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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 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 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/min with
workers sitting or standing to sort incoming materials. There is obviously a challenge for the Nigerian engineers in the design of both workplace 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 deironing 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 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 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.

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

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

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 loss during fabrication if they are manufactured locally.

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

\[ \sum_{i=1}^{I} h(i, t-1(i)) \text{ if imported} \]

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

So we now have that

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

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

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

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

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

This model is shown diagrammatically in Figure 4 and the forecast is shown in Table 1.
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<th>Year</th>
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<th>New Scrap Recovered</th>
<th>Potential Old Scrap</th>
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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 in-degineerise 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 plants 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 scrap 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 Scaps 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 N4 billion by the turn of the century (assuming N200/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>
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<td>3. Test Instruments</td>
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<td>4. Transport facilities</td>
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<td>5. Road network within plant</td>
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<td>6. Security and fire fighting equipment</td>
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<td>7. Utilities with plant</td>
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</table>

**TOTAL:**  

N’14,000

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

PLACE OF ORIGIN

UNSUITABLE FOR DIRECT PILING

SUITEABLE FOR DIRECT PILING

TRANSPORT

COLLECTION AND PREPARATION YARD

SELECTION PREPARING HAND PROCESSING STORAGE

SUITEABLE FOR DIRECT PILING

UNSUITABLE FOR DIRECT PILING

TRANSPORT

MECHANICAL PROCESSING OF SCRAP

TRANSPORT

METALLURGICAL PROCESSING WORKSHOP
FIG. 3: FINISHED STEEL CONSUMPTION/DEMAND BY SECTOR
FIG. 4: Flow Chart of the Production and Use of Iron Steel for the Nigerian case.
FIG. 6: SHORTEST ROUTE DIAGRAM
TABLE 1: RECOVERABLE STEEL SCRAP FORECAST TO 2000 AHEAD

<table>
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<tr>
<th>YEAR</th>
<th>POTENTIAL NEW SCRAP</th>
<th>POTENTIAL OLD SCRAP</th>
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APPENDIX III: COMPUTER LISTING FOR SCRAP ESTIMATION

10 REM *****************************************  
20 REM "PROGRAM FOR STEEL SCRAP ESTIMATION"  
30 REM ""  
40 REM  
50 REM  
60 REM  
70 REM *****************************************  
80 REM  
90 REM  
100 DEFINT L,T,X  
110 DEFINT N  
120 DIM YEAR(40),L(10),NS(40),NSR(40),OS(40),OSR(40),BS(40),BSR(40),GB(40),GBR(40)  
130 M2=1,M3=5,M1=1,MB=1,MS=1,MT=1  
140 FOR I=1 TO N  
150 READ YEAR(I+1),L(I),NS(I),OS(I),BS(I),GB(I)  
160 M(I+1)=M(I)+L(I)-NS(I)-OS(I)-BS(I)-GB(I)  
170 NEXT I  
180 FOR I=1 TO N  
190 READ YEAR(I),L(I)  
200 NEXT I  
210 FOR I=1 TO N  
220 FOR I=1 TO N  
230 NSR(I)+=NS(I)  
240 TIP=0  
250 IF (TIP=0) THEN TIP=NSR(I)+=NS(I)+TIP=GOTO 260 ELSE GOTO 260  
260 MAX(E(I),NSR(I),TIP)  
270 TLT=E(I)  
280 IF (TLT=0) THEN TLT=0  
290 OS(I)=O(I)+T(I)+TLT  
300 OSR(I)=OS(R)+T(I)+TLT  
310 OSR(I)+OSR(I)+OSR(I)+OSR(I)  
320 OSR(I)+OSR(I)+OSR(I)+OSR(I)  
330 OSR(I)+OSR(I)+OSR(I)+OSR(I)  
340 MAX OSR(I)  
350 BIT ON  
360 NPRINT CHR$(13)  
370 LPRINT CHR$(13)  
380 LPRINT * YEAR CARG L/COMM RHY/COMM AGRIC CYCLES STRU  
390 PIPES CAB FAB TM FLAT/SL TOTAL LPRINT  
400 LPRINT "MAX NSR(I)"  
410 NEXT I  
420 LPRINT LPRINT LPRINT LPRINT LPRINT  
430 PRINT "HIT ANY KEY TO CONTINUE PRINTING*:A4=INPUT("");  
440 LPRINT "YEAR(TP)"  
450 TIP=TP=NSR(I)+=TP=RHT  
460 LPRINT TIP=RHT=TP=RHT="SECONDARY"  
470 LPRINT "NEW SCRAP"  
480 LPRINT "RECOVERED"  
490 LPRINT "OLD SCRAP"  
500 LPRINT "PRODUCT"  
510 LPRINT LPRINT LPRINT LPRINT  
520 END
## ORDERED TREE

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**HIT ENTER TO CONTINUE?**

## EVALUATED DECISION TREE

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**HIT ENTER TO CONTINUE?**

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**HIT ENTER TO CONTINUE?**
APPENDIX III: COMPUTER LISTING FOR SCRAP ESTIMATION

10 REM ???????????????????????????????????????????????????????????????????????
20 REM
30 REM
40 REM 
50 REM
60 REM
70 REM ???????????????????????????????????????????????????????????????????????
80 REM
90 REM
100 DEFINT A-Z
110 DIM Y(49), M(10), NS(10), NSR(10), GST(49), GBR(10, 40), GBT(49, 10)
120 N=1; NEI=3; T=1; NEX=B; P=0.05; B=1; P=1
130 FOR T=1 TO NEI+1
140 READ Y(1), Y(2), Y(3), Y(4), Y(5), Y(6), Y(7), Y(8), Y(9), Y(10): N=0
150 H(10,T)=Y(1); H(2,T)=Y(2); H(3,T)=Y(3); H(4,T)=Y(4); H(5,T)=Y(5); H(6,T)=Y(6); H(7,T)=Y(7); H(8,T)=Y(8); H(9,T)=Y(9); H(10,T)=Y(10)
160 NEXT T
170 NEXT T
180 FOR T=1 TO NEI
190 READ H(1), H(2)
200 NEXT T
210 FOR T=1 TO NEI
220 FOR I=1 TO NEI
230 NS(I)=H(I,T)
240 TIP=TIP+T
250 IF (TIP<0) THEN TIP=NEI+1:NST(I)=H(I,T); GOTO 260 ELSE GOTO 260
260 NST(I)=NST(I)
270 TIP=TIP+1
280 IF (TIP<0) THEN TIP=NEI+1
290 GST(I,T)=H(I,T)
300 GST(I,T)=GST(I,T)
310 GBR(I,T)=GBR(I,T)
320 GBR(I,T)=GBR(I,T)
330 GBR(I,T)=GBR(I,T)
340 NEXT I
350 NEXT T
360 WIDTH LPRINT 132
370 LPRINT CHR$(15)
380 LPRINT * YEAR CARS L/COVER MAX/COMB AGRIC CYCLES OTRU
390 PIPE L/COVER MAX/COMB AGRIC CYCLES OTRU
400 FOR T=1 TO NEI
410 LPRINT "YEAR(T)"; "NS(T)"; "GST(T)"; "NSR(T)"; "GSR(T)"; "OGR(T)"; "GBR(T)"; "GB(T)"
420 NEXT T
430 LPRINT "YEAR(T)"; "GST(T)"; "NS(T)"; "GST(T)"; "OGR(T)"; "GBR(T)"; "GB(T)"
440 END
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**Footnotes:**
Appendix V: Decision Tree Solution

- Total number of branches: 13
- Input the discount rate: 10
  - Input branch 1: (from, to) = 1; 1
    - What is the probability of branch 1? 0
  - Input the Naira value: -45
    - Over what # of years is the money invested? 0
  - Input branch 2: (from, to) = 1; 1
    - What is the probability of branch 2? 0
  - Input the Naira value: -300
    - Over what # of years is the money invested? 0
  - Input branch 3: (from, to) = 3, 1
    - 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, 7
    - 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) = 1
  - What is the probability of branch 5? 25
    - Over what # of years is the money invested? 4
  - Input branch 6: (from, to) = 4, 4
    - What is the probability of branch 6? 0
  - What is the Naira value: -45
    - Over what # of years is the money invested? 0
  - Input branch 11: (from, to) = 2, 1
    - What is the probability of branch 11? 1
  - What is the Naira value: 120
    - Over what # of years is the money invested? 0
  - Input branch 12: (from, to) = 4, 4
    - What is the probability of branch 12? 1
  - What is the Naira value: 80
    - Over what # of years is the money invested? 0
  - Input branch 13: (from, to) = 4, 4
    - What is the probability of branch 13? 0
  - What is the Naira value: -15
    - Over what # of years is the money invested? 0
  - Input branch 14: (from, to) = 1
  - What is the probability of branch 14? 25
APPENDIX IV: ILLUSTRATIVE EXAMPLE FOR EFFECT OF POOR MAINTENANCE

**Data Display**

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The optimal route from 1 to 2 has length 346.

**Data Display**

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The optimal route from 1 to 2 has length 346.

The route is:

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