THE NIGERIAN SOCIETY OF ENGINEERS

PROCEEDINGS

OF THE

NATIONAL ENGINEERING CONFERENCE

6TH -- 8TH DECEMBER, 1984

THEME: "STEEL AND PETROCHEMICALS – ENGINEERING CHALLENGES FOR THE FUTURE"

VENUE: DAULA HOTEL, KANO.

THE ENGINEERING CHALLENGE FOR COST EFFECTIVE STEEL SCRAP RECOVERY IN NIGERIA

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Paper submitted for Nigerian Society of Engineers
Annual Conference – December 6th – 8th, 1984
Duala Hotel, Kano

ABSTRACT.

Cost effective steel utilization as distinct from steel utilization is an engineering challenge of our time, especially in this austere period. Steel scrap recovery is definitely one of the areas to be seriously looked into by Nigerian engineers.

After estimating the recoverable steel scrap to the year 200AD, this paper aims at finding an appropriate technology and size for steel scrap recovery bearing in mind the need for self reliance and the level of our technological advancement. Simple and friendly analysis was conducted to look at various alternatives using three industrial engineering techniques namely shortest route programme, linear and decision analysis. The computer programmes written in BASIC language and were run on a microcomputer.

Small dispersed mills are highly favoured demanding the ingenuity of Nigerian engineers to make ti cost effective.

INTRODUCTION.

The role of local steel scrap recovery in national economic self-reliance cannot be over-emphasized. Steel scraps produced by industry and from household are re-usable; the collection, processing and re-application of which are significantly cheaper than the production from iron ore especially in this era of increasing world market prices. This role is even more significant as a good percentage of our steel requirement will continue to be met through imports even after the completion of the Ajaokuta Steel Plants (Reference 1).

It is paradoxical that with the heavy steel import bills and the perennial cry for a good tourist industry, it is common sight to see car carcasses, old refrigerators and other household junks scattered all over the place. There is therefore the need for organised local large scale steel scrap recycling in Nigeria in order to conserve our foreign exchange, reduce environment polution, reduce overall steel production cost and the high rate of both underemployment and unemployement amongst engineers and technical personnel (Reference 9.)

Thus, it is not sufficient to collect metal scrap, as some of our State Task Forces on environmental sanitation are currently doing, but theyshould be brought into a condition to enable industrial processing or commercial use and transportation respectively. This is one of the challenges for the Nigerian Engineerr.

Before identifying what the challenge entails we shall first of all look at the technology and logistics for steel scrap recycling then estimate the recoverable steel scrap to the year 200AD.

2.0 STEEL SCRAP CLASSIFICATION.

Iron and steel scraps can be grouped or classified in various ways depending on the waste processing technology, development level in metallurigcal processing etc. Some of the common classifications are as follows:– (Reference 5, 9).

(a) non-alloyed and alloyed scraps
(b) steel scraps and cast iron scraps - carbon content
(c) appearance and quality characteristics e.g. lumps, pressed, chippings.
(d) based on ratio of alloying elements
(e) end-use e.g. Home or Mill scraps; Industrial or processing scraps, amortisation obsolete or old scraps.

Narancsik (Reference 5) suggest that for developing countries that iron and steel scraps be classified as follows:–

(A) Non-alloyed Scraps.

(i) Heavy scraps - rolled bars, sections plates over 6mm etc.

(ii) Miscellaneous Scrap – same as (i) but thickness less than 6mm.

(iii) Loose steel scraps – including rolled bars, plates sections of 6mm; tubes, etc, chippings.

(B) Non-Alloyed Cast Iron Fragments.

(i) Fragments of machine castings

(ii) Fragments of chilled castings and white iron castings.

(iii) Fragments of commercially available cast iron.

(iv) Fragments of burnt and enamelled cast iron.

(v) Cast iron scraps.

(C) Cast Steel Scraps.

(i) Steel lumps
(ii) Steel cuttings.

(D) Fragments of Alloyed Cast Iron.

(i) Cast Iron lumps.
(ii) Cast Iron Cuttings.

For this paper and especailly in estimating the recoverable iron and steel scraps we will be using the END–USE classification as there are inadequate statistics to base on the non-alloyed/alloyed classification.

The classification will be as follows:–

(A) Home or Mill scraps – These are recycled scrap obtained in the metallurgical production processes such as the scraps of metallurgical plants, steel making plants, rolling mills and foundries. Almost all the scraps so generated are reused and will not be estimated.

(B) Industrial or processing scraps – are scraps generated in the consumption and processing of steel products. The raw materials used are mainly rolled products as well as forged and steel castings.

(C) Amortization, obsolete or old scraps are generated from iron and steel products e.g. obsolete machines, vehicles, structural steel from buildings, demolitions, railroad equipment, household wastes, such as refrigerators, etc.

3.0 TECHNOLOGY AND LOGISTICS OF COLLECTION AND PROCESSING

3.1 Transportation.

Steel scrap transportation can be classified as follows:–

(a) Transit transport - direct transport from consumer to scrap processor.

(b) Transport by supplier - scrap supplied company delivers to the collecting and processing company (e.g. by trucks, trailers, etc.).

(c) Transport by the processing company - Processor uses equipment to collect scraps from smaller scrap enterprieses.

Figure 1 shows a Flow Chart of scrap transportation from the place of generation to the processing plant.

3.2 Technology for scrap preparation.

3.2.1 SORTING.

This is the first and most important step which is decisive for the profitability of the plant. Sorting is aimed at separating mixed scrap metal on the basis of quality. Some of the sorting methods are:–

(a) Visual inspection - sorted on the basis of external distinctive characteristics such as colour, surface of fracture, oxide colour, hardness, scratch or file scratch test, magnetizability, etc.

(b) Drop Analysis Test – Sorted on basis of colour reaction of various chemical reagent. Used for isolating various alloys is time and labour intensive.

(c) Spectroscopy- On the basis of the characteristic spectral lines, or conductivity measurement using eddy-current gauge, primarily used for copper and non-alloy aluminium scraps.

Design of the work place for sorting could be such that sorting is done simply by manual or on a sorting belt running at about 2-3m/men with workers sitting or standing to sort incoming materials. There is obviously a challenge for the Nigerian engineers in the design of both work place and equipment.

3.2.2. CUTTING

Scraps metals are cut in order to allow the charging of furnaces e.g. 50kg to 200kg depending on the size of the furnace or crucible. Alligator shears, flame cutters, pneumatic hammers are used.

3.2.3 BURNING

AGO - poured on heap to remove coatings or insulations.

3.2.4 BALING.

Loose sorted scraps baled to facilitate transport or charging. Pressure minimum of 350 atmosphere.

3.25 DISASSEMBLY

For engines etc could be done manually by mechanised tools or pyrometallurgically of removing babbit from bushes or lead from water fittings.

3.2.6 PREPARATION OF CHIPPINS

Chippings may consist of small grains or entangled flexes or mixture of both. Such chipping could be separated by screening (stationary or vibratory) then crushed (by hammer mills) then degreased (by centrifuging, chemical degreasant or roasting). Magnetic separation for de-ironing the chippings normally are compressed (briquetting) to reduce burning losses in furnaces.

3.3. Preparation Equipment.

3.3.1 Cutting Equipment.

- Alligator shears - manual or hydraulic cut up to 50mm∅ bars or 20mm thick plates and 200mm width in a single cut. Problem - wear of blades.
- Guillotine shears - Scrap feed by overhead cranes - cutting force upto 800 tons developed at 5 to 7 cuts/minimum.
- Flame cutting - used where heavy duty hydraulic cutters are not available. They are also used for cutting oversize scraps such as large section beams, bars, etc.

  Productivity: 1–1.2 tons/man-hour in a working area of 20m2/man also gas and oxygen demand high.

3.3.2 CASTING CRUSHER.

Castings are crushed by pig breakers. Productivity – 1 to 1.5 tons/hours. This is manual removal. A more productive one is the ARNOLD'S CASTING CRUSHER which operates automatically by remote control and fed by crane or loading machine.

3.3.3. BALING PRESSES

3.3.4. PREPARATION OF CHIPPINGS

- Rotary sieve - separation of fibrous and small lump chipping.
- Hammer mill - grinding and crushing of fibrous chippings.
- Degreasing furnace.
- Briquetting press.

3.4. Scrap Storage.

Storage is an important aspect of scrap collection and processing. It is basically the store for "balancing" of the time. It is stored to ensure the availability of suitable quantity for processing or delivery. The storage period could be for few days to over one year. Storage could be open-air, covered stores or warehouse.

4.0 RECOVERABLE STEEL SCRAP ESTIMATION.

4.1 Classification.

For the recoverable steel scrap estimation we shall be dividing the scraps into two types:–

(A) Industrial or New Scrap
(i) Plants using rolled and cast products.

(B) Old, Amortization or Obsolete Scrap
(i) Car and light commercial
(ii) Medium/Heavy Commercial, Agricultural
(iii) Motorcycles and bicycles
(iv) Structural
(v) Rails and Rail materials
(vi) Pipes, tubes and fittings
(vii) Machinery and equipment
(viii) Local production.

4.2 Notation.

p	=	loss during fabrication process
t	=	time (years)
q	=	recovery efficiency of new scrap
w(i)	=	recovery efficiency of sector i old scrap
tp	=	new scrap recovery delay (years)
l(i)	=	average life of sector i
h(i,t)	=	end-use quantity by sector i in time t.

4.3 Methodology for estimation.

4.3.1 Potential new scrap (NS) - During the fabrication process there is always some amount of scraps generated say in the fabrication of buckets, domestic wares, etc. Bulk of the inputs are flat-rolled materials for autobodies, pipes, tin plates, galvanised sheets. This is given as

$$NS(t) \quad = \quad pd(t) \quad .....$$

4.3.2 New scrap recovered (NSR) – Usually not all industrial scraps are recovered as they could take sometime before collection for processing is initiated or they may not be collected at all. Thus the recovered scrap depend on the efficiency of recoverey and is given by

$$NSR(t) \quad = \quad qNS(t-tp)$$

4.3.3. Potential old scrap (OS) – This is actually the aggregated consumption of finished goods less the loss during fabrication if they are manufactured locally.

$$OS(t) = \begin{cases} (1-p) \sum_{i=1}^{I} h(i,t-1\ (i)) \text{ if local production} \\ \sum_{i=1}^{I} . h(i,t-1(i)) \text{ if imported} \end{cases}$$

Since the available statistics is so scanty we shall lump all the locally produced items as one sector.

So we now have that

$$OS(i,t) \quad = \quad h(i,t-1\ (i))$$

4.3.4 Recovered old scrap (OSR) - This depends on how efficient the collection and processing systems are. This is given as

$$OSR(i,t) \quad = \quad w(i) \quad *OS(i,t)$$

4.3.5 Recoverable steel scrap(S) – This is obtaine by the sum total of the recoverable Mill scrap and amortised scrap given as

$$S(t) = NSR(t) \quad + \quad \sum_{i=1}^{8} w(i) * OS(i,t)$$

This model is shown disgrammatically in Figure 4 and the forecast is shown in Table 1.

TABLE 1: RECOVERABLE STEEL SCRAP FORECAST TO 2000AD

Year	Potential New Scrap	New Scrap Recovered	Potential Old Scrap	Recovered Old Scrap	Secondary Production
1971	8,230	82,299	189,998	11,999	196,298
1972	10,599	4,115	189,998	113,999	118,114
1973	11,804	5,300	189,998	113,999	119,298
1974	13,873	5,902	189,998	113,999	119,901
1975	16,324	6,937	189,998	113,999	120,935
1976	35,316	8,162	189,998	113,999	122,161
1977	38,433	17,658	189,998	113,999	131,657
1978	42,000	19,217	257,756	154,654	173,870
1979	46,000	21,000	257,295	154,377	175,377
1980	49,500	23,000	310,175	186,105	209,105
1981	52,500	24,750	990,150	594,090	618,840
1982	55,000	26,250	771.270	462,762	489,012
1983	57,500	27,500	870,172	522,103	549,603
1984	59,500	28,750	1,080,000	648,000	676,750
1985	60,500	29,750	1,160,000	696,000	725,750
1986	62,500	30,250	1,230.000	738,000	768,250
1987	63,000	31,250	1,290,000	774,000	805,250
1988	64,500	31,500	1,330,000	798,000	829,500
1989	65,000	32,250	1,360,000	816,000	848,250
1990	66,000	32,500	1,400,000	840,000	872,500
1991	66,500	33,000	1,420,000	852,000	885,000
1992	67,000	33,250	1,450,000	870,000	903,250
1993	67,500	33,500	1,470,000	882,000	915,500
1994	68,500	33,750	1,480,000	888,000	921,750
1995	69,000	34,250	1,500,000	900,000	934,250
1996	69,500	34,520	1,520,000	912,000	946,500
1997	70,000	34,750	1,530,000	918,000	952,750
1998	70,500	35,000	1,540,000	924,000	959,000
1999	71,000	35,250	1,550,000	930,000	965,250
2000	71,500	35,500	1,550,000	930,000	965,500

5.0 THE CHALLENGE FOR THE ENGINEERS

There are lots of questions that come to mind as one looks at the prospects of steel scrap recycling. Some of them are: -

1. What can the Nigerian engineer do to produce equipment to facilitate scrap sorting such as drop analysis equipment, sorting conveyors?.

2. What can the Nigerian engineers and engineering enterprises do to encourage the manufacture of scrap cutting equipment (e.g. Alligator shears, flame cutters pneumatic hammers, Guillotine shears), Baling presses, Hammer mills, briquetting presses and Furnaces?

3. What can the Nigerian materials engineers do to develop local foundry raw and process materials and what can the Nigerian Industrial engineers do to design scrap processing work places for high productivity?

4. Should we build one large processing plant or small dispersed units and what can the Nigerian engineer contribute to indeginise the technology?

5. What will be the effect of good maintenance of our roads. Is there any significant effect to scrap collection from place of origin to processing mills?

6. What will be the optimum spatial distribution of small scrap processing plant in terms of the transportation cost, cost of foreign exchange, etc. To answer some of these questions raised we shall be using three Operational Research techniques namely; decision analysis, shortest route approach and mathematrical programming. The decision tree and shortest route diagram are shown in Figure 5 and 6 respectively. The results, discussions and conclusion are jointly treated in the next section.

6.0 RESULTS, DISCUSSIONS AND CONCLUSION.

1. Between 1970 and 1984 thre is an aggregate accumulated steel scrap of over 6 million MT (or over 8 million MT crude steel equivalent (C.SE.) and upto 1.6 million MT annually by the year 2,000AD.

2. Assuming a 50% recovery efficiency for Industrial scrpas and between 60-80% for amortization scraps over 5 million MT C.S.E. of recoverable scrap has accumulated in the country since 1970 consisting of mainly the old scraps. This includes the estimated aggregate local scrap utilization of about 2.0 million MT C.S.E. by the local mini-steel mills in Lagos, Kano and Enugu.

3. Given the availability of steel scraps processing mills in Nigeria over 1 million MT of steel industry "raw material" is available annually for the rest of this decade and over 1.5 million MT C.S.E. annually in the next decade. This represents a foreign exchange savings of over ₦4 billion by the turn of the century (assuming ₦200/MT savings). This is obviously a colossal sum of money.

4. The establishment of these steel scrap processing mills could be done in two days:–

   (a) By a turn-key contract for say a 1 million MT plant in one or more locations or

(b) By a time phased establishment of smaller capacity involving the importation of machinery and the development of machinery and equipment by Nigerian Engineers and Technologists.

5. The latter is highly favoured if the cost foreign is heavily weighted as well as denial of Nigerian Engineers from developing the technology locally (enhancing self. reliance). This is shown in the result of the "Friendly" Decision Tree in Table 8.

6. When analysing this problem as a Transportation problem small and dispersed steel scrap processing mills are highly favoured to large centralised mills. This is because development of machinery and equipment for smaller mill by Nigerian Engineers is more likely than for large automated ones. Also the huge transportation cost due to the large country size necessitate the decentralization of processing operations. The effort by the Nigerian Engineers is assumed to be equivalent to plant(s) of capacity 50,000 MTY established every year.

7. Since dispersed mills are favoured, prompt and efficient maintenance of roads will contribute heavily to the overall cost reduction for the logistics of scrap collection and transportation. For example, if we take a trivial case (See Figure 5) of the disruption of free traffic flow of lorries from Lagos to Ibadan due to bad road, one will be forced to either pay more to transport scraps from Lagos to Ibadan (if Ibadan is made one of the processing centres) or go through Abeokuta which is a non-optional route. (See Appendix III).

8. This huge savings in foreign exchange will be possible if the Nigerian Engineer takes up challenge of the development of "appropriate" scrap processing machinery and equipment, attends promptly to roads that require repairs, etc, etc. This is obviously, a challenge to the Nigerian Engineer for Cost Effective steel scrap recovery.

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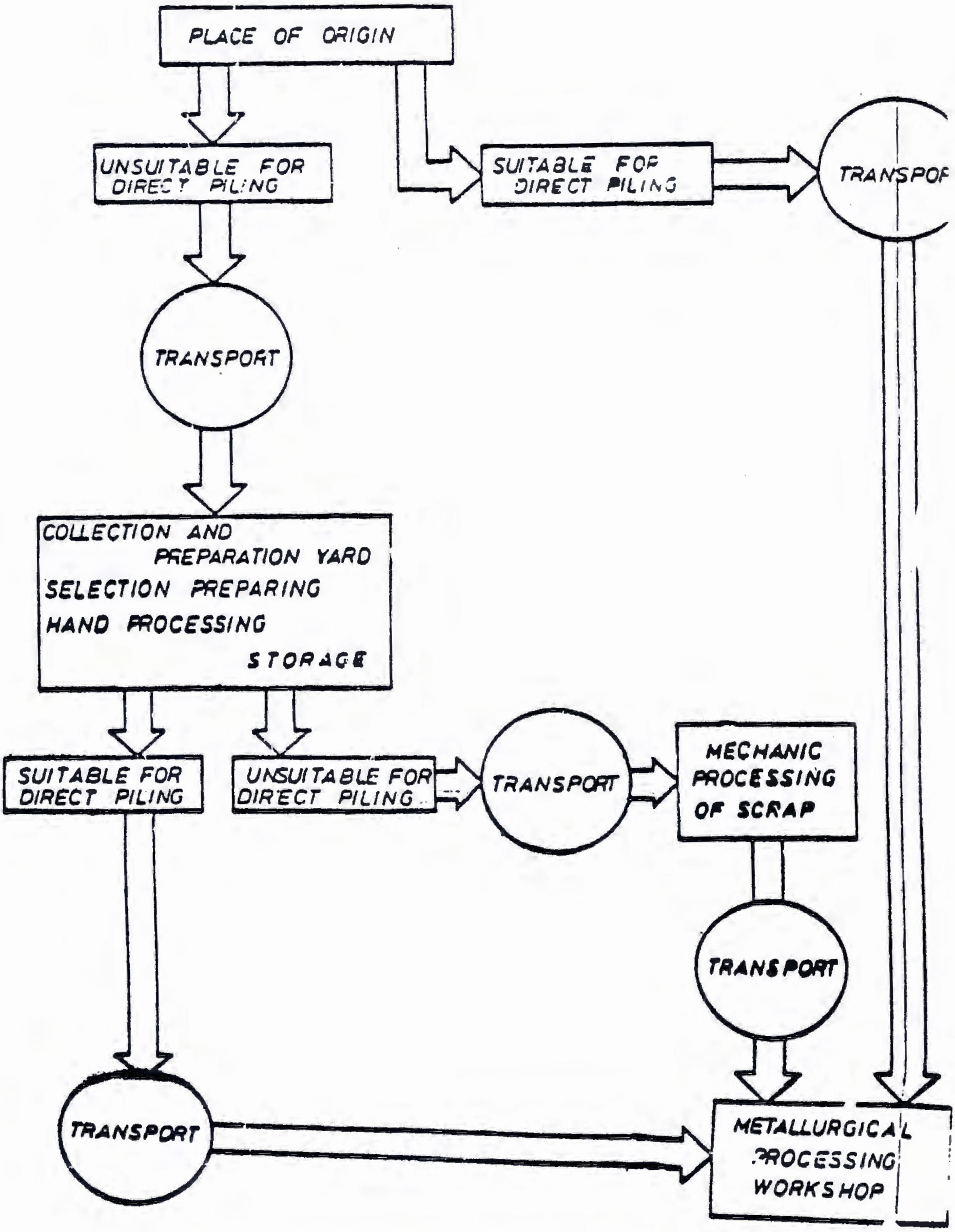
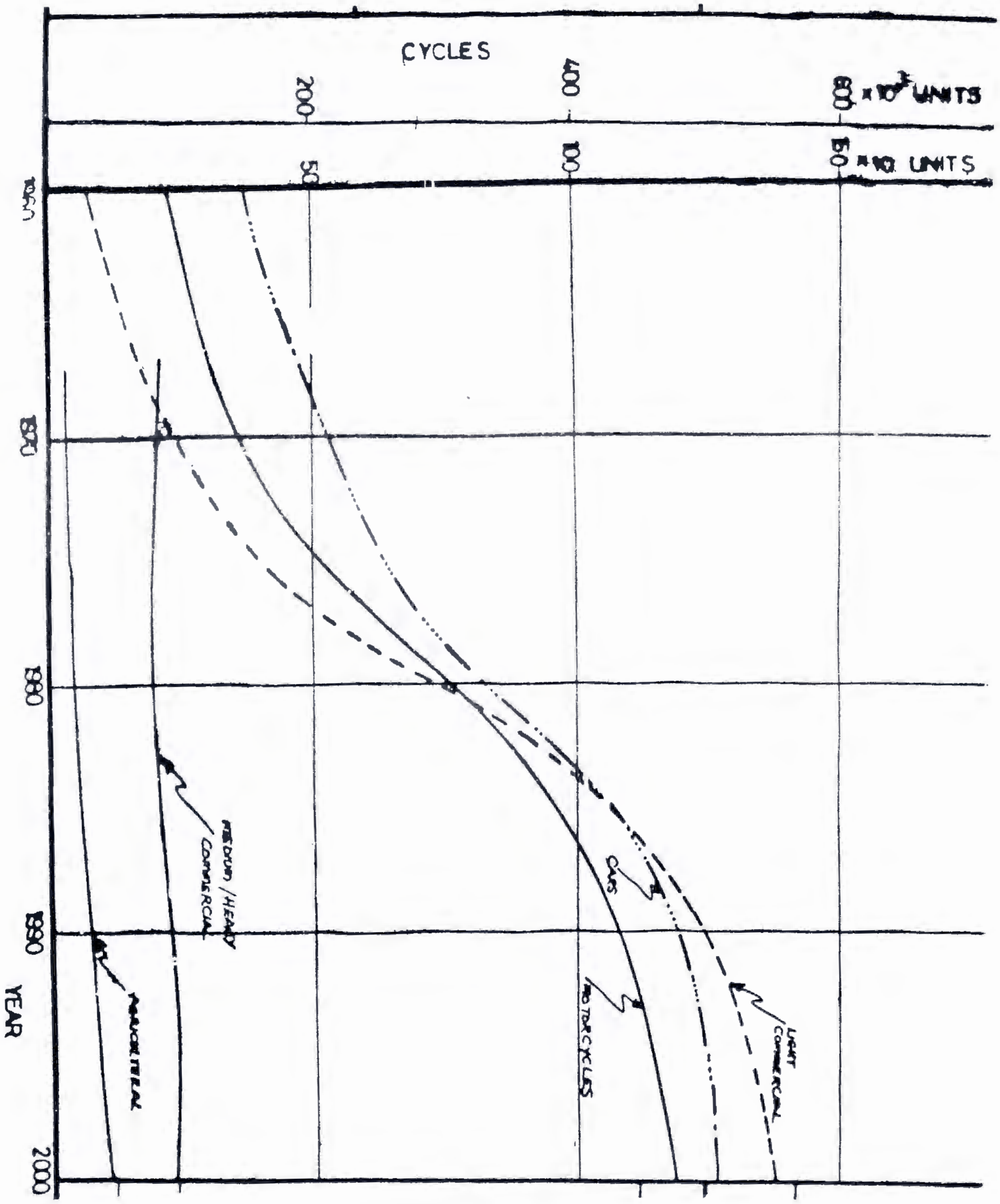
APPENDIX II: ESTIMATE COST FOR 50,000MT SCRAP COLLECTION AND PROCESSING PLANT

		₦' 000
1.	Construction Cost	8,000
2.	Processing machines and equipment	3,500
3.	Test Instruments	100
4.	Transport facilities	1,500
5.	Road network within plant	300
6.	Security and fire fighting equipment	200
7.	Utilities with plant	400
	TOTAL:	**₦14,000**

Source: Calculations from Ref:

FIG.1: FLOW SHEET OF SCRAPS TRANSPORT




CYCLES
200
400
600
50
100
150
YEAR
MEDIUM / HEAVY COMMERCIAL
CARS
MOTORCYCLES
LIGHT COMMERCIAL

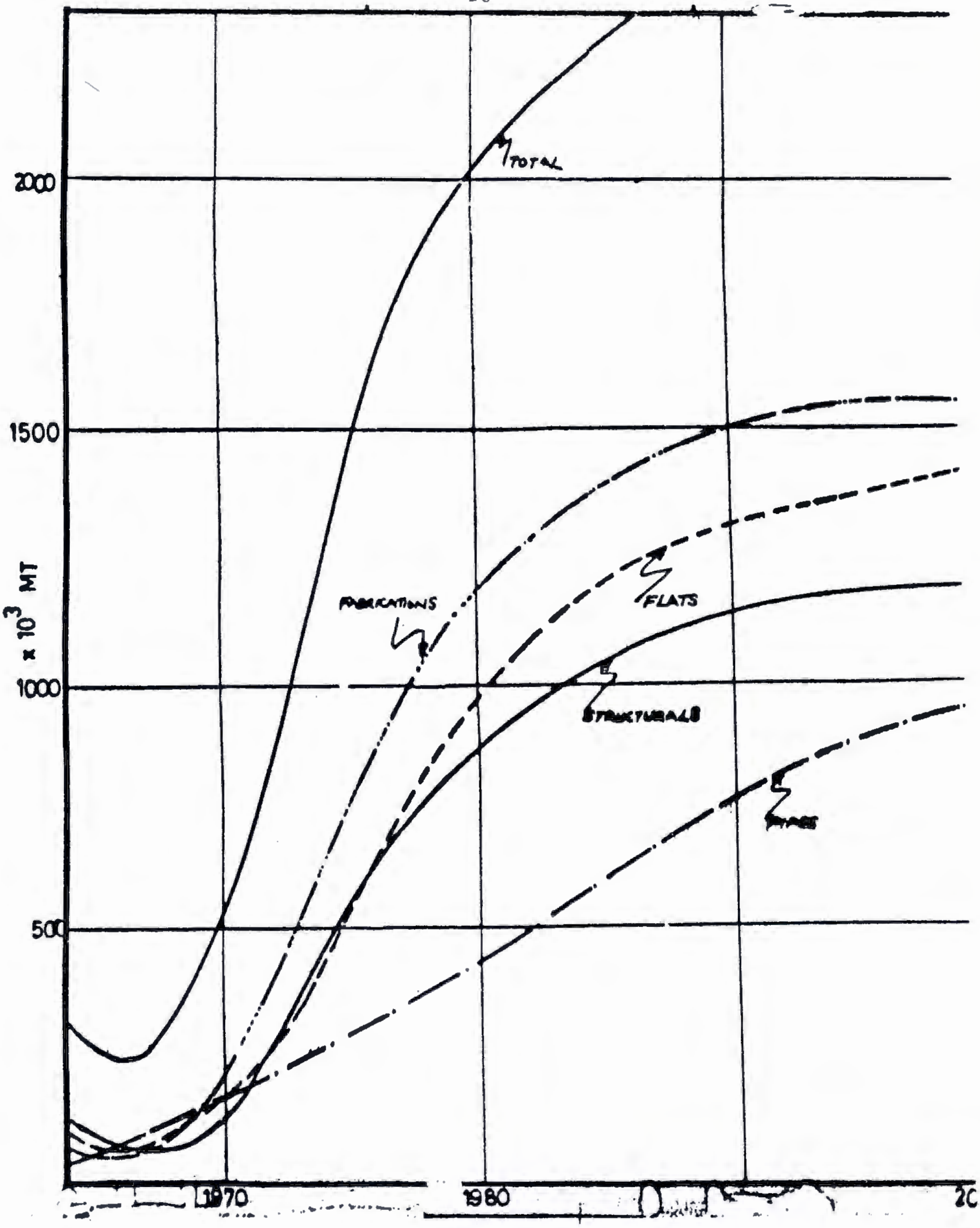


FIG.3: FINISHED STEEL CONSUMPTION/DEMAND BY SECTOR

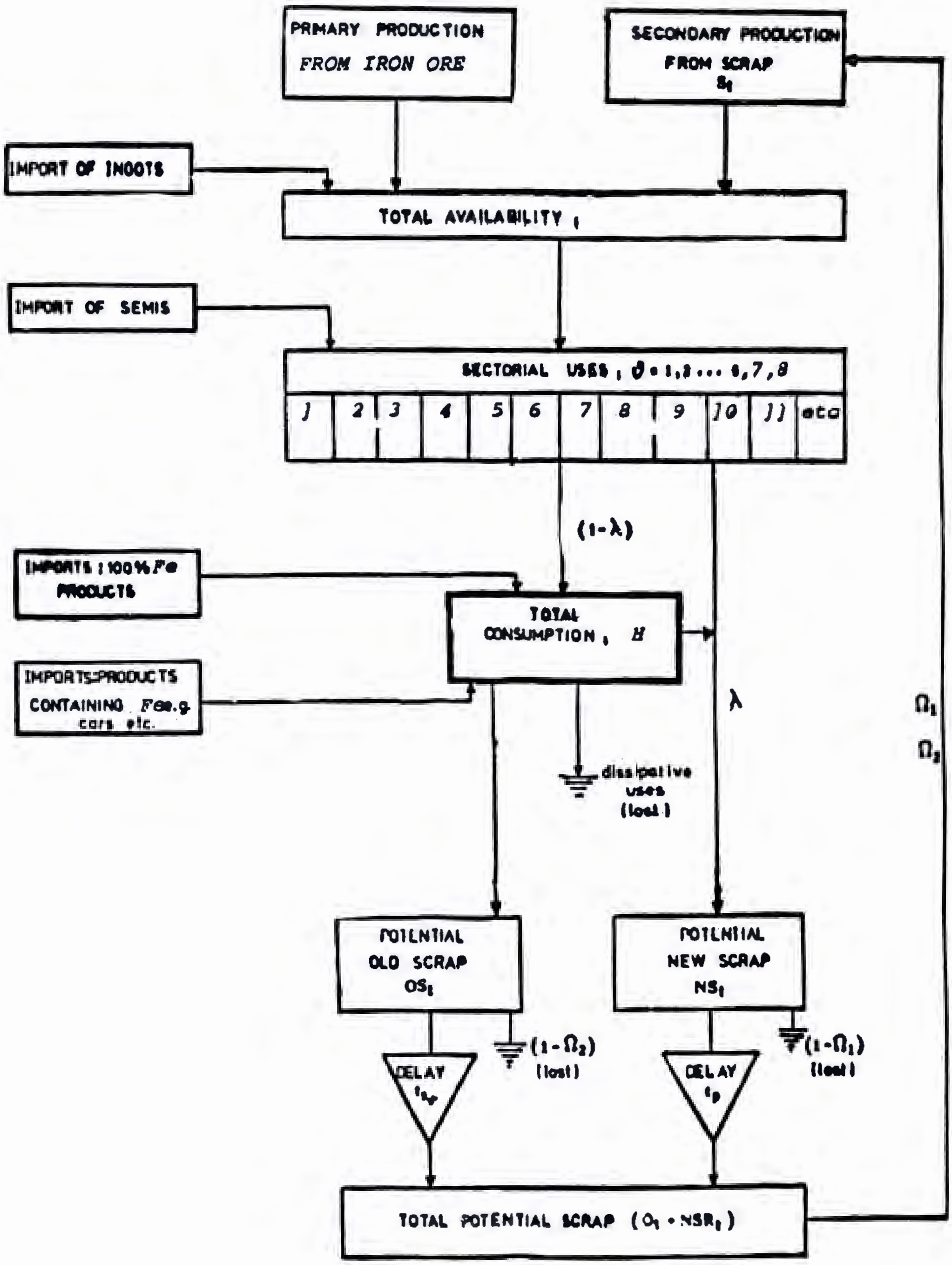


FIG.4 : Flow Chart of the Production and Use of *Iron Steel* for the Nigerian case.

ASSUMPTIONS

1. 50,000MT plant cost ₦15million
2. Nigerian Engineers establish equivalent of 50,000MT plant annually
3. Efficiency increases with time and high with Local Technology
4. Problems of spare parts decreases imported plant utilization
5. Terminal Capacity by year 2000AD is 1million MT.

KEY

S: Savings (₦million)

C: Capacity (million MT)

η: operating efficiency/utilization

P: Cost of plant (₦million)

p: probability of branch

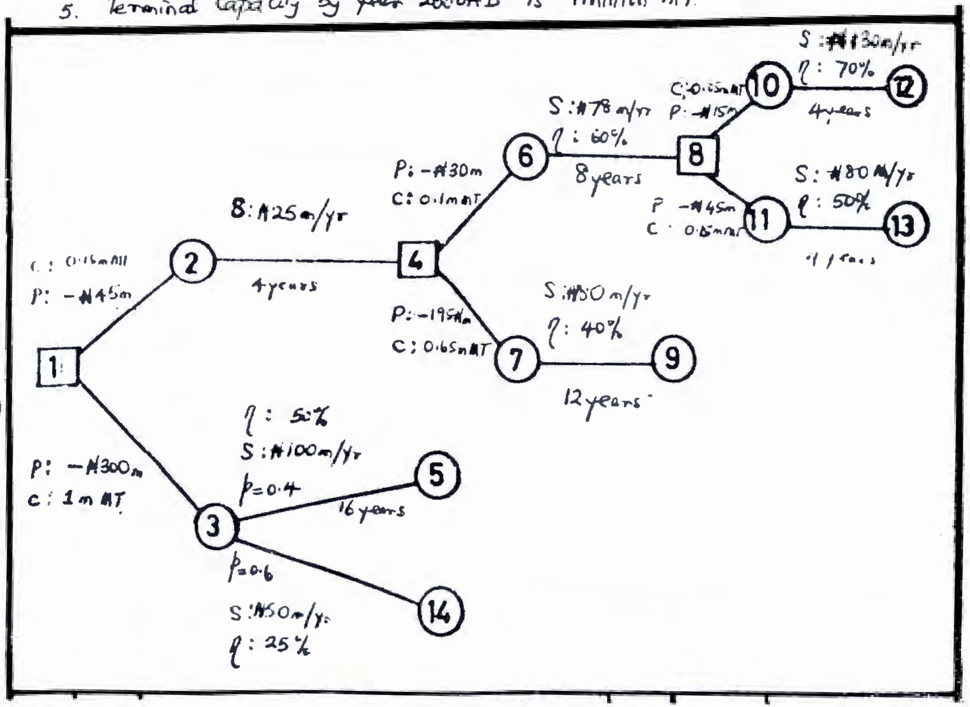


FIG.5: THE INVESTMENT DECISION TREE

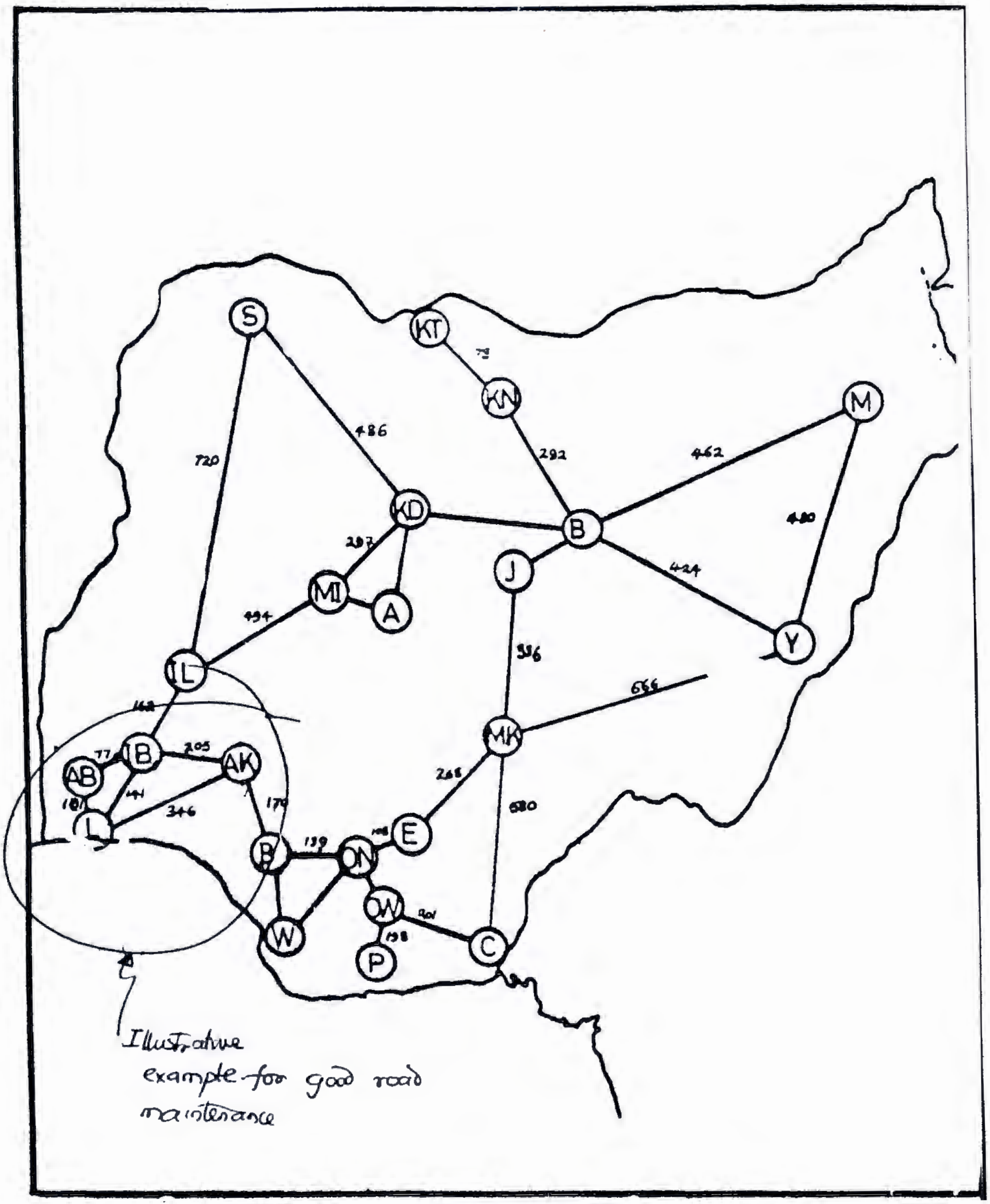


FIG. 6: SHORTEST ROUTE DIAGRAM

APPENDIX I: IRON & STEEL CONSUMPTION/DEMAND BY SECTOR

YEAR	CARS	L/COMMER	M&H/COMM	ASRIC	CYCLES	STRUCTLS	PIPES	LOC FABTN	FLAT/SH	TOTAL
1971	55,000.	54,000.	120,000.	8,000.	31,200.	134,129.	253,461.	189,998.	164,598.	845,788.
1972	57,000.	58,000.	120,000.	8,000.	32,800.	216,065.	105,072.	257,756.	211,981.	854,693.
1973	60,000.	64,000.	120,000.	8,000.	35,200.	323,212.	172,180.	257,295.	236,078.	1,039,887.
1974	62,000.	70,000.	120,000.	8,000.	36.800.	553,962.	309,713.	310,175.	277,462.	1,470,650.
1975	71,049.	76,000.	120,000.	8,000.	40,000.	549,521.	347,475.	990,150.	326,477.	2,202,195.
1976	73,224.	84,600.	170,496.	17,600.	43,200.	589,007.	208,783.	771,270.	706,319.	1,958,180.
1977	90,950.	118,940.	201,756.	17,800.	50,400.	681,371.	378,672.	870,172.	768,661.	2,410,061.
1978	67,364.	107,290.	164,286.	20,000.	54,000.	650,000.	350,000.	1,080,000.	840,000.	2,492,940.
1979	63,381.	94,096.	82,824.	8,664.	58,000.	710,000.	380,000.	1,160,000.	920,000.	2,556,965.
1980	75,413.	159,446.	93,828.	12,684.	62,400.	780,000.	410,000.	1,230,000.	990,000.	2,823,771.
1981	106,079.	251,968.	123,012.	14,368.	65,600.	830,000.	450,000.	1,290,000.	1,050,000.	3,131,027.
1982	89,818.	168,900.	114,000.	15,200.	60,000.	880,000.	480,000.	1,330,000.	1,100,000.	3,137,918.
1983	97,000.	182,000.	111,600.	20,000.	72,000.	920,000.	520,000.	1,360,000.	1,150,000.	3,282,600.
1984	104,000.	196,000.	117,000.	16,800.	76,000.	940,000.	550,000.	1,400,000.	1,190,000.	3,419,800.
1985	112,000.	210,000.	123,000.	17,600.	80,000.	999,000.	590,000.	1,420,000.	1,210,000.	3,542,600.
1986	112,000.	224,000.	120,000.	20,000.	80,000.	1,020,000.	620,000.	1,450,000.	1,250,000.	3,646,000.
1987	114,000.	232,000.	126,000.	22,000.	81,600.	1,040,000.	660,000.	1,470,000.	1,260,000.	3,745,600.
1988	116,000.	240,000.	126,000.	24,000.	83,200.	1,060,000.	690,000.	1,480,000.	1,290,000.	3,819,200.
1989	118,000.	245,000.	132,000.	24,000.	84,800.	1,080,000.	720,000.	1,500,000.	1,300,000.	3,903,800.
1990	120,000.	250,000.	132,000.	28,000.	86,400.	1,100,000.	750,000.	1,520,000.	1,320,000.	3,986,400.
1991	122,000.	254,000.	138,000.	28,000.	86,000.	1,130,000.	770,000.	1,530,000.	1,330,000.	4,058,000.
1992	123,000.	258,000.	138,000.	28,000.	88,800.	1,150,000.	800,000.	1,540,000.	1,340,000.	4,125,800.
1993	124,000.	262,000.	141,000.	28,000.	89,600.	1,160,000.	840,000.	1,550,000.	1,350,000.	4,194,600.
1994	125,000.	264,000.	141,000.	28,000.	91,200.	1,170,000.	860,000.	1,550,000.	1,370,000.	4,229,200.
1995	126,000.	268,000.	141,000.	28,000.	92,000.	1,170,000.	890,000.	1,550,000.	1,380,000.	4,265,000.
1996	127,000.	270,000.	144,000.	36,000.	92,800.	1,180,000.	910,000.	1,560,000.	1,390,000.	4,319,800.
1997	127,000.	270,000.	144,000.	40,000.	93,600.	1,180,000.	930,000.	1,560,000.	1,400,000.	4,344,600.
1998	128,000.	274,000.	144,000.	40,000.	93,600.	1,190,000.	950,000.	1,560,000.	1,410,000.	4,379,600.
1999	128,000.	274,000.	144,000.	44,000.	93,600.	1,190,000.	960,000.	1,560,000.	1,420,000.	4,393,600.
2000	128,000.	274,000.	144,000.	44,000.	93,600.	1,190,000.	970,000.	1,560,000.	1,430,000.	4,403,600.

TABLE 1: RECOVERABLE STEEL SCRAP FORECAST TO 2000AD

YEAR	POTENTIAL NEW SCRAP	NEW SCRAP RECOVERED	POTENTIAL OLD SCRAP	RECOVERED OLD SCRAP	SECONDARY PRODUCTION
1971	8,230.	82,299.	189,998.	113,999.	196,298.
1972	10,599.	4,115.	189,998.	113,999.	118,114.
1973	11,804.	5,300.	189,998.	113,999.	119,298.
1974	13,873.	5,902.	189,998.	113,999.	119,901.
1975	16,324.	6,937.	189,998.	113,999.	120,935.
1976	35,316.	8,162.	189,998.	113,999.	122,161.
1977	38,433.	17,658.	189,998.	113,999.	131,657.
1978	42,000.	19,217.	257,756.	154,654.	173,870.
1979	46,000.	21,000.	257,295.	154,377.	175,377.
1980	49,500.	23,000.	310,175.	186,105.	209,105.
1981	52,500.	24,750.	990,150.	594,090.	618,840.
1982	55,000.	26,250.	771,270.	462,762.	489,012.
1983	57,500.	27,500.	870,172.	522,103.	549,603.
1984	59,500.	28,750.	1,080,000.	648,000.	676,750.
1985	60,500.	29,750.	1,160,000.	696,000.	725,750.
1986	62,500.	30,250.	1,230,000.	738,000.	768,250.
1987	63,000.	31,250.	1,290,000.	774,000.	805,250.
1988	64,500.	31,500.	1,330,000.	798,000.	829,500.
1989	65,000.	32,250.	1,360,000.	816,000.	848,250.
1990	66,000.	32,500.	1,400,000.	840,000.	872,500.
1991	66,500.	33,000.	1,420,000.	852,000.	885,000.
1992	67,000.	33,250.	1,450,000.	870,000.	903,250.
1993	67,500.	33,500.	1,470,000.	882,000.	915,500.
1994	68,500.	33,750.	1,480,000.	888,000.	921,750.
1995	69,000.	34,250.	1,500,000.	900,000.	934,250.
1996	69,500.	34,500.	1,520,000.	912,000.	946,500.
1997	70,000.	34,750.	1,530,000.	918,000.	952,750.
1998	70,500.	35,000.	1,540,000.	924,000.	959,000.
1999	71,000.	35,250.	1,550,000.	930,000.	965,250.
2000	71,500.	35,500.	1,550,000.	930,000.	965,500.

APPENDIX III: COMPUTER LISTING FOR SCRAP ESTIMATION

```
10 REM *********************************************************
20 REM *                                                       *
30 REM *                                                       *
40 REM *          PROGRAM FOR STEEL SCRAP ESTIMATION           *
50 REM *                                                       *
60 REM *                                                       *
70 REM *********************************************************
80 REM
90 REM
100 DEFINT I,J,T,X
110 DEFDBL H
120 DIM YEAR(40),H(10,40),L(10),NS(40),NSR(40),OS(10,40),OST(40),OSR(10,40),OSRT
(40),S(40),W(10)
130 NIZ=1:NEZ=3?:NIZ=1:NEZ=8:P=.05:Q=.5:TP=1
140 FOR T=NIZ TO NEZ+1
150 READ YEAR(T),H(1,T),H(2,T),H(3,T),H(4,T),H(5,T),H(6,T),H(7,T),H(8,T),H(9,T)
160 H(10,T)=H(1,T)+H(2,T)+H(3,T)+H(4,T)+H(5,T)+H(6,T)+H(7,T)+H(8,T)
170 NEXT T
180 FOR I=NIZ TO NEZ
190 READ  W(I),L(I)
200 NEXT I
210 FOR T=NIZ TO NEZ
220 FOR I= NIZ TO NEZ
230 NS(T)=P*H(9,T)
240 TTP=T-TP
250 IF(TTP<=0) THEN TTP=NEZ+1:NS(TTP)=H(9,TTP):GOTO 260 ELSE GOTO 260
260 NSR(T)=Q*NS(TTP)
270 TLT=T-L(I)
280 IF(TLT<=0) THEN TLT=NEZ+1
290 OS(I,T)=H(I,TLT)
300 OST(T)=OS(I,T)
310 OSR(I,T)=W(I)*OS(I,T)
320 OSRT(T)=OSR(I,T)
330 S(T)=NSR(T)+OSR(I,T)
340 NEXT I,T
350 BIT ON
360 WIDTH LPRINT 132
370 LPRINT CHR£(15)
380 LPRINT " YEAR       CARS     L/COMMER  M&H/COMM     AGRIC      CYCLES      STRU
CTLS      PIPES      LOC FABTN   FLAT/SH     TOTAL":LPRINT
390 FOR T=NIZ TO NEZ
400 LPRINT USING "££££££  £££££££,.  £££££££,.  £££££££,.  £££££££,.  £££££££,.
££££££££,.  ££££££££,.  ££££££££,.  ££££££££,.  ££££££££,.";YEAR(T);H(1,T);H(2,T
);H(3,T);H(4,T);H(5,T);H(6,T);H(7,T);H(8,T);H(9,T);H(10,T)
410 NEXT T
420 LPRINT :LPRINT :LPRINT :LPRINT :LPRINT
430 PRINT "HIT ANY KEY TO CONTINUE PRINTING":A$=INPUT$(1)
440 LPRINT "YEAR"TAB(12)"POTENTIAL" TAB(24)"NEW SCRAP" TAB(36) "POTENTIAL" TAB(4
8) "RECOVERED" TAB(60) "SECONDARY"
450 LPRINT TAB(12) "NEW SCRAP" TAB(24) "RECOVERED" TAB(36) "OLD SCRAP" TAB(48)"O
LD SCRAP" TAB(60)"PRODUCTION"
460 LPRINT
470 FOR T=NIZ TO NEZ
480 LPRINT USING"££££      ££££££££,.   £££££££,.  ££££££££,.  ££££££££,.   ££££
££££,.";YEAR(T);NS(T);NSR(T);OST(T);OSRT(T);S(T)
490 NEXT T
500 LPRINT CHR$(18)
510 END
```

ORDERED TREE

FROM TO NODE	NODE	PROB	NAIRA VALUE	YEARS	INTEREST RATE
1	2	DECIDE	-45	0	.1
1	3	DECIDE	-300	0	.1
2	4	1	25	4	.1
3	5	.4	100	16	.1
3	14	.6	50	16	.1
4	6	DECIDE	-30	0	.1
4	7	DECIDE	-195	0	.1
6	8	1	78	8	.1
7	9	1	80	12	.1
8	10	DECIDE	-15	0	.1

HIT ENTER TO CONTINUE ?

FROM NODE	TO NODE	PROB	NAIRA VALUE	YEARS	INTEREST RATE
8	11	DECIDE	-45	0	.1
10	12	1	130	4	.1
11	13	1	80	4	.1

EVALUATED DECISION TREE

FROM TO NODE	NODE	PROB	NAIRA VALUE	YEARS	INTEREST RATE
1	2	DECIDE	424.497	0	.1
1	3	DECIDE	247.66	0	.1
2	4	1	469.497	4	.1
3	5	.4	782.371	16	.1
3	14	.6	391.185	16	.1
4	6	DECIDE	571.366	0	.1
4	7	DECIDE	350.095	0	.1
6	8	1	601.366	8	.1
7	9	1	545.095	12	.1
8	10	DECIDE	397.083	0	.1

HIT ENTER TO CONTINUE ?

FROM NODE	TO NODE	PROB	NAIRA VALUE	YEARS	INTEREST RATE
8	11	DECIDE	208.589	0	.1
10	12	1	412.083	4	.1
11	13	1	253.589	4	.1

HIT ENTER TO CONTINUE ?

BEST DECISIONS ARE

FROM NODE	TO NODE	NAIRA VALUE
1	2	424.497
4	6	571.366
8	10	397.083

```
10 REM ***********************************************************
20 REM *                                                         *
30 REM *                                                         *
40 REM *         PROGRAM FOR STEEL SCRAP ESTIMATION              *
50 REM *                                                         *
60 REM *                                                         *
70 REM ***********************************************************
80 REM
90 REM
100 DEFINT I,J,T,X
110 DEFDBL H
120 DIM YEAR(40),H(10,40),L(10),NS(40),NSR(40),OS(10,40),OST(40),OSR(10,40),OSRT
(40),S(40),W(10)
130 NIX=1:NEX=3%:NII=1:NEI=8:P=.05:Q=.5:TP=1
140 FOR T=NIX TO NEX+1
150 READ YEAR(T),H(1,T),H(2,T),H(3,T),H(4,T),H(5,T),H(6,T),H(7,T),H(8,T),H(9,T)
160 H(10,T)=H(1,T)+H(2,T)+H(3,T)+H(4,T)+H(5,T)+H(6,T)+H(7,T)+H(8,T)
170 NEXT T
180 FOR I=NII TO NEI
190 READ  W(I),L(I)
200 NEXT I
210 FOR T=NIX TO NEX
220 FOR I= NII TO NEI
230 NS(T)=P*H(9,T)
240 TTP=T-TP
250 IF(TTP<=0) THEN TTP=NEX+1:NS(TTP)=H(9,TTP):GOTO 260 ELSE GOTO 260
260 NSR(T)=Q*NS(TTP)
270 TLT=T-L(I)
280 IF(TLT<=0) THEN TLT=NEX+1
290 DS(I,T)=H(I,TLT)
300 DST(T)=DS(I,T)
310 DSR(I,T)=W(I)*DS(I,T)
320 DSRT(T)=DSR(I,T)
330 S(T)=NSR(T)+DSR(I,T)
340 NEXT I,T
350 BIT ON
360 WIDTH LPRINT 132
370 LPRINT CHR$(15)
380 LPRINT " YEAR      CARS     L/COMMER  M&H/COMM    AGRIC     CYCLES     STRU
CTLS      PIPES      LOC FABTN   FLAT/SH    TOTAL":LPRINT
390 FOR T=NIX TO NEX
400 LPRINT USING "£££££  £££££££,.  £££££££,.  £££££££,.  £££££££,.  £££££££,.
££££££££,.  ££££££££,.  ££££££££,.  ££££££££,.  ££££££££,.";YEAR(T);H(1,T);H(2,T
);H(3,T);H(4,T);H(5,T);H(6,T);H(7,T);H(8,T);H(9,T);H(10,T)
410 NEXT T
420 LPRINT :LPRINT :LPRINT :LPRINT :LPRINT
430 PRINT "HIT ANY KEY TO CONTINUE PRINTING":A$=INPUT$(1)
440 LPRINT "YEAR"TAB(12)"POTENTIAL" TAB(24)"NEW SCRAP" TAB(36) "POTENTIAL" TAB(4
8) "RECOVERED" TAB(60) "SECONDARY"
450 LPRINT TAB(12) "NEW SCRAP" TAB(24) "RECOVERED" TAB(36) "OLD SCRAP" TAB(48)"O
LD SCRAP" TAB(60)"PRODUCTION"
460 LPRINT
470 FOR T=NIX TO NEX
480 LPRINT USING"££££    ££££££££,.   £££££££,.  ££££££££,.  ££££££££,.   ££££
££££,.";YEAR(T);NS(T);NSR(T);DST(T);DSRT(T);S(T)
490 NEXT T
500 LPRINT CHR$(18)
510 END
```

```
520 DATA 1971, 55000, 54000, 120000, 8000, 31200, 134129, 253461, 189998, 164598
530 DATA 1972, 57000, 58000, 120000, 8000, 32000, 216065, 105072, 257750, 211981
540 DATA 1973, 60000, 64000, 120000, 8000, 35200, 323212, 172180, 257295, 236078
550 DATA 1974, 62000, 70000, 120000, 8000, 36800, 553962, 309713, 310175, 277462
560 DATA 1975, 71049, 76000, 120000, 8000, 40000, 547521, 347475, 990150, 326477
570 DATA 1976, 73224, 84600, 170496,17600, 43200, 589007, 208783, 771270, 706319
580 DATA 1977, 90950,118940, 201756,17800, 50400, 681371, 378672, 870172, 768661
590 DATA 1978, 67364,107290, 164286,20000, 54000, 650000, 350000,1080000, 840000
600 DATA 1979, 63381, 94096,  82824, 8664, 58000, 710000, 380000,1160000, 920000
610 DATA 1980, 75413,159446,  93828,12684, 62400, 780000, 410000,1230000, 990000
620 DATA 1981,106079,251968, 123012,14368, 65600, 830000, 450000,1290000,1050000
630 DATA 1982, 86818,168900, 114000,15200, 60000, 880000, 480000,1330000,1100000
640 DATA 1983, 97000,182000, 111600,20000, 72000, 920000, 520000,1360000,1150000
650 DATA 1984,104000,196000, 117000,16800, 76000, 960000, 550000,1400000,1190000
660 DATA 1985,112000,210000, 123000,17600, 80000, 990000, 590000,1420000,1210000
670 DATA 1986,112000,224000, 120000,20000, 80000,1020000, 620000,1450000,1250000
680 DATA 1987,114000,232000, 126000,22000, 81600,1040000, 660000,1470000,1260000
690 DATA 1988,116000,240000, 126000,24000, 83200,1060000, 690000,1480000,1290000
700 DATA 1989,118000,245000, 132000,24000, 84800,1080000, 720000,1500000,1300000
710 DATA 1990,120000,250000, 132000,28000, 86400,1100000, 750000,1520000,1320000
720 DATA 1991,122000,254000, 138000,28000, 86000,1130000, 770000,1530000,1330000
730 DATA 1992,123000,258000, 138000,28000, 88800,1150000, 800000,1540000,1340000
740 DATA 1993,124000,262000, 141000,28000, 89600,1160000, 840000,1550000,1350000
750 DATA 1994,125000,264000, 141000,28000, 91200,1170000, 860000,1550000,1370000
760 DATA 1995,126000,268000, 141000,28000, 92000,1170000, 890000,1550000,1380000
770 DATA 1996,127000,270000, 144000,36000, 92800,1180000, 910000,1560000,1390000
780 DATA 1997,127000,270000, 144000,40000, 93600,1180000, 930000,1560000,1400000
790 DATA 1998,128000,274000, 144000,40000, 93600,1190000, 950000,1560000,1410000
800 DATA 1999,128000,274000, 144000,44000, 93600,1190000, 960000,1560000,1420000
810 DATA 2000,120000,274000, 144000, 44000, 93600,1190000,970000,1560000,1430000
820 DATA 1970, 55000, 54000, 120000, 8000, 31200, 134129, 253461, 189998, 164598
830 DATA 0.8, 5
840 DATA 0.8, 4
850 DATA 0.8, 4
860 DATA 0.8, 6
870 DATA 0.6, 4
880 DATA 0.6, 10
890 DATA 0.6, 8
900 DATA 0.6, 6
```

APPENDIX V: DECISION TREE SOLUTION

```
TOTAL NUMBER OF BRANCHES ? 13
INPUT THE DISCOUNT RATE ? 10
INPUT BRANCH 1 (FROM , TO) ? 1,2
WHAT IS THE PROBABILITY OF BRANCH 1 ? 0
WHAT IS THE NAIRA VALUE ? -45
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 0
INPUT BRANCH 2 (FROM , TO) ? 1,3
WHAT IS THE PROBABILITY OF BRANCH 2 ? 0
WHAT IS THE NAIRA VALUE ? -300
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 0
INPUT BRANCH 3 (FROM , TO) ? 3,[illegible]
WHAT IS THE PROBABILITY OF BRANCH 3 ? 0.6
WHAT IS THE NAIRA VALUE ? 50
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 16
INPUT BRANCH 4 (FROM , TO) ? 3.[illegible]
WHAT IS THE PROBABILITY OF BRANCH 4 ? 0.4
WHAT IS THE NAIRA VALUE ? 100
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 16
INPUT BRANCH 5 (FROM , TO) ?
WHAT IS THE NAIRA VALUE ? 25
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 4
INPUT BRANCH 6 (FROM , TO) ? 4.[illegible]
WHAT IS THE PROBABILITY OF BRANCH [illegible] ? 0
WHAT IS THE NAIRA VALUE ? -30
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 0
INPUT BRANCH 7 (FROM , TO) ? 6.[illegible]
WHAT IS THE PROBABILITY OF BRANCH [illegible] ? 1
WHAT IS THE NAIRA VALUE ? 78
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 8
INPUT BRANCH 8 (FROM , TO) ? [illegible]
WHAT IS THE PROBABILITY OF BRANCH [illegible] ? 1
WHAT IS THE NAIRA VALUE ? 80
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 12
INPUT BRANCH 9 (FROM , TO) ? 6.[illegible]
WHAT IS THE PROBABILITY OF BRANCH [illegible] ? 0
WHAT IS THE NAIRA VALUE ? -15
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 0
INPUT BRANCH 10 (FROM , TO) ? [illegible]
WHAT IS THE PROBABILITY OF BRANCH 10 ?
WHAT IS THE PROBABILITY OF BRANCH 10 ? 0
WHAT IS THE NAIRA VALUE ? -45
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 0
INPUT BRANCH 11 (FROM , TO) ? 10.11
WHAT IS THE PROBABILITY OF BRANCH 11 ? 1
WHAT IS THE NAIRA VALUE ? 130
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 4
INPUT BRANCH 12 (FROM , TO) ? 11.13
WHAT IS THE PROBABILITY OF BRANCH 12 ? 1
WHAT IS THE NAIRA VALUE ? 80
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 4
INPUT BRANCH 13 (FROM , TO) ? 4.[illegible]
WHAT IS THE PROBABILITY OF BRANCH 13 ? 0
WHAT IS THE NAIRA VALUE ? -195
OVER WHAT # OF YEARS IS THE MONEY INVESTED ? 0
```

APPENDIX IV: ILLUSTRATIVE EXAMPLE **FOR EFFECT OF POOR MAINTENANCE**

DATA DISPLAY

FROM NODE	TO NODE	DISTANCE
1	2	346
1	3	101
1	4	141
2	1	346
2	4	205
3	1	101
3	4	77
4	1	141
4	2	205
4	3	77

THE OPTIMAL ROUTE FROM 1 TO 2 HAS LENGTH 346
THE ROUTE IS :
FROM NODE 1 TO NODE 2 DISTANCE 346
THE OPTIMAL ROUTE FROM 1 TO 3 HAS LENGTH 101
THE ROUTE IS :
FROM NODE 1 TO NODE 3 DISTANCE 101
THE OPTIMAL ROUTE FROM 1 TO 4 HAS LENGTH 141
THE ROUTE IS :
FROM NODE 1 TO NODE 4 DISTANCE 141

DATA DISPLAY

FROM NODE	TO NODE	DISTANCE
1	2	346
1	3	101
1	4	441
2	1	346
2	4	205
3	1	101
3	4	77
4	1	141
4	2	205
4	3	77

THE OPTIMAL ROUTE FROM 1 TO 2 HAS LENGTH 346
THE ROUTE IS :
FROM NODE 1 TO NODE 2 DISTANCE 346
THE OPTIMAL ROUTE FROM 1 TO 3 HAS LENGTH 101
THE ROUTE IS :
FROM NODE 1 TO NODE 3 DISTANCE 101
THE OPTIMAL ROUTE FROM 1 TO 4 HAS LENGTH 178
THE ROUTE IS :
FROM NODE 1 TO NODE 3 DISTANCE 101
FROM NODE 3 TO NODE 4 DISTANCE 77