive Characteristics

The locomotive characteristics of the types of locomotives (see Sections A1.3.1.1 and A1.3.1.2 above) are shown in Table 13 below.

OPTION	1	2	3	4	
Type	OG E	OG D	NG E	NG D	UNITS
Axle Mass	20.5	21	26	21	ton
Continuous TE	300	150	300	260	kN
Starting TE	450	272	392	548	kN
Braking Effort	210	188	288	288	kN
Balance Speed	30	30	30	30	kph
Aggregate Fuel Consumption	1032	189	1273	197	l/h or kW
Fuel Capacity	0	6000	0	7000	l
Length	18.4	19.2	18.3	20	m
Cost	4.0	3.62	4.25	4	m$
Power	3000	1250	3000	2167	kW

OPTION	1	2	3	4	
Type	**OG E**	**OG D**	**NG E**	**NG D**	**UNITS**
Area	12.15	11.06	12.09	12.10	m^2
Maintenance	366	612	229	550	$/day

Table 13 Locomotive Characteristics

A1.3.4.3 Wagon Characteristics

The wagon characteristics are defined as similar for the four types of traction selections in Section A1.3.4.2 above. Also see Table 14 below.

OPTION	1	2	3	4	UNITS
Type	**CG HH G**	**CG HH G**	**CG HH G**	**CG HH G**	
Axle mass	26	26	26	26	ton
Tare	20.82	20.82	20.82	20.82	ton
Load	84	84	84	84	ton
Length	12.1	12.1	12.1	12.1	m
Volume	85.66	85.66	85.66	85.66	m^3
Area	9.20	9.20	9.20	9.20	m^2
Cost	0.16	0.16	0.16	0.16	m$
Maintenance	41	41	41	41	$/day

Table 14 Wagon Characteristics

The type of wagon used by in the simulations is the “Gondola” type wagon.

CG HH G – CAP gauge heavy haul (26t per axle).

A1.3.4.4 Infrastructure Cost Factors

The Infrastructure Cost Factors have been derived from various heavy haul studies compiled for networks in Southern Africa and are shown in Table 15 below.

ID	Item	Unit	Now
1	**Substation spacing**		
2	ac	km	34
3	**CAPEX**		0
4	OHTE	$/km	104587
5	Subs	$ ea	402290
6	Fuel station	$ ea	321805
7	Yard Electrification	$ ea	0
8	ac	$ /km ea	257444
9	Loops OHTE	$ ea	0
10	ac	$ /km ea	32181
11	Power supply to OHTE	$ /km	751815
12	**OPEX /year**		0
13	OHTE		0
14	ac	$/km	1722
15	Subs		0
16	ac	$/ea/y	5771
17	Fuel station	$/ea/y	965
18	Yard Electrification		0
19	ac	$/km	164
20	Energy		0
21	Electricity	US c/kWh	9.4
22	Diesel fuel	US $/l	1.5
23	Life cycle period	Years	20

Table 15 Infrastructure Cost Factors

A1.4 Analysis

A1.4.1 Locomotive Load Profile

The locomotive load profile analysis yielded the train consist sizes in Table 16 below. The results in the table is limited to a maximum locomotive consist of 6. The full set of results is contained lie in an EXCEL workbook and can be forwarded on request.

			Alignment Type					
			A	B	C	D	E	F
Generation	**Type**	**Loco Consist**	**Number of Wagons in Train Consist**					
NG	D	1	31	21	17	14	10	7
		2	72	48	38	30	21	15
		3	108	72	58	45	32	23
		4	144	96	77	61	42	31
		5	180	120	96	76	53	39
		6	217	145	116	91	64	47
NG	E	1	35	24	20	16	11	8
		2	83	55	44	35	24	17
		3	125	83	66	52	36	26
		4	167	110	88	70	49	35
		5	209	138	111	87	61	44
		6	251	166	133	105	73	53
OG	D	1	17	11	9	7	5	3
		2	41	26	21	16	11	8
		3	61	40	32	24	17	12
		4	81	53	42	33	22	16
		5	102	66	53	41	28	20
		6	122	80	64	49	34	24

			Alignment Type					
			A	B	C	D	E	F
Generation	Type	Loco Consist	Number of Wagons in Train Consist					
OG	E	1	36	25	20	16	11	8
		2	72	44	44	34	24	18
		3	109	66	66	51	36	27
		4	145	89	88	68	48	37
		5	181	111	111	85	60	46
		6	218	133	133	102	73	55

Table 16 Locomotive Load Profile Analysis

The above train consists were applied in the systemic life cycle analysis matching the number of trains required to traffic demand as a function of line speed and route distance.

A1.4.2 General Observations

In the following synopsis the impact of the variables; line speed, route distance, alignment and train consist are examined as function of traffic demand and the network (old/new diesel-electric/electric traction types). In all instances the objective function is systemic life cycle costs (SLCC) (over a period of 20 years). Each variable is quantified as a dependent variable for a specific value of the other variables (independent variable) as follows:-

- Line speed = 60 kph;
- Route distance = 400 km; variables
- Alignment = A; and
- Train consist equivalent to a 4 locomotive consist.

The format of the discussion is:-

- Statement of analysis;
- Figure and/or table; and
- Observations pertinent to the figure.

Note:-

- The “Network” refers to the locomotive type namely NGD, NGE, OGD and OGE;
- It is assumed that the primary electrification network to supply power to the rail network exists.

Statement 1– Impact of Line Speed: Loco consist=4, Route distance = 400 km, Alignment = A

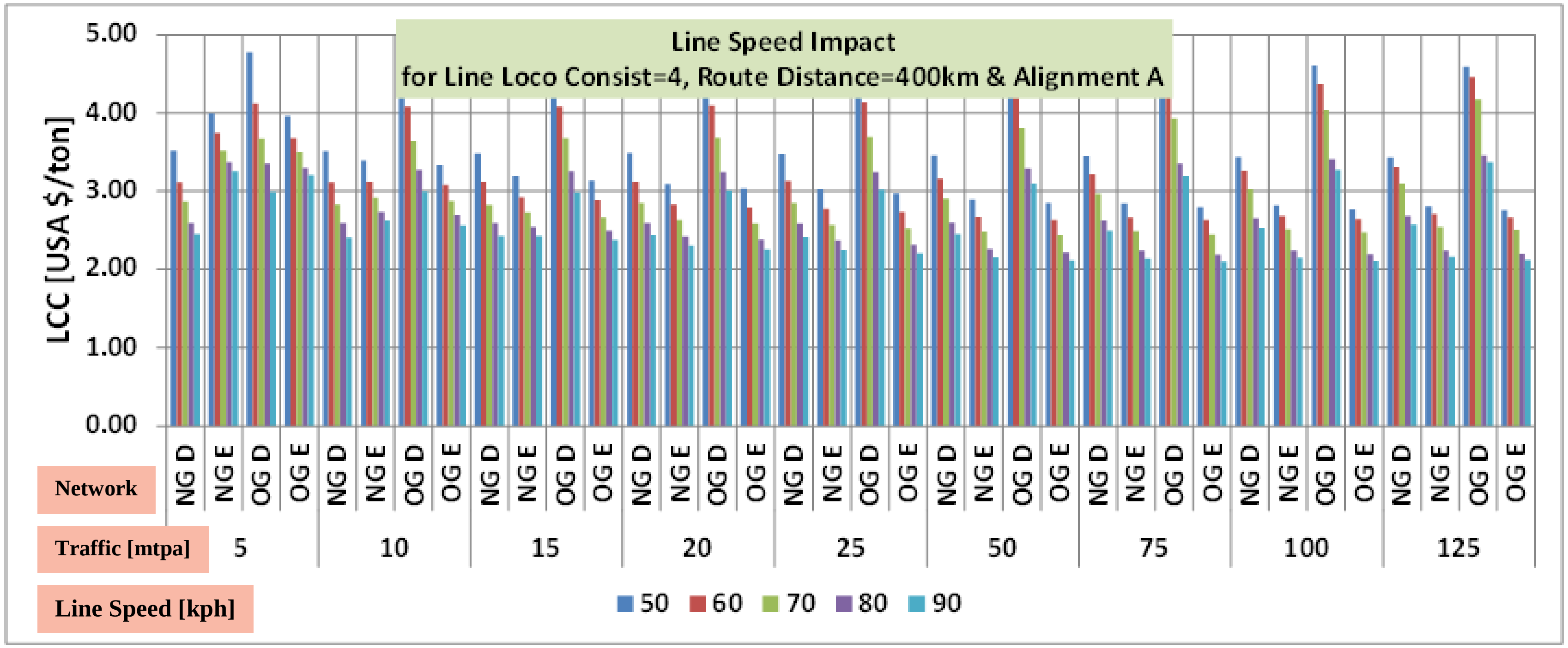

Figure 17 Graphs showing the impact of line speed

Observations:-

- LLC decreases with increasing speed irrespective of network to a traffic level of 50 mtpa

- Beyond 50mtpa speeds of 60 and 70 are sub optimal, 80 kph appears to be optimal speed
- Beyond 20mtpa NGE LCC is less than NGD.
- The OGD generally has the highest LCC and OGE and NGE show little difference in LCC

Statement 2– Impact of Route Distance: Loco consist=4, Line speed = 60kph, Alignment = A

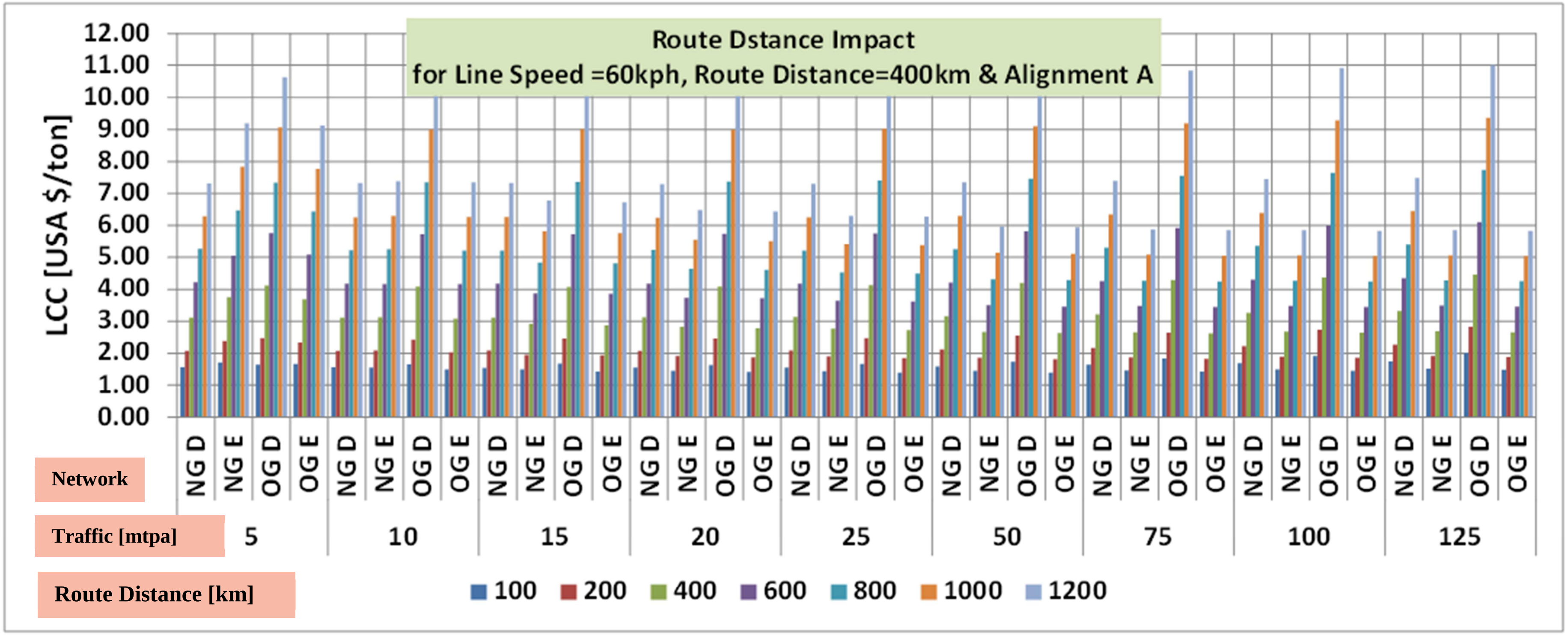

Figure 18 Graphs showing the Impact of Route distance

Observations:-

- LLC increases with increasing distance (The Turnaround Time (TAT) increases hence assets and energy consumption increases);
- As for an activity level from 20mtpa and more, the LCC for NGE is less than the NGD;
- The OGD is outperformed in all instances.

Statement 3– Impact of Alignment: Loco consist=4, Line speed = 60kph, Route distance = 400km

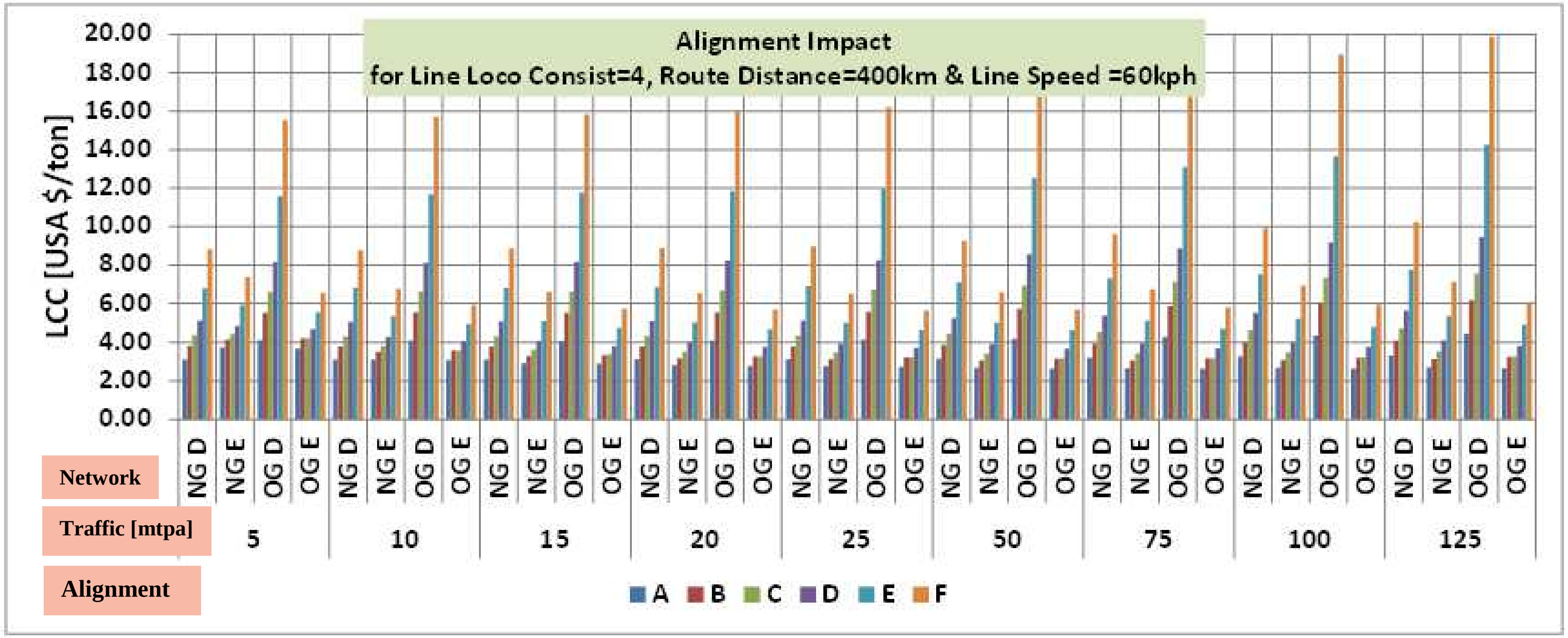

Figure 19 Graphs showing the impact of Alignment

Observations:-

- The LCC increases in the case of greater tractive effort required to negotiate the alignment (the more awkward the alignment the more the LCC will increase)

- For an activity level of 10mtpa and more the, LCC for NGE is less than that of the NGD;

- The OGD is outperformed in all instances.

Statement 4– Impact of locomotive consist: Route distance = 400km, Line speed = 60kph, Alignment = A

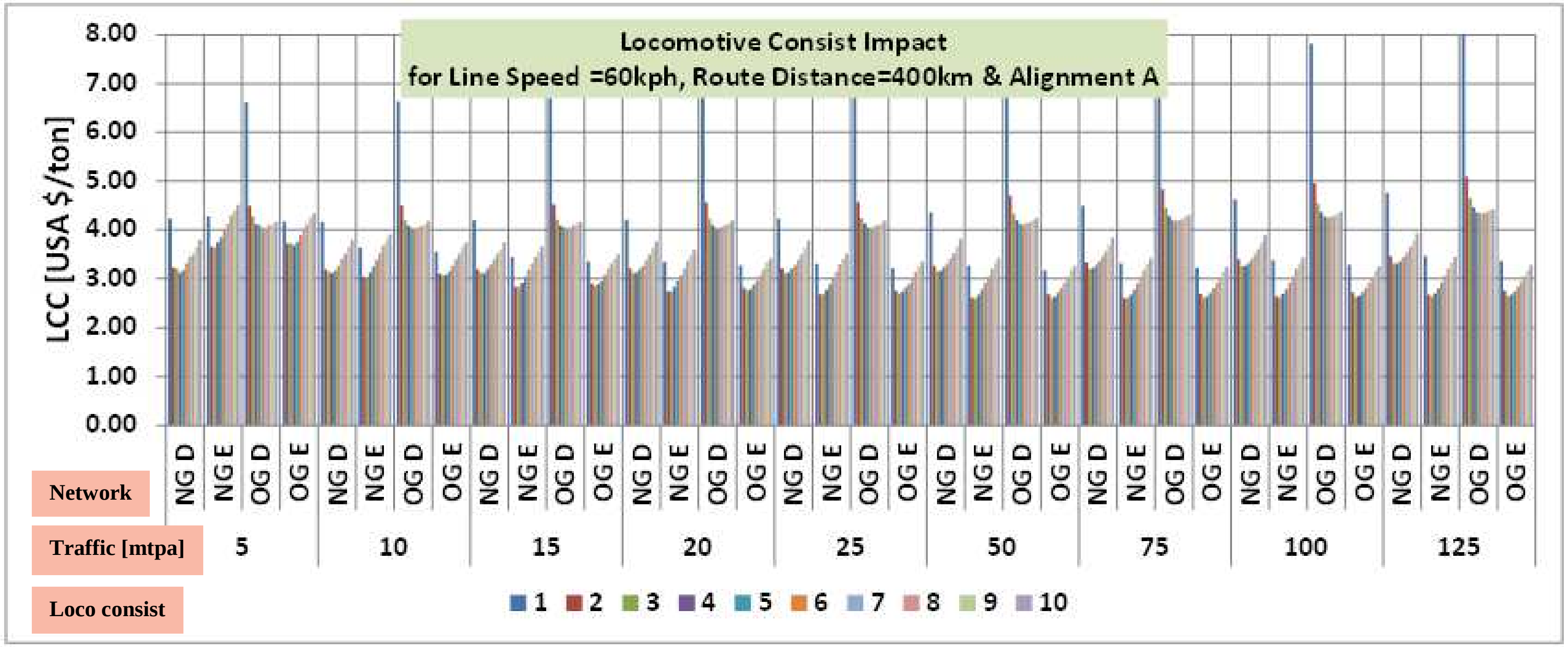

Figure 20 Graphs showing the impact of Locomotive Consists

Observations:-

- The Life Cycle Costing (LLC) show that a consist of 4 locomotives are the optimal configuration of locomotives in all instances
- From an activity level in excess of 10mtpa the LCC for NGE is less than NGD;

- The OGD is outperformed in all instances.

A1.4.3 Objective 1

Determine at which traffic demand level (million tons per annum [mtpa]) would the systemic cost (US $ /ton) favour electric traction to diesel-electric traction, that is when does the latter alignment become less competitive.

The LCC per ton for the electric and diesel-electric locomotive consists (New generation and old generation models in both cases) were compiled for activity levels of operations (Mtpa), based on historic South African locomotive performance data of which the results are shown in Figure 21 below

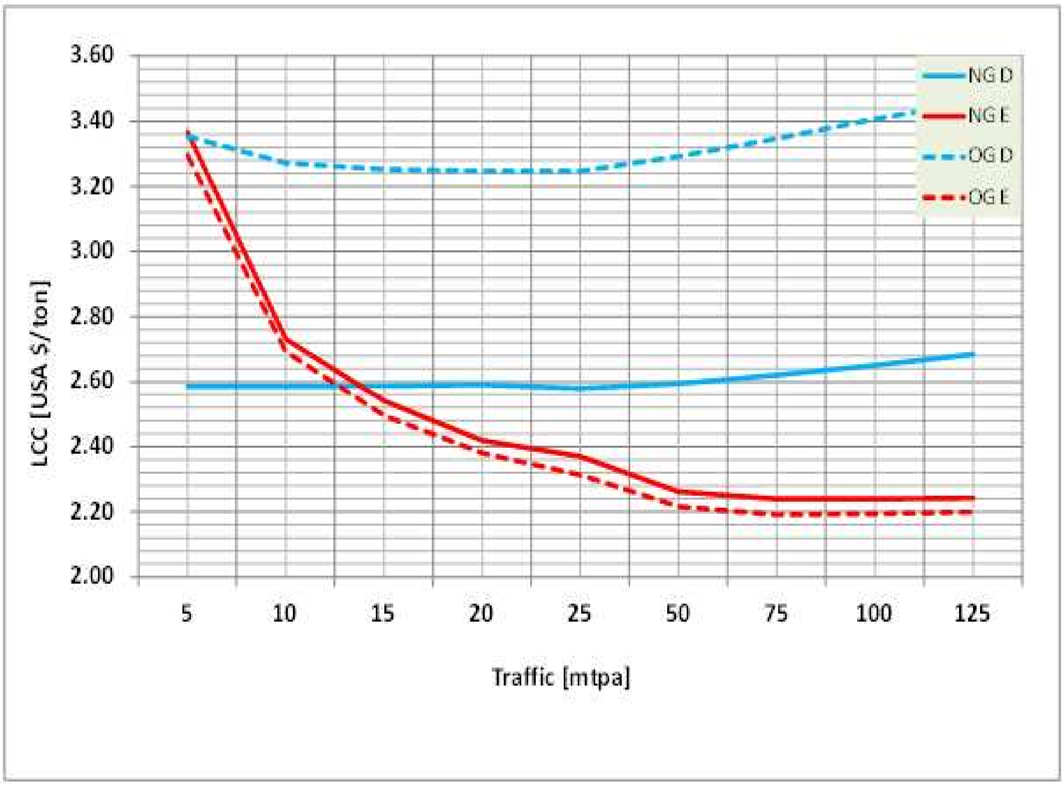

Figure 21 Graph showing the Traffic Demand level versus the Systemic Cost for the various Traction Types

The calculations in the above scenario was based on a route distance =400km, alignment=A, line speed=80kph and loco consist of 4. The breakeven point within a generic analysis occurs at ~5mtpa for electric versus old generation diesel-electric traction and at ~12,5 mtpa for electric versus the new generation diesel-electric traction.

A1.4.4 Objective 2

Illustrate the systemic cost performance differential between new and old generation traction models for both electric and diesel-electric.

The LCC per ton for the electric and diesel-electric locomotive consists (New generation and old generation models in both cases) were compiled for activity levels of operations (Mtpa), based on historic South African locomotive performance data.

The systemic cost differential between new and old generation traction models for both electric and diesel-electric is demonstrated in Figure 22 below.

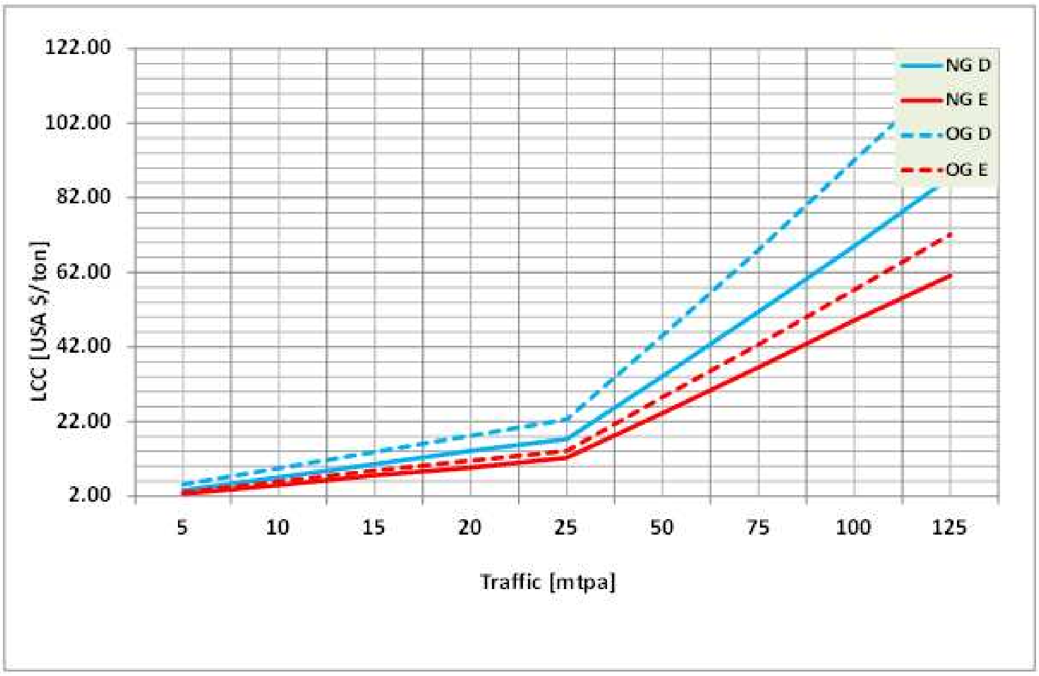

Figure 22 Graph showing the Systemic Cost Performance for the various Traction Types

The calculations in the above scenario was based on locomotive life cycle cost over 20 years for a route distance =400km, alignment=A, line speed=80kph, loco consist of 4 as a function of traffic demand. (Traffic volumes are shown in increments of 5mtpa for 5 to 25 mtpa and changes to increments of 25mtpa from 25 to 125 mtpa) Inspection of Figure 23 and Table 17 of values below shows the operational and technical efficiency improvement of new generation locomotives compared to the old generation locomotive types. In the case of diesel-electric traction, a ~32% improvement has been made between the new generation over the old generation versus a ~17% for electric traction, measured at a traffic level of 50mtpa. Although there has been a significant improvement in the technology of the diesel-electric locomotive type, the performance of electric traction locomotives determined in terms of lower LCC, is still more favourable for this specific scenario.

	Locomotive Type			
	NG D	NG E	OG D	OG E
Traffic [mtpa]	Life Cycle Costs [$/ton]			
5	3.5	2.6	5.1	3.0
10	7.1	5.0	9.5	5.9
15	10.6	7.6	13.8	8.9
20	14.1	9.7	18.2	11.5
25	17.3	12.3	22.5	14.1
50	34.1	24.3	45.1	28.5
75	51.4	36.6	68.0	42.6
100	69.1	49.1	92.1	57.4
125	87.5	61.1	115.9	72.2

Table 17 LCC Results for various Locomotive Types

The LCC results for various locomotive types determined from costing results at activity levels (Mtpa); are shown in the Table 17 above.

The new and old generation electric locomotives are shown to be more economically viable than the new and old generation diesel-electric locomotives as from an activity level of 5 Mtpa to 125 Mtpa.

A1.4.5 Objective 3

Illustrate the impact of the availability or not of the primary electrical energy supply.

The LCC per ton for electric and diesel-electric locomotive consists (new and old generation models in both cases) were compiled for activity levels (Mtpa) for a scenario where the primary electrical energy supply is existing (no capex required) and not existing (additional capex required to construct such primary electrical energy supply)

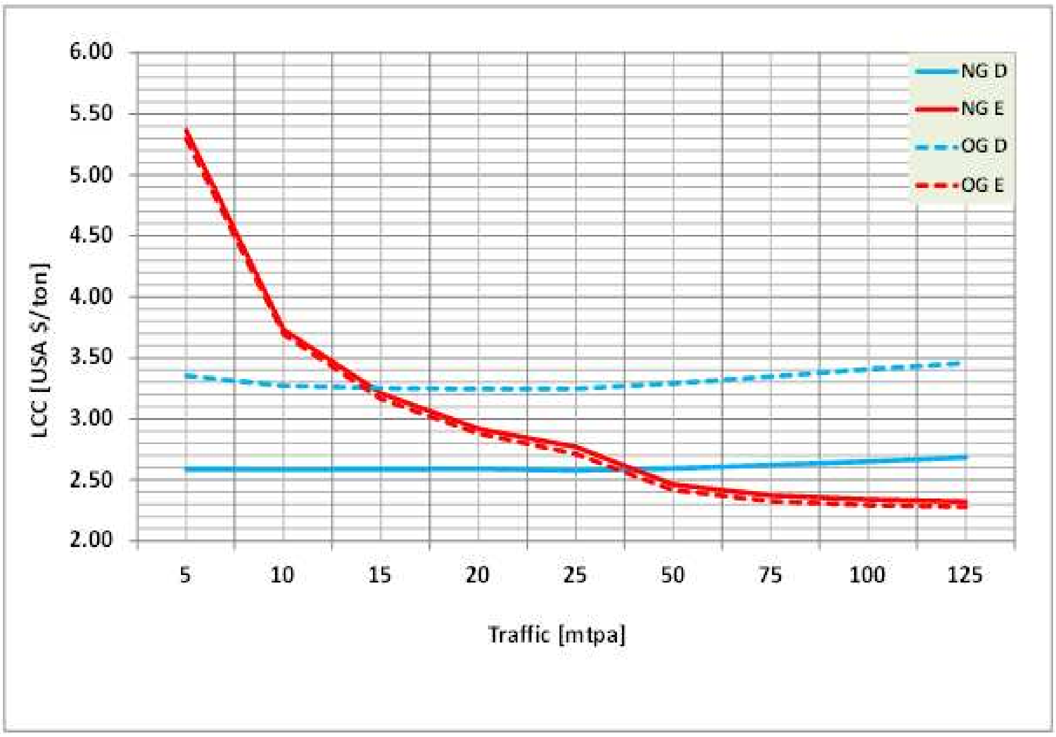

Figure 23 Graph showing the impact of the availability of primary electric energy supply

The calculations in the above scenario (Figure 23) was based on a route distance =400km, alignment=A, line speed=80kph, loco consist of 4 and includes the cost of establishing the primary power network. It is clear that a breakeven point within a generic analysis exists and increases from 5 mtpa (see Figure 21) to ~14mtpa Figure 23 for electric versus old generation diesel-electric traction and from 12.5 mtpa (see Figure 21) to ~37,5 mtpa (Figure 23) for the new generation diesel-electric traction.

A1.4.6 Objective 4

Illustrate the systemic cost impact of running diesel-electric traction where electric traction equipment (OHTE – overhead traction equipment) already exists.

The systemic cost of the logistic chain is fixed in terms of its infrastructure investment. Hence operating diesel-electric traction on a network where the configuration is for electric traction, the diesel-electric traction should contribute towards the infrastructural costs. Should the tariff structure be so amended, then the LCC for diesel-electric traction would be as shown in Figure 24 below.

The Figure 24 below is derived for a locomotive consist of 4, alignment A, route distance of 400 and 800 km and a line speed of 60 and 80 kph.

The NGD LCC is increased by the infrastructural LCC if the NGD is contributing towards it.

Inspection of the curves in Figure 24 compared to that in Figure 25 (NGD without infrastructural cost included) indicate that the “hybrid” use of a network designed and constructed for electric traction, is not beneficial to the rail logistic chain costs.

From Figure 24 it is apparent that irrespective of route distance and/or line speed, the LCC for a hybrid diesel-electric utilisation on an electric network is less favourable in the cases analysed in this Report.

The differential in LCC increases with increasing route distance and decreases with increasing line speed.

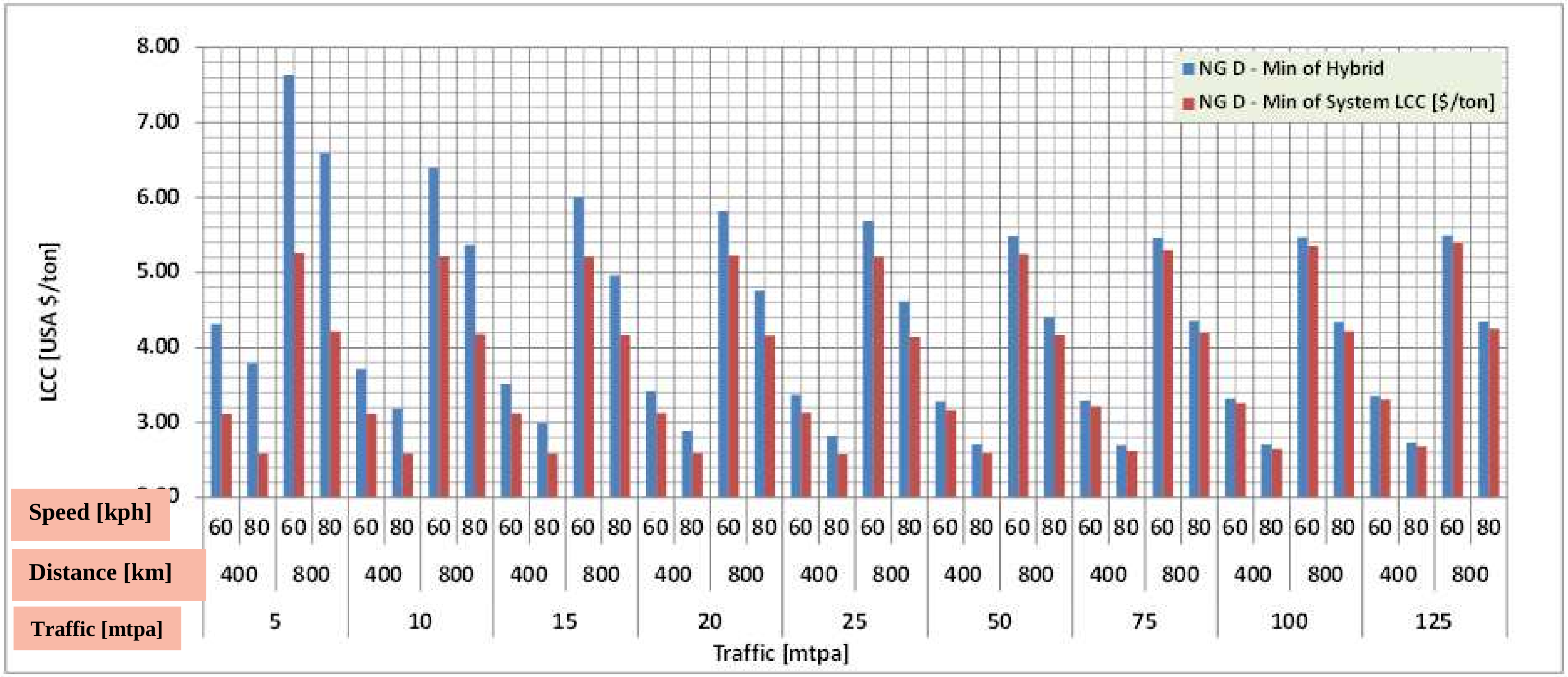

Figure 24 Graph showing the Systemic Cost Impact on diesel traction where OHTE infrastructure exist

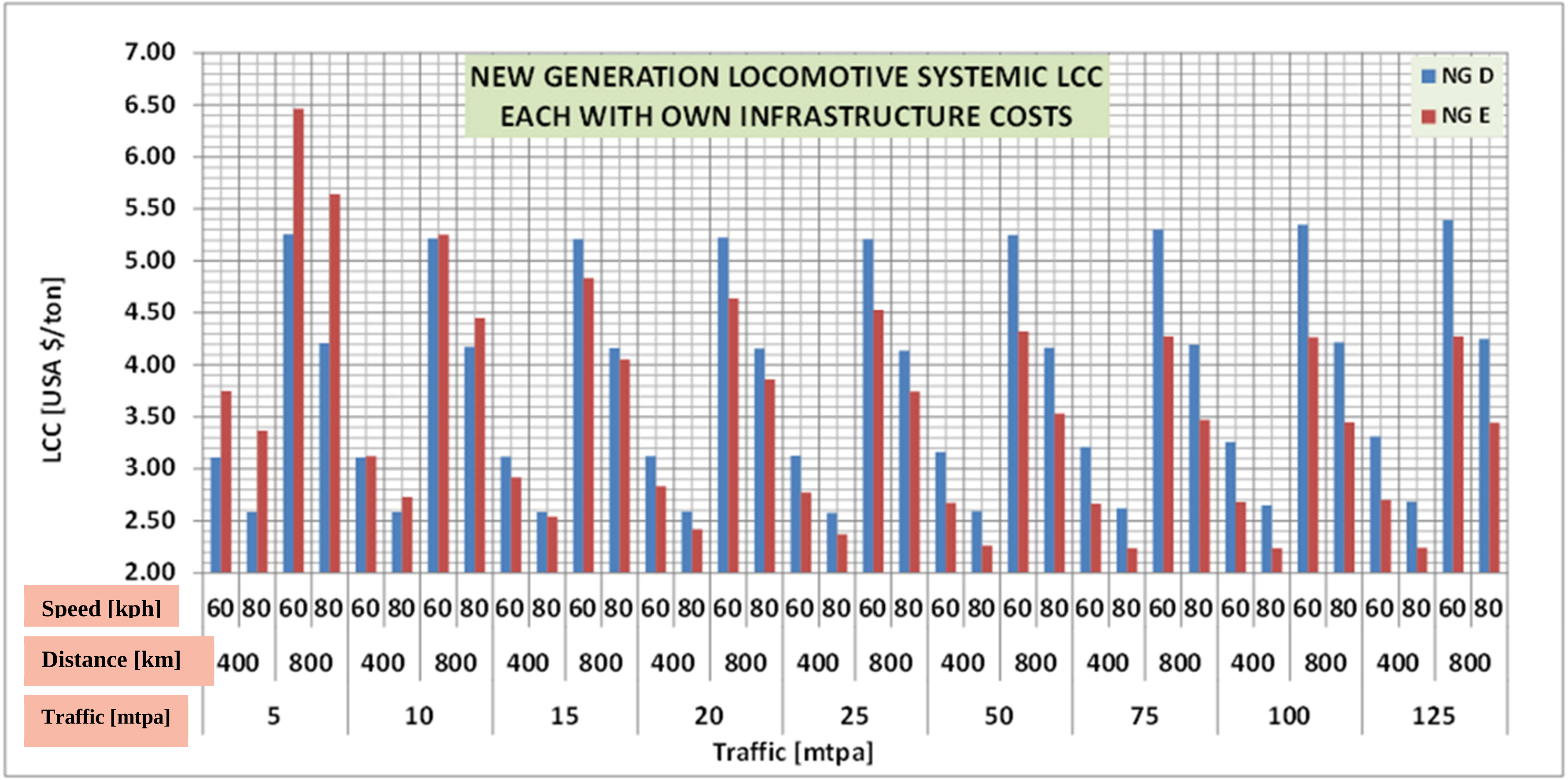

Figure 25 Graph showing the Systemic Cost impact on diesel-electric and electric traction with own infrastructure

In the case where a line has a fixed capacity and is electrified and diesel-electric traction proliferate and continuously absorb more of the capacity of the line, then the LCC for electric traction would increase to the detriment of the logistic chain cost. This is illustrated in Figure 26

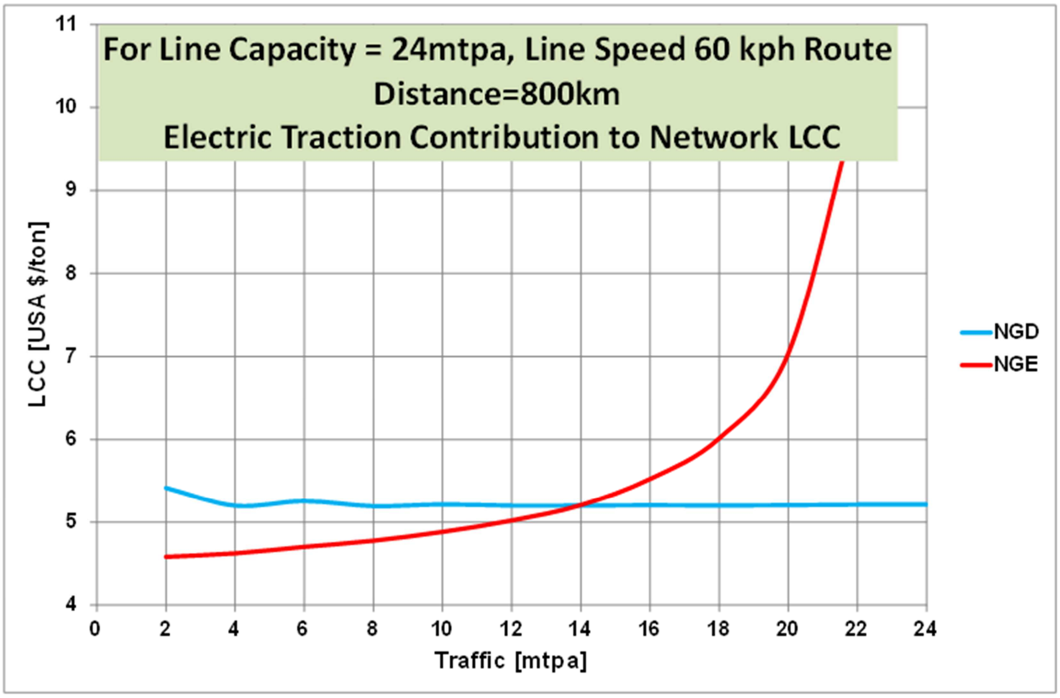

Figure 26 Impact on Electric LCC

With reference to Figure 26 as the diesel-electric traction claims more capacity on the line with the result that the contribution the electric traction needs to make towards the network LCC (US$/ton), increases. As the activity level increases from 14 mtpa onwards, electric traction pays on premium towards the usage of diesel-electric of the rail infrastructure.

A1.5 Conclusions

The following is concluded:-

1. From the observations of the results in Figure 21 above it is apparent that a breakeven point does exist (in this case at 12.5 mtpa) resulting in electrical traction being a more viable alternative than diesel-electric traction, measured In terms of LCC and provided the primary power source already exists. The exact position of the breakeven point is a function of which variable is being considered.

   The value of the analysis is the resultant indication that a breakeven point exists. The continued use of diesel-traction beyond this breakeven point results in a cost which would impede the competitive export of the commodity on that specific logistic chain. The impediment is further increased, should the required OHTE already exist.

2. From Section A1.4.4 above it is apparent that a performance improvement has been realised in terms of Life Cycle Cost as follows:-

    - NGD versus OGD an improvement of 32%;
    - NGE versus OGE an improvement of 17%; and
    - NGE versus NGD an improvement of 40%.

    (The above is based upon an activity level of 50mtpa)

3. From Section A1.4.5 above it is evident that in the case of the primary electrical power source being existent; then the benefits of electric traction over diesel electric traction is realised sooner at an activity level of 5 (see Figure 21) versus 14 mtpa (see Figure 23) for the old generation traction and 12,5 (see Figure 21) versus 37,5 mtpa (see Figure 23) for new generation traction.

    See the summary of break-even volumes in the Table 18 below.

	Break-even Volumes (Mtpa)	
	Electrification Network	
	Existing	Not Existing
OG	5 (Fig 21)	14 (Fig 23)
NG	12.5 (Fig 21)	37.5 (Fig 23)

Table 18 Break-even Traffic Volumes for Electrification Network

4. From Section A1.4.6 above it is evident that the hybrid traction scenario operating on a network, is not beneficial to the LCC of the rail logistic chain. Rather it is considered to be an impediment to the cost competitiveness of the network.

5. With reference to Figure 26; as the diesel-electric traction claims more capacity on the line; the contribution that the electric traction makes towards the network, [LCC (US$/ton)] increases. As from an activity level of 14 mtpa onwards, electric traction pays a premium towards the non-recovery on volumes hauled by diesel-electric traction.

A1.6 Recommendations

Following on the simulation results in this Appendix A and the Recommendation (Section 7 above); the following recommendations are to be considered:-

- Based upon conclusion 1 above a detailed simulation of the existing Route specific environment with its associated tractive effort characteristics, alignment and cost factors should be conducted in order to determine the breakeven point on the QRNN rail network specific conditions;
- An in depth analysis of the driving cost factors of QRNN should be included in the above analysis in order to ensure that the cost factors are representative of the application of best practice and to identify the potential for improvement on the cost factors;
- QRNN should be granted the opportunity to avail them of such a detail analysis in order to reconstruct the tariff structure for industry. What is of cardinal importance is that the analysis must be conducted with a cost to Australia emphasis and not maximum return to a specific industry and/or company; and
- It is recommended that a study be undertaken based on QRNN rail network alignment data (for simulation purposes), QRNN cost factors and network specific efficiency results.

  A network specific analysis should be conducted to determine the break-even points based on optimized capacity analysis.

  The tariff structure should then be compiled for various scenarios based on historic investment levels, redemption scenarios of capital expenditure and optimized operational expenses. The spectrum of tariff structures can then be evaluated with the object of adopting a feasible tariff for the capacity takers.

Appendix B

South African Locomotive Fleet

B1 South African Locomotive Fleet

South African Electric Locomotive Fleet

Class	Wheel Arrangement	Supplier	Manufacturer	Voltage	First Year	Fleet
New GFB		CSR	WICTRA	3kV DC/25kV AC	2014	95
Class 15E	Co-Co	Mitsui /Toshiba	Union Carriage & Wagon	50kV AC 50Hz	2010	76
Class 18E, Series 2	Bo-Bo	Union Carriage & Wagon	Transnet Rail Engineering	3kV DC	2010	90
Class 19E	Bo-Bo	Mitsui / Toshiba	Union Carriage & Wagon	3kV DC/25kV AC	2009	110
Class 18E, Series 1	Bo-Bo	6E1 upgrade	Union Carriage & Wagon	3kV DC	2000	446
Class 7E4	Co-Co	Hitachi - upgrade	Dorbyl	25kV AC, 50Hz	2000	17
Class 14E1	Bo-Bo	50 C/S Group	Union Carriage & Wagon	3kV DC/25kV AC	1994	10
Class 17E	Bo-Bo	6E1 upgrade	Union Carriage & Wagon	3kV DC	1993	134
Class E38	Bo-Bo	Siemens	Union Carriage & Wagon	3kV DC	1993	50
Class 14E	Bo-Bo	50 C/S Group	Swiss Locomotive & Machine Works	3kV DC/25kV AC	1991	3
Class 10E1, Series 2	Co-Co	General Electric Company	Union Carriage & Wagon	3kV DC	1990	50
Class 16E	Bo-Bo	6E1 upgrade	Union Carriage & Wagon	3kV DC	1990	68
Class 10E2	Co-Co	Toshiba	Union Carriage & Wagon	3kV DC	1989	25
Class 10E1, Series 1	Co-Co	General Electric Company	Union Carriage & Wagon	3kV DC	1987	50

Class	Wheel Arrangement	Supplier	Manufacturer	Voltage	First Year	Fleet
Class 10E	Co-Co	Toshiba	Union Carriage & Wagon	3kV DC	1985	50
Class 11E	Co-Co	General Motors	General Motors South Africa	25kV AC, 50Hz	1985	45
Class 6E1, Series 11	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1984	45
Class 7E3, Series 2	Co-Co	Hitachi	Dorbyl	25kV AC, 50Hz	1984	24
Class 12E	Bo-Bo	Union Carriage & Wagon	Union Carriage & Wagon	3kV DC	1983	5
Class 7E2, Series 2	Co-Co	50 C/S Group	Union Carriage & Wagon	25kV AC, 50Hz	1983	40
Class 7E3, Series 1	Co-Co	Hitachi	Dorbyl	25kV AC, 50Hz	1983	44
Class 8E	Bo-Bo	BBC-Siemens	Union Carriage & Wagon	3kV DC	1983	107
Class 6E1, Series 10	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1982	55
Class 7E2, Series 1	Co-Co	50 C/S Group	Union Carriage & Wagon	25kV AC, 50Hz	1982	25
Class 9E, Series 2	Co-Co	General Electric Company	Union Carriage & Wagon	50kV AC, 50Hz	1982	6
Class 6E1, Series 9	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1981	85
Class 7E1	Co-Co	Hitachi	Dorbyl	25kV AC, 50Hz	1980	50
Class 6E1, Series 8	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1979	105
Class 7E	Co-Co	50 C/S Group	Union Carriage & Wagon	25kV AC, 50Hz	1978	100
Class 9E, Series 1	Co-Co	General Electric	Union Carriage & Wagon	50kV AC, 50Hz	1978	25

Class	**Wheel Arrangement**	**Supplier**	**Manufacturer**	**Voltage**	**First Year**	**Fleet**
		Company				
Class Exp AC	Bo-Bo	Union Carriage & Wagon	Transwerk	25kV AC, 50Hz	1978	1
Class 6E1, Series 7	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1977	150
Class 6E1, Series 6	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1975	100
Class 6E1, Series 5	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1974	99
Class 6E1, Series 4	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1973	100
Class 6E1, Series 2	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1971	50
Class 6E1, Series 3	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1971	150
Class 6E	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1970	80
Class 6E1, Series 1	Bo-Bo	Alstom	Union Carriage & Wagon	3kV DC	1969	20
Class 5E1, Series 5	Bo-Bo	Metropolitan-Vickers	Union Carriage & Wagon	3kV DC	1966	225
Class 5E1, Series 4	Bo-Bo	Metropolitan-Vickers	Union Carriage & Wagon	3kV DC	1965	100
Class 5E1, Series 3	Bo-Bo	Metropolitan-Vickers	Union Carriage & Wagon	3kV DC	1964	100
Class 5E1, Series 2	Bo-Bo	Metropolitan-Vickers	Union Carriage & Wagon	3kV DC	1963	130
Class 5E1, Series 1	Bo-Bo	Metropolitan-Vickers	Vulcan	3kV DC	1959	135
Class 5E, Series 3	Bo-Bo	English Electric	Vulcan	3kV DC	1958	55
Class 5E,	Bo-Bo	English	Vulcan	3kV DC	1957	45

Class	Wheel Arrangement	Supplier	Manufacturer	Voltage	First Year	Fleet
Series 2		Electric				
Class 5E, Series 1	Bo-Bo	English Electric	Vulcan	3kV DC	1955	60
Class 4E	1Co+Co1	General Electric Company	North British	3kV DC	1952	40
Class 3E	Co+Co	Metropolitan-Vickers		3kV DC	1947	28
Class 2E	Bo+Bo	Henschel	Siemens	3kV DC	1937	3
Class ES	Bo-Bo	Swiss Locomotive & Machine Works	Metropolitan-Vickers Werkspoor SAR	3kV DC	1936	28
Class 1E & 1ES	Bo+Bo	Swiss Locomotive & Machine Works	Metropolitan-Vickers Werkspoor Robert Stephenson & Hawthorns	3kV DC	1925	172

Table **19** South African Electric Locomotive Fleet

South Africa Diesel-Electric Locomotive Fleet

Class	Wheel Arrangement	Supplier	Supplier Type	Manufacturer	First Year	Fleet
Class 31-000	Bo-Bo	General Electric	U12B	GE	1958	45
Class 32-000	1Co+Co1	General Electric	U18C1	GE	1959	115
Class 32-200	1Co+Co1	General Electric	U20C1	GE	1966	10
Class 33-000	Co+Co	General Electric	U20C	GE	1965	65
Class 33-200	Co+Co	GM-EMD	GL26MC	EMD	1966	20
Class 33-400	Co+Co	General Electric	U20C	RSD	1968	115
Class 34-000	Co+Co & Co-Co	General Electric	GT26MC	RSD	1971	125

Class	Wheel Arrangement	Supplier	Supplier Type	Manufac turer	First Year	Fleet
Class 34-200	Co+Co	GM-EMD	U26C	EMD	1971	50
Class 34-400	Co+Co & Co-Co	General Electric	U26C	RSD	1973	139
lass 34-500	Co-Co	General Electric	U26C	RSD	1974	46
Class 34-600	Co+Co	GM-EMD	GT26MC	GM SA	1974	100
Class 34-800	Co+Co	GM-EMD	GT26MC	GM SA	1978	58
Class 34-900	Co+Co & Co-Co	General Electric	U26C	RSD	1979	30
Class 35-000	Co+Co	General Electric	U15C	GE	1972	70
Class 35-200	Co+Co	GM-EMD	GT18MC	GM SA	1974	150
Class 35-400	Co+Co	General Electric	U15C	RSD	1976	100
Class 35-600	Co+Co	GM-EMD	GT18MC	GM SA	1976	100
Class 36-000	Bo-Bo	General Electric	SG10B	RSD	1975	124
Class 36-200	Bo-Bo	GM-EMD	SW1002	GM SA	1980	101
Class 37-000	Co+Co	GM-EMD	GT26M2C	GM SA	1981	100
Class 39-000	Co+Co	EMD	GT26CU-3	TRE	2006	5
Class 39-200	Co+Co	EMD	GT26CU-3	TRE	2010	50
Class 43-000	Co+Co	General Electric	C30Aci	TRE	2011	100
Class 91-000	Bo-Bo	General Electric	UM6B	GE	1973	20

Table 20 South African Diesel-Electrical Locomotive Fleet