

C H A P T E R

V I

C O N C L U S I O N

VI CONCLUSIONS

This concluding chapter highlights the research contributions of the thesis in investigating the Systems Approach to Petroleum process Engineering in Nigeria. It briefly refers to the limitations of the research study reported in this thesis and brings out further scope for future researchwork.

6.2 PETROLEUM SYSTEM: RESEARCH CONTRIBUTIONS

The research investigation has estimated, the present and future patterns of indigenous demand and supply of oil for the different states of Nigeria during the expected course of its economic development. The inter-zonal petroleum product flows over the transport network have been modelled through a suitably calibrated and validated gravity model with predictive capability for future years. Suitable export-import models turn out to be useful in assessing domestic supply availability for future target years.

It is abundantly clear that the economic development of Nigeria is dependent on its oil resources. In this connection a relatively simple "scenario approach" has been adopted in this thesis for making energy demand projections. Three demand scenarios have been generated.

Scenario I considers the sectoral trends observed in the past to continue in the future. Scenario II considers that the total energy demand mix may change as the country adopts a high energy intensity growth path, and Scenario III considers that the total energy demand mix may change further as energy conservation demand management measures are adopted keeping in mind alternative energy sources which may become viable. The energy

demands in each of the aggregate sectors ,viz, industry, transport, agriculture, comercial/ services/ government and residential sectors, have been computed on the basis of appropriate statistical relations norms identifying major determinants of energy demand to the concerned sectors. Wherever adequate data base has not been found to be available for Nigeria, relationship/ norms similar to those observed in India have been assumed. Energy demand scenario approach results in the preparation of a consolidated scenario which gives complete information about energy supplies of different kinds required over the next 15 years for steering the national economy of Nigeria along the desired lines of planned development.

An underlying objective for studying alternative energy policy options (with particular reference to oil, petroleum products and natural gas) as per three demand scenarios is to demonstrate the importance of energy demand management as an energy policy tool.

The Net Present Value (NPV) concept is useful in the context of Nigerian situation to analyse the implications of international oil market for the development in the Nigerian Petroleum Industry and the economy as a whole. The study proposes different simulation runs that suggest a range of policy options with regard to choices particularly for refining oil and exporting /importing of oil and its products.

Some general policy guidelines may be drawn from the illustrative results obtained for Nigeria. It is interesting to note that the first new FCC refinery of 6 mtpa capacity will be economically viable for Nigeria in 1995-96.

6.3 ENVIRONMENTAL ENGINEERING:RESEARCH CONTRIBUTION

The thesis highlights the petroleum process and environmental engineering impact assessment in the Nigerian Oil Industry and suggested environmentally sound technology for sustainable development. The water, marine, air, and land environments in relation to the refinery processes have been treated in sufficient details. Automotive emission, control and air quality standards and design technological alternative automotive fuels have been advocated in accordance to research and development. Powered gasoline fueled motor cycles, cars and so on are the major sources of vehicular emission of CO and HC pollution. give rise to health problems. Diesel powered heavy vehicles used for transporting goods and services pose air pollution problem by emitting out black smoke. The catalytic converter is relevant to controlling vehicular exhaust CO and HC emissions and provides conversion efficiencies and ease of adaptation to existing vehicular engine. Similarly, reliable carburectr tuning for gasoline fuelled vehicles and enforcement of strict preventive maintenance schedules for diesel powered buses and trucks can contain the vehicular pollution problem.

The study is of the view that any percentage reduction in the vehicles prices without the government using the reduction to install reliable technology in cars and increase the cars prices by a small percentage where people can still buy more cars, is rather meaningless. The environmental engineering planning strategies, policy implementations of the petroleum regulations are highlighted as revealed in chater 2.

6.4 LIMITATIONS OF THE STUDY

Some of the limitations of the present study are identified as follows: The gravity model formulation for the transport network flows of petroleum products is a descriptive technique which in the form used in the thesis assumes the impedance or friction factor to be the distance of separation between origin and destination zones. Accordingly, this version of the gravity model does not truly reflect the dependence of network flows as transportation costs.

The scenario approach for estimating energy demand is data intensive and entails considerable approximations and assumptions in the absence of requisite data base for the Federal Republic of Nigeria.

Naphtha, kerosene, diesel, LPG and fuel oil are the major products of the petroleum industry which are used for household, manufacturing, transport, and agricultural sectors of the economy. The proportions in which these products could be obtained would depend on the type of crude oil that is processed and the technological refining option (eg. FCC,HC) that is exercised over the time-horizon of interest. Each of the import/export (of crude or petroleum product) and technological refining options would imply different economic consequences, such as foreign exchange costs of import of crude oil, operating costs of various refinery processing units, and capital costs of new units. The wide range of such choices in the presence of uncertainties would need to be investigated through a detailed sensitivity analysis on the basis of the proposed NPV (Net Present Value) Methodology to enable robust investment decisions to be made.

6.5 EXTENSIONS AND SCOPE OF FUTURE RESEARCH

Some of the avenues of future research work that may be suggested, based on limitations of the present study as discussed in section 6.4 and further extensions of research work reported in the thesis are as follows:

The Environmental Engineering study in the oil industry indicate the need for more research and development in this sector.

With regard to the petroleum process, there is a considerable scope of extension by way of a wide range of simulations of the Net Present Value model in the form of sensitivity studies. This should then reveal how robust and resilient the decision for NPV would likely be. In making investment priority decisions in this regard fuzzy-set theory and meta-game theory based approaches might also be useful in view of the prevailing imprecision/uncertainty and conflicting interests of the various stake holders.

A mathematical programming construct, such as linear programming and or goal programming formulation, may be introduced in the Petroleum Industry.

A knowledge based expert system (decision support system) may also be designed for petroleum process engineering based on fuzzy logic.

The gravity model formulation for the analysis of petroleum product flows on the transport network in Nigeria could be suitably modified by choosing an appropriate impedance or friction factor which is a function of the transportation cost associated with the concerned links so that the modelling formulation is rendered realistic in reflecting its dependence on transportation

cost also. Other components of level of service could also be accounted for by considering effective transport costs using appropriate direct/indirect methods.

Sectoral energy demand projections need to be made not only at the national level but also at the state level and other sub-regional levels so as to take into account regional disparities between energy supply demand and conversion and end-use technologies. This points to the imperative need for strengthening the existing data base for Nigeria so as to enable suitable energy economy models to be developed on the basis of potential energy reference diagramme for making effective and efficient planning decisions.

In the context of the petroleum policy alternatives, in view of the dynamic and uncertain international market conditions, the NPV (Net Present Value) methodology should be widely simulated in the form of sensitivity studies to investigate the relative economics of the various refining options to help suggest broad policy guidelines regarding the types of hydrocarbon supply and demand management policies that should be adopted for Nigeria.

ANNEXURES

Nigeria imports small fragments of special crude to meet the domestic consumption requirements as shown in Table 3.15. It is possible to identify a compound growth rate Import Model formulated along similar lines as in section (3.10) :

$$I_t^m = I_0^m (1+r_2)^t \quad \dots\dots(3.28)$$

where I_t^m = quantity of crude oil imported in t^{th} year

I_0^m = quantity of crude oil imported in the base year

r_2 = compound import growth rate

t = time in year (1973 = 0)

This model characterizes compound growth of crude oil import over the time period of observation. Taking logarithm on both sides of equation 3.28 one gets :

$$\text{Log } I_t^m = \text{Log } I_0^m + \text{Log } (1+r_2)^t \quad \dots\dots(3.29)$$

The parameters of this straight line eqn. can be determined by obtaining a linear regression plot of $\text{Log } I_t^m$ versus t . For the Nigerian situation the form of relationship among $\text{Log } I_t^m$ and t is as follows :

$$\text{Log } I_t^m = 13.35 - 0.1757t; \quad R^2 = -0.53$$

(0.37)	(0.197)		
{99.9%}	{32.3%}	[46.8%]	\dots\dots(3.30)

On comparing eqn. 3.30 and eqn. 3.29 one gets $\text{Log } (1+r_2) = -0.1757$ and $\text{Log } I_0^m = 13.35$ suggesting a reduction in the import growth rate of crude oil of -0.33% compound. It should also be noticed that the Import Model as identified by eqn 3.30 is neither adequately explanatory nor significant at the 95% confidence level and is therefore not a valid hypothesis.

Accordingly, the Import Model has not been used in conjunction with the gravity model for estimating commodity trans-shipment.

ANNEXURE IV.1 ELECTRICITY CONSERVATION IN INDUSTRY

The sample cost/benefit analysis presented below, refers to the use of motors for a 5 hp (3.73 kw) load. For other loads, similar computations may be made.

Table IV.1.1

	Oversized standard Motor	Proper size standard Motor	Proper size High Eff. Motor	Proper size High Eff. Motor with Power Factor Correction
a. Load(kw)	3.73	3.73	3.73	3.73
b. Motor Rating (kw)	5.00	3.73	3.73	3.73
c. Efficiency (%)	81	83	88.2	88.2
d. Capacitor Rating(kVAR)	-	-	-	0.945
e. Power Factor (%)	83.7	83.7	88.9	96.0
f. Power Demand (kVA)	5.502	5.369	4.757	4.405
g. Energy Demand (kWh)	18420	17976	16916	16916
Source: ICICI (1983).				

d. If the power factor is to improve from 88.9% to 96%, the capacitor rating is computed as follows:

(i) Calculate kVA demand without capacitor:

$$= \frac{3.73}{0.882(0.889)} = 4.757 \text{ KVA}$$

(ii) Calculate active power = $\frac{3.73}{0.882} = 4.229 \text{ kw}$

(iii) Calculate reactive power without capacitor:

$$= \left\{ \frac{4.757^2}{2} - \frac{4.229^2}{2} \right\}^{1/2} = 2.178 \text{ kVAR}$$

(iv) Calculate kVA demand if power factor is to increase to 96%:

$$= \frac{3.73}{0.882(0.96)} = 4.405 \text{ KVA}$$

(v) Calculate reactive power if power factor increases to 96%:

$$= \left\{ \frac{4.405^2}{2} - \frac{4.229^2}{2} \right\}^{1/2} = 1.233 \text{ kVAR}$$

(vi) Capacitor rating = 0.945 KVAR

Assume that the motor operates for 4000 hours per annum.

Table IV.1.2

	Oversized standard Motor	Proper size standard Motor	Proper size High Eff. Motor	Proper size High Eff. Motor with Power Factor Correction
a. Capital cost(N)				
-Motor	3700	2700	4000	4000
-Capacitor	-	-	-	237
-Total	3700	2700	4000	4237
b. Annual Operat ing costs(N)				
-O&M costs	370	270	400	424
-Demand Charge	2311	2255	1998	1850
-Energy Charge	9210	8988	8458	8458
-Total	11891	11513	10856	10732
c. Present value of operating costs(N)	67187	65051	61339	60638
d. Present value of Total costs(N)	70887	67751	65339	64875

- a. Capital costs as in ICICI (1983).
Cost of polypropylene dielectric capacitor = N 250/kVAR.
- b. Demand charge = N 35/KVAR/month; energy charge= N0.5/kWh;
Annual O&M cost for motor= 10% of capital cost.
- c. Assuming 10 years life time of major capital equipment; and
discount rate of 12% per annum.(Conversion rate 1N=1R)
From the calculations above, it is clear that the use of proper
size motors, high efficiency motors and capacitors is likely
to pose less costs to the user. And if the annual motor
utilization rates increase, or if electricity generation costs
are to increase further, the relative benefit to the society,
of using even standard motors of proper size (instead
of oversized motors), or high efficiency motors with power factor
correction equipment, will increase further. It is against this
background that the electricity intensity is conservatively
projected to reduce by 8% by 2005/06 for three industrial categories.

ANNEXURE IV.2 FUEL OIL AND COAL CONSERVATION IN INDUSTRY.

Fuel Oils and non-coking coals are used largely in Industrial boilers and furnaces. As the boiler flue gas temperatures are usually between 300⁰ C to 400⁰ C in some industries, waste heat may be recovered from flue gases and used either to preheat the inlet air, or to heat boiler feedwater. According to Chiogoji [], air preheaters are usually employed for boilers of capacity more than 20 tph, while economizers are used for boilers of size less than 20 tph. ICICI (1983) also conservatively estimates that a boiler's overall thermal efficiency improves by 5% at least if such heat recovery equipment is installed. A sample calculation below reveals the relative social benefits of retrofitting a boiler which generates steam at the rate of 10 tonnes per hour (tph). Likewise, Inter-Ministerial Working Group IMWG [36] also notes that fuel savings of 15% to 30% could be achieved by retrofitting furnaces with preheaters (recuperators or regenerators) which preheat the inlet combustion air. This is particularly so because (in 1981/82) over 80% of furnaces in the industry let out flue gases at temperatures over 500⁰ C. And even if the costs of retrofits were as high as that of the furnace, the rate of return is likely to be attractive if 20% or more fuel savings are achieved IMWG [36].

Table IV.2.1

	Boiler only	Boiler with Economizer
a. Capacity (tph)	10	10
b. Ave. efficiency(%)	50	55
c. Annual utilizationHrs	6500	6500
d. EnergyInput(kCal/annum)	7.215x10 ¹⁰	6.5591x10 ¹⁰
e. Coal Required (tonnes)	14430	13118.2
f. Capital cost(Naira000)		
boiler	X	X
economizer	-	350
g. Annual Operating cost (N000)		
D&M cost of boiler	y	y
D&M cost of economizer	-	70
Coal costs	3305	3004
h. PV of Annual Operating costs(N000)	y'+24,687	y'+22788
i. PV of capital costs and Annual operating costs(N000)	{ X+y'+24,687 }	{ X+y'+22788 }

Notes

- b. typical boiler efficiency in Industry is 50%(IMWG, 1983a)
- c. typical annual utilization rate(ICICI, 1983).
- d. heat required to generate steam:
 555 kCal/kg of steam(Chiogioji, 1979)
 = -----
 efficiency
- e. 500 kCal/kg coal.
- f. Max. capital cost for an economizer which may be retrofitted to a boiler of size 10 tph [9]. Includes installation costs.
- g. Maxi. annual D&M cost for an economizer is 20 % of capital cost(Chiogioji, 1979). Average cost of extracting 1 tonne of coal from recently sanctioned open -cast coal mining projects is Naira 229/tonne (Nigeria Planning Commission, 1986).
- h. Assume a life time of 20 years; and social rate of discount of 12 % p.a.

The table above indicates that less costs to the society are incurred (over a 20 year time period), if a boiler is retrofitted with an economizer. This is shown even if only a 5% increase in overall efficiency is achieved, with a corresponding reduction in non-coking coal consumption. The relative benefit of course is higher if a reduction in fuel oil consumption is effected

(because the cost of fuel oil per tonne is more than twice that of coal, while the calorific value is only twice), or if coal extraction costs increase further. It may also be noted in the calculation above that coal transport costs (from the pit-head to the user) are not included--a reduction in coal transport needs may itself imply added benefits to the society. Furthermore, similar calculations for a boiler of higher capacity reveal a relatively higher reduction in social costs because the cost of retrofits increases less than proportionally with increase in boiler size.

ANNEXURE IV.3 LOW GRADE SOLAR THERMAL APPLICATIONS IN INDUSTRY.

A fairly large range of industries offer a potential market for both solar hot water and hot air systems. According to Advisory Board on Energy (1984), these include textiles, chemicals, paints, dairies etc. for hot water systems; and agroforestry based processing industries such as timber, tea, pepper, cardamom etc. for hot air systems. In India collector area of over 6100 square metres had been installed in various industrial establishments. Table IV.3.1 shows the data for an economic analysis of a 10,000 litres per day IPWH system which provides hot water at 65 C, vis-a-vis a conventional furnace oil boiler. The system design parameters are based on an actual installation in India. A collector area of about 150 square metres is required, which is based on the design with a special point such that the solar fraction of annual energy requirements is approximately 80%. The remaining 20% of energy requirements would be met from a conventional back-up system--the furnace oil boiler itself. For analytical purposes therefore, it is assumed that the solar IPWH system is a retrofit

on an existing boiler. Other assumptions are that the gross boiler efficiency is 50% and the system is to be used for about 300 days per year—typical situations in a country like India or even Nigeria . The capital cost of solar IPWH system is based on the actual experience of several projects already installed or under installation in India or Nigeria :Rs 50/N50 to Rs60/N60 per litre of hot water at 60-65 C . Therefore, a capital cost of Naira 550,000 is assumed for the solar IPWH system for the base case analysis. However, keeping in view that more cost-effective light weight solar thermal systems with polymer film collectors are anticipated to emerge in the future,an alternative system capital cost of Naira 350,000 is also assumed for sensitivity analysis [60].

Table IV.3.1

	<u>Conventional system</u>	<u>Solar IPWH with conventional back-up</u>
Capacity(lpd)	10,000	10,000
Inlet water Temp(C)	20	20
Outlet water temp(C)	65	65
Annual utilization (days)	300	300
Furnace Oil Cons. (t/year)	26.6	5.3
Economic Life (years)*	15	15

*typical lifetime for medium to large solar IPWH installations.

Although the economic life of a boiler may be very different, it is not of direct relevance for the purpose of a comparative analysis.

Table IV.3.2

Solar IPWH with conventional back-up			
Conventional system		Current	Alternative
a. Capital Cost (N000)			
-boiler	X	X	X
-IPWH	-	550	350
b. Annual Operating Costs (N000)			
- O&M cost of boiler	y	y	y
-O&M cost of IPWH system	-	11	7
c. PV of Annual operating costs (N 000)			
	y'+453	y'+165	y'+138
d. Present value of capital costs and Annual operating costs (N 000)			
	X+y'+453	X+y'+715	X+y'+488
Notes			

a. Furnace oil price =N2000/tonne. This is multiplied by 1.25 to obtain the shadow price of furnace oil—an internationally traded commodity. The factor of 25% is added to reflect the scarcity of foreign exchange in a developing country.

b. Assuming life time of 15 years, and social rate of discount of 12% per annum.

The calculations in table V.3.2 above assume no subsidy for solar IPWH systems, as is the practice in India/Nigeria today. A subsidy of as much as 75% on capital cost can be offered by the Government. However, it is relatively clear from Table V.3.2 that solar IPWH systems with light weight, plastic collectors are likely to be an attractive alternative from the society's viewpoint, particularly if furnace oil price levels are to increase.

For coal fired systems, if one takes into account costs associated with transportation, storage handling and ash disposal as well, the solar IPWH system may again become an economically viable alternative.

Source: ICICI (Industrial Credit and Investment Corporation of India) Energy Utilization and Conservation Equipment: Boilers, Furnaces, Electric Motors, and Instrumentation, Proceedings of a Workshop on Energy, Bombay (1983).

(Inter-Ministerial Working Group), (1983), a Report on Industrial Energy Conservation: Policies and Programmes, GOI, New Delhi.

ANNEXURE IV.4

(i) As per the Nigerian Government document: Haulage of Essential Goods and Passenger Services—Role of Nigerian Railway Corporation and National Transport Development Corporation, the share of passenger traffic and freight traffic among various modes of transport are as given in Tables A.4 and A.4.1

TABLE A 4

	ROAD	RAIL	WATER	AIR	TOTAL
Passenger traffic in %	60	20	12	8	100
ratio: Passenger traffic by Road				60	
Passenger traffic by rail				20	
					= 3

TABLE A 4.1

Freight traffic in %	ROAD	RAIL	WATER	AIR&PIPELINE	
	50	25	15	10	
ratio: Freight Traffic by Road				50	= 2
Freight Traffic by Rail				25	

(ii) Based on the data sources as referred in subsection (i) above, the data statistics on passenger traffic by rail and freight traffic by rail as given in the Fifth National Plan are fitted in the form of statistical regression equations (4.17 and 4.18) as shown in Tables A 4.2 and A 4.3 respectively by including forecasts for the horizon years 1995, 2000, and 2005 as obtained from the foregoing regression equations.

TABLE A 4.2

PASSENGER TRAFFIC BY RAIL IN MILLION

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000	2005
Mil.	12.5	13.0	15.5	16.5	17.5	18.5	19.5	20.5	21.3	27.35	32.7	38.6

TABLE A 4.3

FREIGHT TRAFFIC BY RAIL IN MILLION TONNE

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000	2005
Miltne.	1.278	1.8	2.9	3.5	4.0	4.3	4.5	4.7	4.9	7.61	9.88	12.148

Source: Nigerian Railway Corporation and National Transport Devel.Co.

$$Y_1 = 0.11558 \times 10^2 + 0.11283 \times 10^{-1} X ; R = 0.9903 \dots \text{equation (4.17)}$$

$$S.D (0.3353796 \times 10^0) (0.5959852 \times 10^{-1})$$

F {99.9999%} {99.9998%} [0.9999]

where Y1= Passenger traffic in million by rail

X= time in years (1982=1)

$$Y_2 = 0.12763 \times 10^1 + 0.453133 \times 10^0 X ; R = 0.9566 \dots \text{equation(4.17a)}$$

$$S.D (0.2933 \times 10^0) (0.5213 \times 10^{-1})$$

F {99.83%} {99.99%} [0.9999]

where Y2 = Freight traffic in million tones by rail

X=time in years (1982=1)

(iii) Given the benefit of passenger and freight traffic by rail as compiled in Tables A 4.2 and A 4.3, we may compute the

corresponding passenger and freight traffic by road for any selected year by invoking relevant ratios as determined in step (i) above. The resulting passenger and freight traffic by road are tabulated in Tables A 4.4 and 4.5.

TABLE A 4.4

PASSENGER TRAFFIC BY ROAD IN MILLION.

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000	2005
Million	37.5	39.0	46.5	49.5	52.5	55.5	58.5	61.5	63.9	82.06	98.1	115.9

TABLE A 4.5

FREIGHT TRAFFIC BY ROAD IN MILLION TONNE

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000	2005
Mill Tonne	2.556	3.6	5.8	7.0	8.0	8.6	9.0	9.4	9.8	15.236	19.76	24.3

ANNEXURE IV.5 MINIMUM PERMISSIBLE SPEED OF GOODS ROLLING STOCK (CME/GRC FILE NO.2629)

Wagon No.	of CC	TARE	Gross	Length	over	Max.	Permissible	Remark
Type	Wheels	Tonn-	Tonn-	MM	FT.	IN	LOADED	EMPTY
		-es	es					
BCN (8)		55.8	25.5	81.28	15429			
cv/kc	4	23.47	9.4	32.51	72124	23-8	75	75
crt	4	27.54	13.10	40.64	8824		75	75
t1	4	18.29	12.40	30.69	7211	28-8	65	65
bto	8	44.1	20.9	65.00	1261		65	65
torx	4	20.00	12.5	32.5	8280	22-2	65	65
tp	4	17.57	14.93	32.5	8280	22-2	65	65
bob	8	55.62	25.65	81.27	12852	42-2	75	75
bobc	8	45.57	19.45	65.02	10006	32-10	75	75
bobx	8	63.8	27.7	91.7	11596	38-1/2	56	56
						3		
bobs	8	61.21	30.23	91.44	11638	38-3/4	32	48 monsoon
							40	56 non monsoon
bobsmarkII								
22.8axle								
ld	8	61.2	30.4	91.6	11597		48	75
bobsmarkI								
20.32axle								
load	8	61.21	30.23	91.44	11678	38-3	75	75
						1		
boxt	8	54.6	26.7	81.3	14082	48-2/2	65	65
box	8	56.1	25.2	81.3	13716	45-0	65	65
boxn	8	58.81	22.47	81.28	10713	35-1	75	80

boxn	8	58.81	22.47	81.28	10713	35-1	75	75
bkcx	8	55.6	25.7	81.3	14070	46-2	65	65
boxmarkI	8	55.04	26.2	81.26	14082		75	75
boxmarkII	8	55.04	26.2	81.28	14082		75	75
boI	8	58.3	23.0	81.3	11615	38-1 3/4	75	75
boy	8	70.4	20.2	91.47	11930	39-1 1/2	65	65
brh	8	57.4	23.9	81.3	14986	49-2	75	75
brht	8	57.4	23.9	81.3	14998		75	75
tpgltank4		20.10	11.17	31.17	8352		75	75
bws	24	132.9	91.44	223.53	27559	90-5	30	75
bhs		91.4	45.7	137.1	18800		30	50
bhs/bw		91.44	43.95	135.49	20472	67-2	50	50
bcxmarkI	8	52.8	28.98	81.28	15710		75	75
bcxmarkII	8	52.3	28.98	81.28	16782	80-10	80	100
bvgt	4	-	12.7	12.7	7261	23-10	65	65

wagontype cc tonnes tare tonnes grosstonnes multiplyingfactor C=
gross weight in tonnes/
CC weight in tonnes

bcn	55.8	25.5	81.28	1.456
crt	27.54	13.10	40.69	1.4777
tl	18.29	12.40	30.69	1.6779
bto	44.1	20.9	65.00	1.473
torx	20.0	12.5	32.5	1.625
ip	17.57	14.93	32.5	1.849
bob	55.62	25.65	81.27	1.4611
bobc	45.57	19.45	65.02	1.4268
bobs	61.21	30.23	91.44	1.4938
bobsmarkII	61.2	30.4	91.6	1.49673
bobsmarkI	61.21	30.23	91.44	1.49387
boxt	54.6	26.7	81.3	1.4890
box	56.1	25.2	81.3	1.44919
boxn	58.81	22.47	81.28	1.3820
boxn	58.81	22.47	81.28	1.3820
bkcx	55.6	25.7	81.3	1.4622
boxmarkI	55.04	26.2	81.26	1.4763
boxmarkII	55.04	26.2	81.28	1.4767
boI	58.3	23.0	81.3	1.3945
boy	70.4	20.2	91.47	1.29928
brh	57.4	23.9	81.3	1.41637
brht	57.4	23.9	81.3	1.41637
tpgltank	20.10	11.17	31.17	1.5507
bws	132.9	91.44	223.53	1.6819
bhs	91.4	45.7	137.1	1.5
bhs/bw	91.44	43.95	135.40	1.4807
bcxmarkI	52.8	28.98	81.28	1.5393
bcxmarkII	52.3	28.98	81.28	1.5541
bvgt	-	12.7	12.7	1.5541

Source: RITES

Three Tier Sleeper: Weight of coach = 41.7 tonnes. Pay load=5.82 tonnes
Gross weight = 47.52 tonnes. Multiplying factor = 47.52/5.82 = 7.01.
Source: Research Design Standard Organization Lucknow India.

ANNEXURE IV.6a (i). RAIL TRAFFIC ENERGY DEMAND SCENARIO I RESULTS

$$E_{1t} = \sum_{i=1}^3 n_{1it} f_{it} R_t \text{ (type } i = 1 \text{ for steam, } 2 \text{ for diesel, } 3 \text{ for electric locomotion)}$$

where E_{1t} = total energy demand

n_{1it} = energy consumption intensity for locomotion type i in year t ,

f_{it} = share of total rail traffic by locomotion type i

R_t = total rail traffic in year t (billion gross t km)

$$E_{1t} = (n_{11t} f_{1t} + n_{12t} f_{2t} + n_{13t} f_{3t}) R_t$$

$$n_{11t} = 0.07 \text{ mtoe/bgtkm (steam locomotion)}$$

$$n_{12t} = 0.0038 \text{ mtoe/bgtkm (diesel locomotion)}$$

$$n_{13t} = 0.004 \text{ mtoe/bgtkm (electric locomotion)}$$

For 1990 :the relative shares are $f_{1t} = 15\%$ for steam locomotion,

$f_{2t} = 52\%$ for diesel locomotion, $f_{3t} = 33\%$ for electric locomotion

$$E_{1t} = (0.07 \times 0.15 + 0.0038 \times 0.52 + 0.004 \times 0.33) 11.774$$

$$= (0.0105 + 0.001976 + 0.00132) 11.774$$

$$= (0.123 + 0.023 + 0.01554) = 0.16154 \text{ mtoe}$$

with respective shares of steam, diesel and electric locomotions being 76.10% , 14.32% and 9.5679%

For 1995: shares, steam locomotion 10%, diesel locomotion 55%, and electric locomotion 35%,

$$E_{1t} = (0.07 \times 0.10 + 0.0038 \times 0.55 + 0.004 \times 0.35) 16.319$$

$$= (0.007 + 0.00209 + 0.00140) 16.319$$

$$= (0.114233 + 0.03410671 + 0.0228466) = 0.17118631 \text{ mtoe}$$

with respective shares of steam, diesel and electric locomotions being 66.73%, 19.9% & 13.3%

For 2000, the relative shares, are steam locomotion 2%, diesel locomotion 60%, electric locomotion 38%

$$E_{1t} = (0.07 \times 0.02 + 0.0038 \times 0.6 + 0.004 \times 0.38) 20.199$$

$$=(0.0014+0.00228+0.00152)20.199$$

$$= (0.0282786 + 0.04605372 + 0.03070248) = 0.1050348 \text{ mtoe}$$

with respective shares of steam, diesel and electric locomotions being 26.9%, 43.8% and 29.2%,

For 2005, the respective shares are steam locomotion 0%, diesel locomotion electric locomotion 40%

$$E1t = (0.07 \times 0.0 + 0.0038 \times 0.60 + 0.004 \times 0.40) 24.335$$

$$= (0.0 + 0.00228 + 0.0016) 24.335$$

$$= (0 + 0.0554838 + 0.038936) = 0.0944198 \text{ mtoe}$$

with respective shares of steam, diesel and electric locomotions being 0%, 58.7% and 41.2%

(ii.) Rail Traffic Energy Demand Scenarios II and III Results

$$\text{For 1990: } E1t = (0.07 \times 0.15 + 0.0038 \times 0.52 + 0.004 \times 0.33) 11.774$$

$$= (0.0105 + 0.001976 + 0.00132) 11.774$$

$$= (0.123627 + 0.023265424 + 0.01554168) = 0.16154 \text{ mtoe}$$

with respective shares of steam, diesel and electric locomotions being 76.1%, 14.3% and 9.56%

$$\text{For 1995: } E1t = (0.07 \times 0.10 + 0.0038 \times 0.55 + 0.004 \times 0.35) 15.636$$

$$= (0.007 + 0.00209 + 0.00140) 15.636$$

$$= (0.109452 + 0.03267924 + 0.0218904) = 0.16402164 \text{ mtoe}$$

with respective shares of steam, diesel and electric locomotions being 66.7%, 19.9% and 13.3%

$$\text{For 2000: } E1t = (0.07 \times 0.02 + 0.0038 \times 0.6 + 0.004 \times 0.38) 18.629$$

$$= (0.0014 + 0.00185 + 0.00152) 18.629$$

$$= (0.0260806 + 0.0344636570 + 0.02831608) = 0.08886 \text{ mtoe}$$

with respective shares of steam, diesel and electric locomotions being 29% , 38% and 31%

$$\begin{aligned}
 \text{For 2005: E1t} &= (0.07 \times 0.0 + 0.0038 \times 0.60 + 0.004 \times 0.40) 21.525 \\
 &= (0.0 + 0.00228 + 0.0016) 21.525 \\
 &= (0 + 0.049077 + 0.03444) = 0.083517 \text{ mtoe}
 \end{aligned}$$

with respective shares of steam, diesel and electric locomotions being 0%, 58.76% and 41.237%

ANNEXURE IV.6b i. Road Traffic Energy Demand Scenarios I, II and III

The following data on energy consumption intensity norms are used for making projections:

- (i) 0.04712 mtoe/billion (bp-km) for cars/taxis, (nat)
- (ii) 0.01543 mtoe/bpkm for 2/3 wheelers, (nbt);
- (iii) 0.00581 mtoe/bpkm for buses, (n22t) and
- (iv) 0.05226 mtoe/btkm for trucks, (n21t)

The former two are based on an average occupancy rate of 2 and 1 for the two types of vehicles respectively. Although the occupancy rate of "1" for 2/3 wheelers may not be correct. It is assumed for further computations as other reliable estimates are not available.

Based on number of cars/taxis and 2/3 wheelers n23t can be computed for different years by invoking equation (4.12) (Tables 5, and 6).

TABLE 5
Data showing number of vehicles in the past year

	units	1976	1977	1978	1979	1980	1981
No. of cars	thousands	45495	77706	66260	61679	75413	82873
No. of 2/3 wheelers	"	119605	147333	133680	120000	134236	194314
No. of buses	"	47293	78564	60185	66060	80112	91385
No. of trucks	"	25803	43683	46710	61931	75105	85673

Source: Digest of Statistics Vol.28, 1981 Federal Office of Statistics, Lagos Nigeria and Ministry of Transport.

(i) Regression equation for cars/taxis is shown below:

$$Y = 0.52206 \times 10^5 + 0.43813 \times 10^4 X^2, R = 0.5381 \dots (4.17b)$$

S.D(0.131413 × 10⁵) (0.39622 × 10⁴)

F {98.57%} {82.52%} [0.6504]

where Y = no. of cars/taxis in thousands

X = Time in years (1976=1)

(ii) Regression equation for 2/3 wheelers:

$$Y = 0.1094706 \times 10^6 + 0.9159257 \times 10^4 X^2, R = 0.6152 \dots (4.17c)$$

(0.228547 × 10⁶) (0.58685 × 10⁴)

{99.56%} {90.319%} [0.80639]

where Y = no. of 2/3 wheelers in thousands

X = Time in years (1976=1)

(iii) Regression equation for buses:

$$Y = 0.475017 \times 10^5 + 0.65994 \times 10^4 X^2, R = 0.778 \dots (4.17d)$$

(0.10367 × 10⁵) (0.266906 × 10⁴)

{99.49%} {96.58%} [0.9317]

where Y = no. of buses in thousands

X = Time in years (1976=1)

(iv) Regression equation for trucks:

$$Y = 0.156004 \times 10^5 + 0.11681 \times 10^5 X^2, R = 0.9914 \dots (4.17e)$$

(0.29915 × 10⁴) (0.76816 × 10³)

{97.67%} {99.99%} [0.999]

where Y = No. of trucks in thousands

X = Time in years (1976=1)

These regression equations are neither significant at 95% level nor highly explanatory. However these have still been used to estimate energy consumption in the absence of more reliable estimates.

TABLE 6
Number of Vehicles computed for 1990-2005 based on regression

units	1990	1995	2000	2005
No. of cars thousand	122302	144207	166112	188017
No. of 2/3 wheelers "	256014	301809	347604	393399
No. of buses "	153085	186080	219075	252070
N. of trucks "	202496	260901	319306	377711

Based on no. of cars and 2/3 wheelers we compute n23t for different years as follows,

For 1990:

$$\begin{aligned}
 n23t &= \frac{(0.04712 \times 2 \times 122302) + (0.01543 \times 256014)}{(2 \times 122302) + (1 \times 256014)} \\
 &= \frac{(11525.74048) + (3950.29602)}{(244604) + (256014)} = \frac{15476.0365}{500618} = 0.0309137 \text{ mtoe}
 \end{aligned}$$

$$\begin{aligned}
 \text{For 1995, } n23t &= \frac{(0.04712 \times 2 \times 144207) + (0.01543 \times 1 \times 301809)}{(2 \times 144207) + (1 \times 301809)} \\
 &= \frac{13590.06768 + 4656.91287}{288414 + 301809} = \frac{18246.98055}{590223} = 0.0309154 \text{ mtoe}
 \end{aligned}$$

$$\begin{aligned}
 \text{For 2000, } n23t &= \frac{(0.04712 \times 2 \times 166112) + (0.01543 \times 347604)}{(2 \times 166112) + (1 \times 347604)} \\
 &= \frac{15654.39488 + 5363.52972}{332224 + 347604} = \frac{21017.9246}{679828} = 0.030916532 \text{ mtoe}
 \end{aligned}$$

$$\begin{aligned}
 \text{For 2005, } n23t &= \frac{(0.04712 \times 2 \times 188017) + (0.01543 \times 393399)}{(2 \times 188017) + (1 \times 393399)} \\
 &= \frac{17718.72208 + 6070.14657}{376034 + 393399} = \frac{23788.86865}{769433} = 0.03091740 \text{ mtoe}
 \end{aligned}$$

Result that $E2t = n21tF2t + n22Put + n23Prt$

We may use for $n21t$ and $n22t$, the values given earlier in this section for $F2t$, Put and Prt thus the values given in Table 5.6 and for $n23t$ the values as calculated above for different years.

ii. Total Energy Demand for Road Transport: Scenario I

$$\begin{aligned} \text{For 1990} = t1: E2t1 &= n21t1 F2t1 + n22t1 Put1 + n23t1 Prt1 \\ &= 0.05226 \times 5.00 + 0.00581 \times 7.98 + 0.0309137 \times 7.98 \\ &= 0.2613 + 0.0463638 + 0.2466913 = 0.5543551\text{mtoe} \end{aligned}$$

$$\begin{aligned} \text{For 1995} = t2: E2t2 &= n21t2 F2t2 + n22t2 Put2 + n23t2 Prt2 \\ &= 0.05226 \times 7.78 + 0.00581 \times 10.24 + 0.0309154 \times 10.24 \\ &= 0.4065828 + 0.0594944 + 0.3165737 = 0.7826509\text{mtoe} \end{aligned}$$

$$\begin{aligned} \text{For 2000} = t3: E2t3 &= n21t3 F2t3 + n22t3 Put3 + n23t3 Prt3 \\ &= 0.05226 \times 10.08 + 0.00581 \times 12.26 + 0.030916532 \times 12.26 \\ &= 0.5267808 + 0.0712306 + 0.3790362 = 0.9770476\text{mtoe} \end{aligned}$$

$$\begin{aligned} \text{For 2005} = t4: E2t4 &= n21t4 F2t4 + n22t4 Put4 + n23t4 Prt4 \\ &= 0.05226 \times 12.41 + 0.00581 \times 14.48 + 0.030917401 \times 14.48 \\ &= 0.6485466 + 0.0841288 + 0.4476839 = 1.1803594\text{mtoe} \end{aligned}$$

iii. Total Energy Demand for Road Transport: Scenarios II and III

$$\begin{aligned} \text{For 1990} = t1: E2t1 &= n21t1 F2t1 + n22t1 Put1 + n23t1 Prt1 \\ &= 0.05226 \times 5.00 + 0.00581 \times 7.98 + 0.0309137 \times 7.98 \\ &= 0.2613 + 0.0463638 + 0.2466913 = 0.5543551\text{mtoe} \end{aligned}$$

$$\begin{aligned} \text{For 1995} = t2: E2t2 &= n21t2 F2t2 + n22t2 Put2 + n23t2 Prt2 \\ &= 0.05226 \times 8.16 + 0.00581 \times 9.64 + 0.0309154 \times 10.87 \\ &= 0.4264416 + 0.0560084 + 0.3360504 = 0.8185004\text{mtoe} \end{aligned}$$

$$\begin{aligned} \text{For 2000} = t3: E2t3 &= n21t3 F2t3 + n22t3 Put3 + n23t3 Prt3 \\ &= 0.05226 \times 10.97 + 0.00581 \times 10.79 + 0.030916532 \times 13.73 \\ &= 0.5732922 + 0.0626899 + 0.4244835 = 1.0604656\text{mtoe} \end{aligned}$$

$$\text{For 2005} = t4: E2t4 = n21t4 F2t4 + n22t4 Put4 + n23t4 Prt4$$

$$= 0.05226 \times 13.95 + 0.00581 \times 11.88 + 0.030917401 \times 17.09$$

$$= 0.729027 + 0.0690228 + 0.5283783 = 1.3264282 \text{ mtoe}$$

ANNEXURE V.6c Water Transport Energy Demand Results

Water Transport: $V3t$ has been obtained for different years using regression equation given in section 4.3.3.1 and 4.3.4.3 (Tables 4.9 and 4.12).

For 1990 : Given $V3t$ = value added in water transport = 13.96 bN

$$= V3ft + V3dt$$

$$= (8.7948 + 5.1652) \text{ billion naira}$$

= (value added in furnace oil) + (value added in diesel oil powered
powered vessels) vessels)

$$= 0.63V3t + 0.37 V3t$$

Energy consumption intensity for water transport in year t

if furnace oil is used = $n3f = 0.3826 \text{ mtoe/billion naira}$

Energy consumption intensity for water transport in year t

if diesel oil is used = $n3d = 0.0742 \text{ mtoe/billion naira}$

$$E3t = n3fV3t + n3dV3dt.$$

$$= 0.3826 \times (8.7948) + 0.00742 (5.1652) = 3.748 \text{ mtoe}$$

$$\text{Energy consumption intensity , } n3t = \frac{3.748}{13.96} = 0.269 \text{ mtoe/Nbillion}$$

For 1995 : Given $V3t$ = value added in water transport = 17.96 Nbil.

$$= V3ft + V3dt$$

$$= (10.4168 + 7.5432)$$

= (value added in furnace oil) + (value added in diesel oil powered
powered vessels) vessels)

$$= 0.58 \times 17.96 + 0.42 \times 17.96$$

Energy consumption intensity for water transport in year t if furnace
oil is used = $n3f = 0.3826 \text{ mtoe/Nbillion}$

Energy consumption intensity if diesel oil is used

$$= n_{3d} = 0.0742 \text{ mtoe/Nbillion}$$

$$E_{3t} = n_{3f}V_{3ft} + n_{3d}V_{3dt} = 0.3826 \times 10.4168 + 0.0742 \times 7.5432 = 4.5451731 \text{ mtoe}$$

$$\text{Energy consumption intensity, } n_{3t} = \frac{4.5451731}{17.96} = 0.253072$$

For 2000: Given V_{3t} = value added in water transport = 21.96Nbil.

$$= V_{3ft} + V_{3dt}$$

$$= (11.6388 + 10.3212)$$

= (value added in furnace oil) + (value added in diesel oil powered
powered vessels) vessels)

$$= 0.53 V_{3t} + 0.47V_{3t}$$

Energy Consumption intensity for water transport in year t

if furnace oil is used = $n_{3f} = 0.3826 \text{ mtoe/Nbillion}$

Energy Consumption intensity if diesel oil is used

$$= n_{3d} = 0.0742 \text{ mtoe/Nbil.}$$

$$E_{3t} = n_{3f}V_{3ft} + n_{3d}V_{3dt} = 0.3826 (11.6388) + 0.0742 (10.3212) \\ = 5.2188379 \text{ mtoe}$$

$$\text{Energy consumption intensity, } n_{3t} = \frac{5.2188379}{21.96} = 0.237652 \text{ mtoe/Nbil.}$$

For 2005 Given : V_{3t} = value added in water transport = 25.96 Nbillion

$$= V_{3ft} + V_{3dt} = (11.9416 + 14.0184)$$

= (value added in furnace oil) + (value added in diesel oil powered
powered vessels) vessels)

$$= 0.46 \times 25.96 + 0.54 \times 25.96$$

(Energy consumption intensity = $n_{3f} = 0.3826 \text{ mtoe/N billion}$
if furnace oil is used)

(Energy consumption intensity = $n_{3d} = 0.0742 \text{ mtoe/N billion}$
if diesel oil is used)

$$E_{3t} = n_{3f}V_{3ft} + n_{3d}V_{3dt}$$

$$= 0.3826 (11.9416) + 0.0742 (14.0184) = 5.6090215 \text{ mtoe}$$

$$\text{Energy consumption intensity, n3t} = \frac{5.6090215}{25.96} = 0.216064 \text{ mtoe/Nbillion}$$

ANNEXURE IV.7 Rationale for Reducing Electricity and Diesel Consumption for lift Irrigation [THUKRAL [40]].

1 Conservation Measures

Thukral [40] notes that farmers are generally not aware of the potential for reducing energy consumption in electric and diesel pumpsets, and estimates that an investment of about Naira 500 per pumpset may be enough to effect savings of 15% to 30% in the pumpsets already in use. Even if, with this expenditure, only an average 20% of energy savings are possible, an estimated 684 kWh of electricity consumption, or about 160 litres diesel consumption may be reduced per pumpset per annum.

It is understood that the economic cost (to the society) of supplying electricity to scattered consumers in rural areas is at least Naira 0.75/kWh. Assuming a cost of Naira 0.75/kWh, the costs incurred for introducing conservation measures would be recovered in just over one year. Similarly, even if the price of diesel oils were to reduce to Naira 1.2/litre in the international market, the annual savings by reducing diesel consumption would be Naira 200 per pumpset—even if savings in diesel transport costs and the shadow price of foreign exchange (a scarce commodity in Nigeria) are not considered.

It therefore becomes relatively clear that introduction of conservation measures considered by Thukral [40] will be cost effective, with payback periods of about 2 to 3 years or less.

2. Renewable Energy Technologies for Pumping.

The use of windmill and PV pumping systems for lift irrigation is environmentally benign. In addition, despite the present high costs of PV arrays, PV pumping systems are being seriously considered in Nigeria due largely to two advantages: (i) their modular construction, which is desirable from the viewpoint of maintenance and field application; and (ii) higher reliability because they convert solar energy directly into electricity.

It is against this background that a sizeable wind pump demonstration programme was launched by the Federal Government during the Fourth FYP period; and significant R & D activity for both technologies is being encouraged in Nigeria. The purpose of this R & D effort is to improve conversion efficiencies and to bring down costs to acceptable levels.

Although PV arrays today are very expensive, this technology is also the most promising. For instance, Sumitomo Electric Industry Co., Tokyo has projected that thin-film and amorphous-silicon/germanium solar cells can be marketed at a price of US \$ 1.13/peak-watt within three years (Solar Energy Intelligence Report, March, 1986). Even if the price falls to US \$2/peak-watt, the economic attractiveness of PV pumps can be illustrated.

ANNEXURE IV.8
PETROLEUM PRODUCT AND NATURAL GAS DEMAND PROJECTION :SCENARIO 1

UNIT		1990	1991	1992	1993	1994	1995
-----3-----							
1.NG	MM	198.2	224.64	257.08	277.52	303.96	330.4
2.L	MMT	1.1804	1.34624	1.51208	1.6779	1.8437	2.0096
3.N	MMT	9.73	10.378	11.026	11.674	12.322	12.97
4.K	MMT	3.0963	3.9684	4.2405	4.5127	4.7848	5.057
5.D	MMT	2.654	2.8792	3.1044	3.3296	3.5548	3.78
6.F	MMT	8.3604	8.637	8.914	9.191	9.4689	9.74589
		1996	1997	1998	1999	2000	2001
	1.	359.66	388.92	418.18	447.44	476.7	517.868
	2	2.04548	2.08136	2.1172	2.1531	2.189	2.3098
	3.	13.616	14.262	14.908	15.554	16.2	16.846
	4.	5.1688	5.2806	5.3924	5.5042	5.616	6.0726
	5.	3.826	3.872	3.918	3.964	4.01	4.186
	6.	9.964	10.182	10.399	10.618	10.8358	11.123
		2002	2003	2004	2005		
	1	559.032	600.198	641.364	682.53		
	2.	2.4306	2.5514	2.6722	2.793		
	3	17.492	18.138	18.784	19.43		
	4	6.5292	6.9858	7.4424	7.899		
	5	4.362	4.538	4.714	4.89		
	6	11.411	11.698	11.986	12.273		

PETROLEUM PRODUCT AND NATURAL GAS DEMAND PROJECTION: SCENARIO II								
UNIT		1990	1991	1992	1993	1994	1995	1996
-----3-----								
1.NG	MM	198.2	225.9	253.6	281.3	308.05	336.76	364.75
2.L	MMT	1.228	1.3843	1.5406	1.6969	1.8533	2.009	2.0654
3.N	MMT	9.73	10.378	11.026	11.674	12.322	12.97	13.616
4.K	MMT	3.724	4.0139	4.30345	4.5928	4.8823	5.172	5.449
5.D	MMT	2.654	2.7612	2.8684	2.9756	3.0828	3.190	3.3698
6.F	MMT	8.3604	8.642	8.924	9.206	9.488	9.77	9.997
		1997	1998	1999	2000	2001	2002	2003
	1	392.73	420.7	448.7	476.7	526.7	576.8	626.8
	2	2.1213	2.1772	2.233	2.288	2.4159	2.5429	2.6699
	3	14.262	14.908	15.554	16.20	16.846	17.492	18.138
	4	5.726	6.0034	6.2807	6.5599	6.863	7.1678	7.4727
	5	3.5496	3.7294	3.9092	4.089	4.149	4.209	4.269
	6	10.22	10.45	10.679	10.907	11.210	11.514	11.817
		2004	2005					
	1	676.9	726.98					
	2	2.7969	2.924					
	3	18.784	19.43					
	4	7.7776	8.0826					
	5	4.329	4.389					
	6	12.12	12.425					

IV.8 Cont.

PETROLEUM PRODUCT AND NATURAL GAS DEMAND PROJECTION :SCENARIO III

	UNIT	1990	1991	1992	1993	1994	1995	1996
		-----3-----						
1	MM	198.2	222.09	245.98	269.87	293.76	317.65	344.3
2	MMT	1.778	2.0972	2.4164	2.7356	3.0548	3.374	3.6914
3	MMT	9.73	10.378	11.026	11.674	12.322	12.97	13.616
4	MMT	4.0589	4.603	5.147	5.691	6.2357	6.78	7.298
5	MMT	2.654	2.6752	2.6964	2.7176	2.7388	2.76	2.92
6	MMT	8.3604	8.627	8.894	9.1617	9.429	9.676	9.897

continued

		1997	1998	1999	2000	2001	2002	2003
1		370.95	397.6	424.25	450.90	488.67	526.44	564.22
2		4.0088	4.3262	4.6486	4.961	5.3112	5.6614	6.0116
3		14.262	14.908	15.554	16.20	16.846	17.492	18.138
4		7.816	8.334	8.882	9.373	9.93	10.489	11.049
5		3.08	3.24	3.4	3.56	3.726	3.892	4.0576
6		10.109	10.321	10.533	10.745	11.022	11.299	11.576

continued:

		2004	2005
1		601.99	639.766
2		6.3618	6.712
3		18.784	19.43
4		11.609	12.1689
5		4.2234	4.389
6		11.853	12.130

NOTE :NG : NATURAL GAS L : LPG N : NAPHTHA K : KEROSENE
D : DIESEL F : FUEL OIL.

ANNEXURE V.1 PRODUCT YIELD COEFFICIENTS OF VARIOUS CRUDES

	<u>Arab/Venezuela Mix</u>	<u>Bonny Light</u>	<u>Bonny Medium</u>
<u>Crude Distillation</u>			
Unit(Feed:Crude Oil)			
Sour Gas	0.00033	0.00033	0.00500
LPG	0.01271	0.01448	0.01000
Naphtha	0.11382	0.11819	0.19000
Kerosene/ATF	0.14767	0.17500	0.19300
Gas Oil	0.18547	0.26334	0.23900
ResidualFuel Oil	0.54000	0.42866	0.36300
<u>Vacuum Distillation</u>			
Unit(Feed:ResidualOil)			
Vacuum Gas	0.45309	0.66019	0.78237
Vacuum Bottom	0.54691	0.33981	0.21763
<u>Visbreaker Unit</u>			
(Feed:Vacuum Bottom)			
Sour Gas	0.06998	0.08696	0.11392
LPG	0.00366	0.00557	0.00836
Motor Spirit Blend	0.01463	0.02373	0.03806
Diesel	0.07314	0.11716	0.18565
Residual Fuel oil	0.83860	0.76659	0.65401
<u>FCUnit(Feed Vac.GasOil)</u>			
Sour Gas	0.02589	0.02591	0.02582
LPG	0.11499	0.11903	0.12089
Motor Spirit Blend	0.20658	0.26938	0.28052
Light Cycle oil	0.54082	0.45258	0.43897
Clarified Oil	0.05450	0.08598	0.08685
Coke	0.05722	0.04711	0.04695
<u>HC+HYDROGEN UNI</u>			
(Feed:Vac.Gas Oil)			
Sour Gas	0.03723	0.02709	0.01056
LPG	0.02182	0.03422	0.02699
MotorSpirit Blend	0.08861	0.10802	0.10798
Kerosene/ATF	0.42952	0.44551	0.45188
Diesel oil	0.42282	0.40989	0.42723

Notes:1. Product yield coefficients are available only for major petroleum products. Using these coefficients for estimating the product output mix of refineries with the desired configuration, the refinery losses range from 5 to 7%. This also conforms to the normal experience. However, it is observed from past data on output mix of Nigerian refineries that:

a) LPG, motor spirit and naphtha comprise 98% of all light distillates, (ii) kerosene, ATF and diesel oils comprise about 98.5% of all middle distillates, and (iii) fuel oils account for about 80% of all heavy ends. Therefore, the product outputs obtained for the new refineries (assuming the given product yield coefficients) are then reduced accordingly. These data are presented in Tables 5.5 and 5.6.

b. The sum of all fractions obtained from the HC unit exceeds 1.0. This only indicates the hydrogen input. To estimate the refinery output mix, it is assumed that the hydrogen is produced from naphtha (45000 tonnes of hydrogen from 135,000 tonnes of naphtha) and the output of naphtha/motor spirit is thus correspondingly reduced.

ANNEXURE Table V.1
Capital and operating costs of new refineries

unit	capacity (mtpa)	Capital costs		constructi. on Time (Years)
		capital cost* (NMillion)	Foreign exchanged component (N Million)	
a. Hydroskimming configuration		213200	710	5
b.1 VDU	4.41	4770	290	4
b.2 Vis-breaker	2.41	7850	470	3
c.1 VDU	3.03	3270	200	2
c.2 vis-breaker	1.03	3350	200	2
d.1 VDU	4.04	4360	260	3
d.2 Vis-breaker	2.04	6630	400	2
e FCC	2.0	10000	1000	2
f.1 HC	2.0	23100	5780	2
f.2 Hydrogen production	0.05	5010	750	2

* Rounded to the nearest unit VDU

a. For all refinery choices considered; although the capacity of catalytic reformers and hydrotreaters may vary marginally with the type of crude produced.

Cost per mtpa based on a refinery of 5.45 mtpa CDU capacity, includes 50% of inside battery limit (IBL) costs as outside battery limit (OBL) costs. Foreign exchange component is 5% of IBL costs.

b.1 cost per mtpa based on a vdu of 1.62 mtpa capacity.

c.1 No OBL costs included as integrated operation is assumed.

d.1 Foreign exchange cost is 6% of IBL costs

b.2 Cost per mtpa based on a unit of 0.5 mtpa capacity.

c.2 No OBL costs included as integrated operation is assumed.

d.2 Foreign exchange component is 6% of IBL costs

b1,b2. For a new refinery operating on Arab mix/Venezuela/Kuwait crude.

d1,d2. For a new refinery operating on a blend of Nigerian Bonny crudes and Arab mix crudes.

e. cost per mtpa based on a FCC unit of size 0.85mtpa. Includes process design charges and cost of first fill of catalyst. No OBL costs included as integrated operation is assumed. Foreign exchange component is 10% of total costs.

f1. Costs per mtpa based on HC unit of 0.85 mtpa capacity. Includes process design charges and cost of first fill of catalyst. No OBL costs included as integrated operation is assumed. Foreign exchange component is 25% of total costs.

f.2 Cost per mtpa based on hydrogen production design unit of 0.025 mtpa capacity. Includes process design charges and cost of fill of catalyst. Foreign exchange component is 15% of total costs.

Source : Wijetilleke and Ody 1984., Thukral , 1987 [40]

ANNEXURE Table V.2
Operating costs (N/tonne of feed processed)

	Fixed operating cost*	Variable oper. cost**	Total oper. cost
a.1 CDU	247	429.3	4564
a.2 Hdroskimming refinery	26.67	892.1	1158.8
b. VDU	32.1	734.6	766.7
c. Visbreaker	367.9	202.33	2391.2
d. FCC	156.5	734.1	890.
e. HC	336.5	1420.0	1756.5
f. Hydrogenproducti on	3000.0	3280.00	6280.0

* Includes labour maintenance, and overhead charges.

** Includes utility charges, refinery fuel costs and costs of catalysts and chemicals. Note: Operating costs of CDU are included in those for a Hydroskimming refinery. All operating costs are obtained from unit sizes as specified in notes to Annexure Table VI.1

Source: Wijetilleke and Ody, 1984, Thukral, 1987 [40].

ANNEXURE V .3
MODEL APPLICATION :FIRST REFINERY IN 1990-91

Items to be considered are: (i) Whether it is feasible, from the point of view of cost to the economy, to install a refinery in 1990-91. (ii) In order to compute the cost to economy we use equation 5.1. (iii) In order to use equation 5.1 we need to know whether any particular petroleum product is being imported or exported. This aspect will decide the value of n_1, n_2, n_3, n_4 , which indicates the year when (1) naphtha/motor spirit, (2) kerosene/ATF (3) diesel oils, and (4) fuel oils first begin to be imported. (iv) To determine the values of n_1, n_2, n_3 , and n_4 we consider the existing availability of above mentioned four petroleum products (i.e. total production from the existing refineries). Add to this the production from the proposed refinery of 6 mtpa capacity coming on stream in 1990/91. The total so obtained is then compared with demand of petroleum products as computed in the previous chapter. If demand is more than products, the products are imported, otherwise this may be exported. For the purpose of this comparison the data is put in tabular form as shown in Tables V.4.1 to V.4.21 on next page. (v) We are also required to compute the exact quantity of products which may be imported/ exported to ascertain the values of $N_i(N_i'), K_i(K_i'), D_i(D_i'), F_i(F_i')$. These values are also obtained from the table as prepared in (iv). (vi) We are also required to compute exact quantity of crude to be fed into the refineries including the proposed one. The crude quantity E_i , the symbol used in equation 5.1 for "crude r" is assumed to be made available from the Nigerian crude production. Computations for this are also shown on the next page.

TABLE V.3 .1

BONNY LIGHT PETROLEUM PRODUCTS PER YEAR FOR EXISTING REFINERIES

		Port Harcourt	Warri	Kaduna	Total
Product output	MMT	4.1861	1.125	4.1861	9.4972
-LPG	MMT	0.248	0.062	0.248	0.558
-Motor Spirit/Naphtha	MMT	0.9351	0.233	0.9357	2.1032
-Kerosene/ATF	MMT	0.7757	0.1939	0.7757	1.7453
-Diesel oils	MMT	1.925	0.48125	1.925	4.33125
-Fuel oils	MMT	0.3022	0.0755	0.3022	0.6799

TABLE V.3.2

YEARLY PRODUCTION FROM EXISTING REFINERIES AND NEW REFINERIES COMING ON STREAM IN 1990/1991

		Existing Refineries	New Refineries	Total
Product output	mmt	9.4972	5.0234	14.5206
-LPG	mmt	0.558	0.2976	0.8556
-motor spirit/naphtha	mmt	2.1032	1.1222	3.2254
-kerosene/ATF	mmt	1.7453	0.9309	2.6762
-diesel oils	mmt	4.33125	2.3100	6.64125
-fuel oils	mmt	0.6799	0.3627	1.0426

TABLE V.3.3

Demand for petroleum products and their production for 1990/91

Product	unit	Demand	Expected Production	Availability of product for import/export	whether import/export	Value of n1,n2,n3,n4
	mmt	25.621				
LPG	mmt	1.1804	0.8556	+0.32485	Import	
motor spirit/naphtha	mmt	9.73	3.2254	+6.5046	Import	n1=1
kerosene/ATF	mmt	3.6963	2.6762	+1.0201	Import	n2=1
diesel oils	mmt	2.654	6.64125	-3.98725	Export	n3=21
fuel oils	mmt	8.3604	1.0426	+7.3178	Import	n4=1
Crude Run:		15.525 MMT				

TABLE V.3.4 1991/92

Product	unit	Demand	Expected product.	Availability for expt/impt	whether impt/expt	Value of n1,n2,n3,n4
LPG	mmt	1.34624	0.8556	+0.49064	import	
motor spirit/naphtha	mmt	10.378	3.2254	+7.1525	import	n1=1
kerosene/ATF	mmt	3.9684	2.6762	+1.2922	import	n2=1
diesel oils	mmt	2.879	6.44125	-3.56205	export	n3=21
fuel oils	mmt	8.637	1.0426	+7.5944	import	n4=1
Crude Run :	mmt	15.525				

Table V.3.5 1992/93

Product	unit	Demand	Expected	Availability	wether	value of
	mmt	28.796	product.	for expt/impt	impt/expt	n1,n2 n3,n4
LPG	mmt	1.51208	0.8556	+0.65648		import
motor spirit/naphtha	mmt	11.026	3.2254	+7.8006		import n1=1
kerosene/ATF	mmt	4.2405	2.6762	+1.5643		import n2=1
diesel oils	mmt	3.1044	6.64125	-3.53685		export n3=21
fuel oils	mmt	8.914	1.0426	+7.8714		import n4=1
Crude Run:	mmt	15.525				

Table V.3.6 1993-94

Product		Demand	Expected	Availability	wether	value of
	mmt	30.3852	product.	for expt/impt	impt/expt	n1 n2,n3,n4
LPG	mmt	1.6779	0.8556	+0.8223		import
motor spirit/naphtha	mmt	11.674	3.2254	+8.4486		import n1=1
kerosene/ATF	mmt	4.5127	2.6762	+1.8365		import n2=1
diesel oils	mmt	3.3296	6.64125	-3.31165		export n3=21
fuel oils	mmt	9.191	1.0426	+8.1484		import n4=1
Crude Run	mmt	15.525				

Table V.3.7 1994.95

Product		Demand	Expected	Availability	wether	value of
	mmt	31.9733	product.	for expt/impt	impt/expt	n1 n2,n3,n4
LPG	mmt	1.8437	0.8556	+0.9881		import
motor spirit/naphtha	mmt	12.322	3.2254	+9.0966		import n1=1
kerosene/ATF	mmt	4.7848	2.6762	+2.1086		import n2=1
diesel oils	mmt	3.5548	6.64125	-3.08645		export n3=21
fuel oils	mmt	9.468	1.0426	+8.4254		import n4=1
Crude Run:	mmt	15.525				

In 1995/96 the second refinery of capacity 6 MTPA came in stream. The availability of the petroleum products therefore change as per the following::

Table V.3.8 1995/96

MMT Petroleum product	availability for	Additional input from	Total availability
	existing refinery	the new refinery	of petroleum product
LPG	mmt 0.8556	0.2976	1.1532
ms/naphtha	mmt 3.2254	1.1222	4.3476
kerosene/ATF	mmt 2.6762	0.9309	3.6071
diesel oils	mmt 6.64125	2.3100	8.95125
fuel oils	mmt 1.0426	0.3627	1.4053
Crude Run For existing refinery		mmt 15.525	
Additional crude required		mmt 5.4	Total = 21.925 mmt

<u>Table V.3.9 1995/96</u>						
Product	unit	Demand	Expected	Availability	wether	value of n1
	mmt	33.562	product.	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt	2.0096	1.1532	+0.88536		import
motorspirit/naphtha	mmt	12.97	4.3476	+8.6224		import n1=1
kerosene/ATF	mmt	5.057	3.6071	+1.4499		import n2=1
diesel oils	mmt	3.78	8.95125	-5.17125		export n3=21
fuel oils	mmt	9.745	1.053	+8.3397		import n4=1
Crude Run	mmt	21.925				

Table V.3.10 1996/97

Product	unit	Demand	Expected	Availability	wether	value of n1,
	mmt	34.52	product.	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt	2.04548	1.1532	+0.89228		import
motor spirit/naphtha	mmt	13.616	4.3476	+9.2684		import n1=1
kerosene/ATF	mmt	5.1688	3.6071	+1.5617		import n2=1
dieseloils	mmt	3.826	8.95125	-5.12525		export n3=21
fuel oils	mmt	9.964	1.4053	+8.5587		import n4=1
Crude Run	mmt	21.925				

Table V.3.11 1997/98

Product	unit	Demand	Expected	Availability	wether	value of n1
	mmt	35.67	product	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt	2.08136	1.1532	+0.92816		import
motor spirit/naphtha	mmt	14.262	4.3476	+9.9144		import n1=1
kerosene/ATF	mmt	5.2806	3.6071	+1.6735		import n2=1
diesel oils	mmt	3.872	8.95125	-5.07925		export n3=21
fuel oils	mmt	10.182	1.4053	+8.7767		import n4=1
Crude Run	mmt	21.925				

Table V.3.12 1998'99

Product	unit	Demand	Expected	Availability	wether	value of n1
	mmt	35.734	product	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt	2.1172	1.1532	+0.964		import
motor spirit/naphtha	mmt	14.908	4.3476	+10.5604		import n1=1
kerosene/ATF	mmt	5.3924	3.6071	+1.7853		import n2=1
dieseloils	mmt	3.918	8.95125	-5.03325		export n3=21
fueloils	mmt	10.399	1.4053	+8.9937		import n4=1
Crude Run	mmt	21.925				

		<u>Table V.3.13</u> 1999/2000			
Product	unit Demand	Expected Availability	wether value of n1		
	mmt 37.793	product for expt/impt	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt 2.153	1.1532	+0.99998	import	
motor spirit/naphtha	mmt 15.554	4.3476	+11.2064	import	n1=1
kerosene/ATF	mmt 5.5042	3.6071	+1.8971	import	n2=1
diesel oils	mmt 3.964	8.95125	-4.98725	export	n3=21
fuel oils	mmt 10.618	1.4053	+9.2127	import	n4=1
Crude Run	mmt 21.925				

In 2000-01 the third refinery of capacity 6MTPA in stream. The availability of the petroleum products therefore change as per the following

		<u>Table V.3.14</u> 2000/01			
MMT	Petroleum product availability from existing refinery	Additional input from the new refinery	Total availability of petroleum products		
LPG	mmt 1.1532	0.2926	1.4508		
ms/naphtha	mmt 4.3476	1.222	5.568		
kerosene/ATF	mmt 3.6071	0.9309	4.538		
diesel oils	mmt 8.95125	2.3106	11.26185		
fuel oils	mmt 1.4053	0.3626	1.7679		
Crude Run:For existing refinery		mmt 21.925			
Additional crude required		mmt 5.4	Total=27.325 mmt		

		<u>Table V.3.15</u> 2000/01			
Product	unit Demand	Expected Availability	wether value of n1		
	mmt 38.8520	product for expt/impt	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt 2.189	1.4508	0.7383	import	
motor spirit/naphtha	mmt 16.2	5.5696	10.6364	import	n1=1
kerosene/ATF	mmt 5.616	4.538	1.078	import	n2=1
diesel oils	mmt 4.01	11.2618	-7.2578	export	n3=21
fuel oils	mmt 10.835	1.7679	9.0671	import	n4=1
Crude Run	mmt 27.325				

		<u>Table V.3.16</u> 2001/02			
Product	unit Demand	Expected Availability	wether value of n1		
	mmt 40.537	product for expt/impt	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt 2.3098	1.4508	0.859	import	
ms/naphtha	mmt 16.846	5.5696	11.2764	import	n1=1
kerosene/ATF	mmt 6.0726	4.538	1.5348	import	n2=1
diesel oils	mmt 4.186	11.2619	-7.07583	export	n3=21
fuel oils	mmt 11.123	1.7679	4.3551	import	n4=1
Crude Run	mmt 27.325				

		<u>Table V.3.17</u> 2002/03			
Product	unit Demand	Expected Availability	wether value of n1		
	mmt 42.224	product for expt/impt	for expt/impt	impt/expt	n2,n3,n4

F

LPG	mmt	2.4306	1.4508	0.9798	import	
ms/naphtha	mmt	17.492	5.5696	11.9224	import	n1=1
kerosene/ATF	mmt	6.5292	4.538	1.9912	import	n2=1
dieseloils	mmt	4.362	11.26183	-6.89985	export	n3=21
fueloils	mmt	11.411	1.7679	9.6434	import	n4=1
Crude Run	mmt	27.325				

Table V.3.18 2003/04

Product	unit	Demand	Expected	Availability	wether	value of n1
	mmt	43.9112	product	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt	2.5514	1.4508	1.1006	import	
ms/naphtha	mmt	18.138	5.5696	12.5684	import	n1=1
kerosene/ATF	mmt	6.9858	4.538	2.4478	import	n2=1
dieseloils	mmt	4.538	11.2618	-6.72385	export	n3=21
fueloils	mmt	11.698	1.7679	9.9301	import	n4=1
Crude Run	mmt	27.325				

Table V.3.19 2004/05

Product	unit	Demand	Expected	Availability	wether	value of n1
	mmt	45.5986	product	for expt/imot	impt/expt	n2,n3,n4
LPG	mmt	2.6722	1.4508	1.2214	import	
ms/naphtha	mmt	18.784	5.5696	13.2144	import	n1=1
kerosene/ATF	mmt	7.4424	4.538	2.9044	import	n2=1
dieseloils	mmt	4.714	11.26185	-6.54785	export	n3=21
fueloils	mmt	11.986	1.7679	10.2181	export	n4=1
Crude Run	mmt	27.325				

In 2005/06 the fourth refinery of capacity 6MTPA in stream. The availability of the petroleum products therefore change as per the following

Table V.3.20 2005/06

MMT	Petroleum product	Additional input from existing refinery	Total availability of petroleum products	
LPG	mmt	1.4508	0.2976	1.7484
ms/naphtha	mmt	5.5696	1.222	6.971
kerosene/ATF	mmt	4.538	0.9309	5.4689
dieseloils	mmt	11.26185	2.3106	13.54166
dieseloils	mmt	1.7679	0.3625	2.1304

Table V.3.21 2005/06

Product	unit	Demand	Expected	Availability	wether	value of n1
	mmt	47.285	product	for expt/impt	impt/expt	n2,n3,n4
LPG	mmt	2.793	1.7484	1.0446	import	
ms/naphtha	mmt	19.43	6.791	12.639	import	n1=1
kerosene//ATF	mmt	7.899	5.4689	2.4301	import	n2=1
diesel oils	mmt	4.89	13.54166	-8.65166	export	n3=21
fueloils	mmt	12.273	2.1304	10.1426	import	n4=1
Crude Run	mmt	32.725				

Annexure V.4
Range of Product Price Ratios for Analysis

The analytical model does not take into account the locational choices of setting new refineries, only some indicative values for product price ratios are used for further analysis. These are shown in Table V.4.1 (1), and more or less span the entire range of product price ratios observed in the past.

Although the price ratio for naphtha is generally lower than that for motor spirit, the analysis assumes that both are equal. This simplification may not cause a serious distortion in the results and in effect assumes that all naphtha requirements are met from indigenous refineries and only motor spirits are imported/exported.

Table V.4.1 Range for Product Price Ratios Considered in the Analysis*

$1+\Delta P_n$	1.30.....1.80
$1+\Delta P_k$	1.25.....1.70
$1+\Delta P_d$	1.10.....1.60
$1+\Delta P_f$	0.8*

* For any single computation however, $1+\Delta P_n > 1+\Delta P_k > 1+\Delta P_d > 1+\Delta P_f$, For the base case analysis : $1+\Delta P_f=0.8$ is then subject to small variations for sensitivity analysis.

International market price for LPG is not readily available.

However, as LPG is a lighter product than motor spirit, the possibility for LPG export is considered keeping

$1+\Delta P_g > 1+\Delta P_n$ P_g refers to the LPG price. The range considered for $1+\Delta P_g$ is 1.35.....1.90.

Base Case Assumptions

1.Product Price Ratios: The values for $1+\Delta P_g$, $1+\Delta P_n$, $1+\Delta P_k$, $1+\Delta P_d$ and $1+\Delta P_f$ which are used for the base case analysis are: $1+\Delta P_g=1.9$,

1. $\Delta P_n = 1.8$, $1 + \Delta P_k = 1.70$, $1 + \Delta P_d = 1.6$ and $1 + \Delta P_f = 0.8$.

2. Annual Rate of Change in c.i.f. price of crude oil in real terms. This is denoted by "s" and is attributed a value of 0.02.

Although this is no reflection of past trend, it does take into account the need for a smooth and gradual rise in crude prices.

More over [] it is observed that the research studies that spell out their price assumptions often assume a constant 2 to 3 % annual increase in the real price of oil.

3. Discount Rate: "r" is equal to 0.12. This is the social rate of discount normally used for planning for evaluating and approximating public investment decisions. This value is lower than what may be used by a private investor, for whom the discount rate may be 0.15 or more. The rationale behind this divergence between social and private rates of discount is that a decision to make an investment priority may usually be based on myopic considerations, while the government or any agency which is responsible for increasing the welfare of the present and future generations, needs to take a long-term view.

4. Ratio between FOB Export Price of any Petroleum Product to c.i.f import Price for that Product. "x" is to be equal to 0.8, although this ratio has normally varied between 0.8 and 0.95 in the past.

5. Factor to Reflect the Scarcity of Foreign Exchange

"y" is equal to 0.25. This value is normally used for planning in developing countries. As a result, the rupee/naira equivalent of expenditure (or earning) in foreign exchange is further increased by a premium of 25%.

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