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

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THE ENGINEERING CHALLENGE FOR COST EFFECTIVE STEEL SCRAP RECOVERY IN NIGERIA

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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 it 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 pollution, reduce overall steel production cost and the high rate of both underemployment and unemployment 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 they should be brought into a condition to enable industrial processing or commercial use and transportation respectively. This is one of the challenges for the Nigerian Engineer.
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 metallurgical 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 enameled 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 especially 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 enterprises.

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.

3.2.5 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 50mmØ 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 up to 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 scrap 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.

\[ \begin{align*}
    p & = \text{loss during fabrication process} \\
    t & = \text{time (years)} \\
    q & = \text{recovery efficiency of new scrap} \\
    w(i) & = \text{recovery efficiency of sector } i \text{ old scrap} \\
    tp & = \text{new scrap recovery delay (years)} \\
    l(i) & = \text{average life of sector } i \\
    h(i,t) & = \text{end-use quantity by sector } i \text{ in time } t.
\end{align*} \]
4.3 Methodology for estimation.

4.3.1 Potential new scrap (NS) - During the fabrication process there is always some amount of scrap 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

\[ NS(t) = pd(t) \]

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 recovery and is given by

\[ NSR(t) = qNS(t-tp) \]

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

\[
OS(t) = \sum_{i=1}^{I} (1-p) \sum_{i=1}^{I} h(i,t-1) \text{ if local production} \\
\quad \quad \quad \quad + \sum_{i=1}^{I} h(i,t-1) \text{ if imported}
\]

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

So we now have that

\[ OS(i,t) = h(i,t-1) \]

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

\[ OSR(i,t) = w(i) * OS(i,t) \]

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

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

This model is shown diagrammatically in Figure 4 and the forecast is shown in Table 1.
<table>
<thead>
<tr>
<th>Year</th>
<th>Potential New Scrap</th>
<th>New Scrap Recovered</th>
<th>Potential Old Scrap</th>
<th>Recovered Old Scrap</th>
<th>Secondary Production</th>
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<td>11,999</td>
<td>196,298</td>
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<td>1,520,000</td>
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<td>1,530,000</td>
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<td>1,540,000</td>
<td>924,000</td>
<td>959,000</td>
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<td>1999</td>
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<td>1,550,000</td>
<td>930,000</td>
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<td>2000</td>
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<td>35,500</td>
<td>1,560,000</td>
<td>930,000</td>
<td>965,500</td>
</tr>
</tbody>
</table>
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 indigenise 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 mathematical 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 there is an aggregate accumulated steel scrap of over 6 million MT (or over 8 million MT crude steel equivalent (C.S.E.)) and upto 1.6 million MT annually by the year 2,000AD.

2. Assuming a 50% recovery efficiency for industrial scrap 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 N260/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-optimal 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.

REFERENCES


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

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (N'000)</th>
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<tbody>
<tr>
<td>1. Construction Cost</td>
<td>8,000</td>
</tr>
<tr>
<td>2. Processing machines and equipment</td>
<td>3,500</td>
</tr>
<tr>
<td>3. Test Instruments</td>
<td>100</td>
</tr>
<tr>
<td>4. Transport facilities</td>
<td>1,500</td>
</tr>
<tr>
<td>5. Road network within plant</td>
<td>300</td>
</tr>
<tr>
<td>6. Security and fire fighting equipment</td>
<td>200</td>
</tr>
<tr>
<td>7. Utilities with plant</td>
<td>400</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>N14,000</strong></td>
</tr>
</tbody>
</table>

*Source:* Calculations from Ref:
FIG. 1: FLOW SHEET OF SCRAPS TRANSPORT

PLACE OF ORIGIN

UNSUITABLE FOR DIRECT PILING

TRANSPORT

COLLECTION AND PREPARATION YARD
SELECTION PREPARING HAND PROCESSING STORAGE

SUITABLE FOR DIRECT PILING

UNSUITABLE FOR DIRECT PILING

TRANSPORT

MECHANICAL PROCESSING OF SCRAP

TRANSPORT

METALLURGICAL PROCESSING WORKSHOP
FIG. 3: FINISHED STEEL CONSUMPTION/DEMAND BY SECTOR
PRMARY PRODUCTION FROM IRON ORE

SECONDARY PRODUCTION FROM SCRAP

IMPORT OF INGOTS

TOTAL AVAILABILITY

IMPORT OF SEMIS

SECTORIAL USES, \( \Omega = 1, 2, \ldots, 7, 8 \)

TOTAL CONSUMPTION, \( \Lambda \)

IMPORTS: 100% Fe PRODUCTS

IMPORTS: PRODUCTS CONTAINING Fe, Co, Cu, etc.

TOTAL POTENTIAL OLD SCRAP, \( OS_i \)

TOTAL POTENTIAL NEW SCRAP, \( NS_i \)

TOTAL POTENTIAL SCRAP, \( \Lambda_i = NS_i \)

FIG. 4: Flow Chart of the Production and Use of Iron Steel for the Nigerian case.
ASSUMPTIONS
1. Plant cost #15 million
2. Plant established at site for 50,000 MT per annum
3. Efficiency increased with time and high risk local technology
4. Problems of spare parts decrease imported plant utilisation
5. Terminal capacity by year 2000 is #1 million MT

KEY
S: Savings (# million)
C: Cost (# million)
q: Operating efficiency
P: Cost of plant (# million)
F: Probability of branch

FIG. 5: THE INVESTMENT DECISION TREE
FIG. 6: SHORTEST ROUTE DIAGRAM
### Appendix I: Iron & Steel Consumption/Demand by Sector

<table>
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<tr>
<th>YEAR</th>
<th>CARS</th>
<th>L/CQM</th>
<th>MIN/COM</th>
<th>ASRRC</th>
<th>CYCLES</th>
<th>STREETLS</th>
<th>PIPES</th>
<th>LSC FAINT</th>
<th>POLISH</th>
<th>TOTAL</th>
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<td>57,000</td>
<td>51,000</td>
<td>150,000</td>
<td>6,000</td>
<td>31,700</td>
<td>134,120</td>
<td>223,410</td>
<td>187,960</td>
<td>114,200</td>
<td>245,780</td>
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<td>1972</td>
<td>57,000</td>
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### Table I: Recoverable Steel Scrap Forecast to 2000 AD

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APPENDIX III: COMPUTER LISTING FOR SCRAP ESTIMATION

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30 REM
40 REM
50 REM
60 REM
70 REM ******************************************************************************
80 REM
90 REM
100 DEFINT A-Z
110 DEFDBL H
120 DIM YEAR(40), T(10), NS(10), NSR(10), O5(10), O6(10), OS(10), OBT(10)
130 M2=1, M3=5, M4=1, M5=0, M6=0, M7=5; TP=1
140 FOR T=1 TO 10
150 READ YEAR(T), T1, T2, T3, T4, T5, T6, T7, T8, T9, T10;
160 H10>T=H1(T), H1(T), H2(T), H3(T), H4(T), H5(T), H6(T), H7(T), H8(T), H9(T); H11(T)
170 NEXT T
180 FOR T=11 TO 20
190 READ T11, T12
200 NEXT T
210 FOR T=21 TO 30
220 FOR T=31 TO 40
230 NS(T)+NS(T+1), T13
240 T1=T-TP
250 IF (T13=0) THEN T13=NS(T)+NS(T+1), T13)
260 M2=M2+1, M2=TP
270 T1=T-TP
280 IF (T13=0) THEN T13=TP+1
290 O5(T)=O5(T)+1, T14
300 O6(T)+O5(T)+1, T15
310 OS(T)+OS(T)+1, T16
320 OSR(T)+OSR(T)+1, T17
330 SS(T)+SSR(T)+SSR(T)+1, T18
340 NEXT T
350 NEXT T
360 NEXT T
370 NEXT T
380 NEXT T
390 NEXT T
400 NEXT T
410 NEXT T
420 NEXT T
430 NEXT T
440 NEXT T
450 NEXT T
460 NEXT T
470 NEXT T
480 NEXT T
490 NEXT T
500 NEXT T
510 END
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HIT ENTER TO CONTINUE?

HIT ENTER TO CONTINUE?
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 DIM Y(40), T(40), N(40), M(40), GSR(40), GBR(40), GSR(40), DBRT(40), S(40), NS(40)
120 FOR T=1 TO 40
130 NEXT T
140 FOR T=1 TO 40
150 REM READ YEAR(H1,T), H2(T), H3(T), H4(T), H5(T), H6(T), H7(T), M10(T), N10(T), M10(T)
160 REM FOR T=40 TO 1
170 NEXT T
180 NEXT T
190 READ M(1), N(1)
200 NEXT I
210 FOR T=NEI TO NEI
220 NEXT T
230 NS(1)=9(1,T)
240 TIP=T-1
250 IF (TIP<0) THEN TTP=NEI+1
260 ELSE GOTO 260
270 NHR(1)+NHR(1)
277 NEXT T
280 IF (TIP<0) THEN TIP=NEI+1
290 DSR(1)+DSR(1)
300 DSR(1)=DSR(1)
310 DSR(1)=DSR(1)
320 DBRT(1)=DBRT(1)
330 BT(1)=BT(1)
340 NEXT T
350 NEXT T
360 NEXT T
370 LPRINT CHR$(12)
380 LPRINT * YEAR CARS L/CONER MAX/COMM AGRIC CYCLES STRU
390 LPRINT BUILD LOC FABRM FLAT/SH TOTAL*LPRINT
400 FOR T=1 TO NEI
410 NEXT T
420 NEXT T
430 NEXT T
440 NEXT T
450 FOR T=1 TO NEI
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<td>93600</td>
<td>119000</td>
<td>970000</td>
<td>1560000</td>
<td>1430000</td>
</tr>
<tr>
<td>2001</td>
<td>82000</td>
<td>130000</td>
<td>274000</td>
<td>144000</td>
<td>30000</td>
<td>93600</td>
<td>119000</td>
<td>970000</td>
<td>1560000</td>
<td>1440000</td>
</tr>
</tbody>
</table>

830 DATA 0.8, 3
840 DATA 0.8, 4
850 DATA 0.8, 5
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
TOTAL DISCOUNT RATE = 10

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 1 (FROM, TO) = 1:1
WHAT IS THE Naira VALUE = -45
WHAT IS THE PROBABILITY OF BRANCH 1 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 2 (FROM, TO) = 1:1
WHAT IS THE Naira VALUE = 0
WHAT IS THE PROBABILITY OF BRANCH 2 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 3 (FROM, TO) = 3:1
WHAT IS THE Naira VALUE = 50
WHAT IS THE PROBABILITY OF BRANCH 3 = ?
WHAT IS THE Naira VALUE = 50

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 4 (FROM, TO) = 3:1
WHAT IS THE Naira VALUE = 100
WHAT IS THE PROBABILITY OF BRANCH 4 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 16
INPUT BRANCH 5 (FROM, TO) =
WHAT IS THE Naira VALUE = 25
WHAT IS THE PROBABILITY OF BRANCH 5 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 4
INPUT BRANCH 6 (FROM, TO) = 4:1
WHAT IS THE Naira VALUE = -30
WHAT IS THE PROBABILITY OF BRANCH 6 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 7 (FROM, TO) = 3:1
WHAT IS THE Naira VALUE = 78
WHAT IS THE PROBABILITY OF BRANCH 7 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 8 (FROM, TO) = 3:1
WHAT IS THE Naira VALUE = 80
WHAT IS THE PROBABILITY OF BRANCH 8 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 9 (FROM, TO) = 6:2
WHAT IS THE Naira VALUE = 100
WHAT IS THE PROBABILITY OF BRANCH 9 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 10 (FROM, TO) = ?
WHAT IS THE Naira VALUE = 100
WHAT IS THE PROBABILITY OF BRANCH 10 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 11 (FROM, TO) = ?
WHAT IS THE Naira VALUE = 150
WHAT IS THE PROBABILITY OF BRANCH 11 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 12 (FROM, TO) = 4:1
WHAT IS THE Naira VALUE = 80
WHAT IS THE PROBABILITY OF BRANCH 12 = ?

OVER WHAT # OF YEARS IS THE MONEY INVESTED = 0
INPUT BRANCH 13 (FROM, TO) = 13:1
WHAT IS THE Naira VALUE = 95
WHAT IS THE PROBABILITY OF BRANCH 13 = ?
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 141:
The route is:

FROM NODE 1 TO NODE 3 DISTANCE 141

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       | 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 141:
The route is:

FROM NODE 1 TO NODE 3 DISTANCE 141

The optimal route from 1 to 4 has length 178:
The route is:

FROM NODE 1 TO NODE 4 DISTANCE 178

FROM NODE 1 TO NODE 3 DISTANCE 101
FROM NODE 1 TO NODE 4 DISTANCE 77