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## IMPROVED TIMBER TRANSPORTATION STRATEGY FOR THE CONIFEROUS FORESTS OF PAKISTAN

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### ABSTRACT

Currently, log transportation from the coniferous forests of Pakistan is done mainly by 4x4 flat-bed trucks (popularly known as Guttoos), mainly on low quality dirt roads (generally known as Guttoo roads) involving rehandling of logs at a transfer yard (transit depot). An improved timber transportation method using permanent forest roads and 2x4 turbo-charged (common wooden-bodied) straight truck with trailer is proposed. The best combination of temporary and permanent roads is suggested as a fixed and variable cost network problem.

**Key Words:** *Truck, Transportation System, Transfer Yard, Dirt Road, Network Analysis, Harvest Scheduling*

### INTRODUCTION

Coniferous forests in Pakistan are either un-roaded or have low quality dirt roads leading to harvest areas. In un-roaded forests, logs are converted to scants at the felling site and transported to the nearest transfer yard by mules or 4x4 jeeps. Where dirt roads exist, logs are transported to the transfer yards by Guttoos carrying about 250 cft (5 tons) of timber in log form. Logs are then unloaded, stored, reloaded on 4x2 straight trucks (usually Bedford) and transported 50 to 100 km to an auction market to be offered to prospective buyers. A minimum of 10% of the wood quality and quantity is lost between felling and its disposal at an auction market. Delays are due to various scheduling

problems caused by weather, road conditions and the non-availability of flat-bed and straight trucks in time.

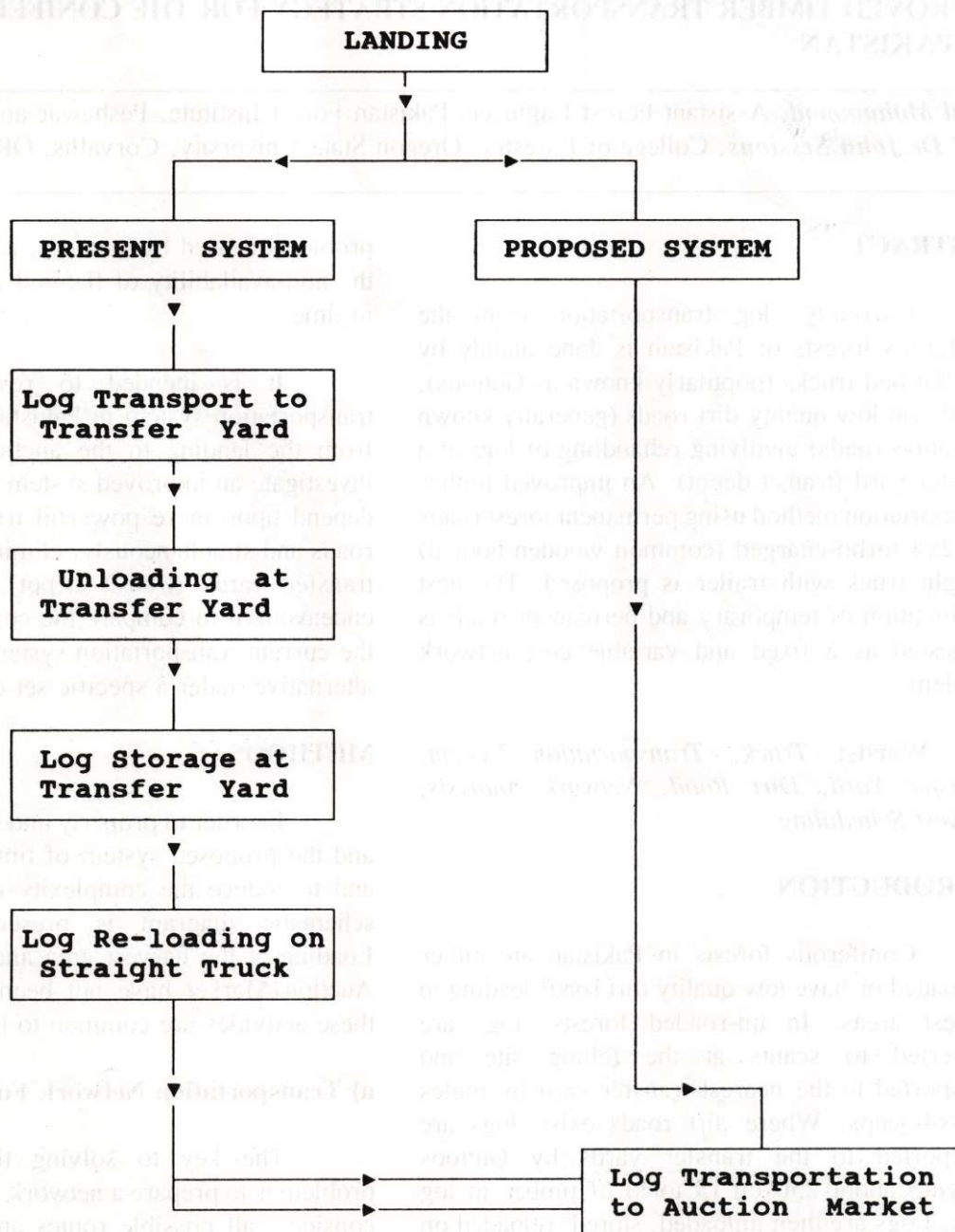
It is intended to review the current transportation system in Pakistan for moving logs from the landing to the auction market and to investigate an improved system that will primarily depend upon more powerful trucks, better forest roads and simultaneously, eliminate dirt roads and transfer yards (transit depot). It will also be endeavoured to compare the costs and benefits of the current transportation system with a proposed alternative under a specific set of conditions.

### METHODS

In order to properly understand the existing and the proposed system of timber transportation and to reduce the complexity of the problem, a schematic diagram is presented (Figure 1). Loading at the harvest area and unloading at the Auction Market have not been considered since these activities are common to both the systems.

#### a) Transportation Network Formulation

The key to solving this transportation problem is to prepare a network representation that considers all possible routes and transfer points. These alternatives are the combination of permanent roads, dirt roads, transfer yards and asphalt roads.



**Figure 1. Schematic Presentation of the Present and Proposed Log Transportation Systems**



The transportation problem to be evaluated is a multi-period, multi-area facilities location problem. It is assumed that a forest manager is given a schedule of harvest areas, the years in which harvests will occur and the quantities of timber to be transported. His task is to determine a transportation plan which will yield the greatest net revenue. This involves the determination of road location and standards and the location and number of transfer yards.

To prepare a network that implicitly includes all the transportation opportunities, three types of links will be used. The nodes may be road junctions, timber entry points into the network, transfer yards, auction markets, etc.

## b) Model Definitions and Assumptions

**Temporary Road Links** - Links which will be used to describe the potential temporary road location between a harvest area and a potential transfer yard. Each harvest area will have one potential temporary road link between the harvest area and the transfer yard for each time the harvest area will be entered over the planning horizon.

**Permanent Road Links** - Links which will be used to describe a segment of the existing (temporary) or the potential permanent road between the two points. Each harvest area will have at least one potential permanent forest road link between the harvest area and other segments of the permanent road system.

**Dummy Links** - Links which are used to clarify the network diagram with no physical identity and have zero costs.

Links have two types of costs: variable and fixed. A variable cost is a cost which is proportional to the quantity of logs transported over the links. Fixed costs are costs which do not

vary with the level of traffic. Fixed costs must be incurred *before* any traffic can occur. Maintenance costs which are not proportional to traffic can also be treated as fixed costs. In this case, variable and fixed costs are:

### 1. Variable Costs (Rs/cft/link):

- haul cost: landing to transfer yard (existing system)
- haul cost: landing to (connection with) asphalt road (proposed system)
- unloading cost at transfer yard (present system)
- reloading cost at transfer yard (existing system)
- haul cost on asphalt road to auction market (both systems)
- loss in timber value after felling and before reaching the auction market (existing system)

### 2. Fixed Costs (Rs/link):

- dirt/forest road construction cost
- dirt/forest road maintenance cost
- rent of transfer yard (existing system)
- personnel cost at transfer yard (existing system)

Details of variable and fixed costs are given in Appendix - I.

As an illustration, consider a transportation



plan for a forest area sub-divided into three unit areas ranging between 100 and 500 acres (40 - 200 ha). These areas produce between 35,000 and 55,000 cft (1000 and 1600 m<sup>3</sup>) of timber per entry. Each unit has three entry periods, two road standards, two transportation combinations and is harvested over a twenty-five year planning horizon. The harvest areas will be entered in 10-year intervals and in different periods. Area 1 will be entered at years 1, 11 and 21, Area 2, at years 3, 13 and 23 and Area 3 at 5, 15 and at year 25. The last entry in area 3 will be the 25th year that will coincide with the technical life of a forest road. The transportation alternatives are formed by constructing some combination of temporary and permanent roads to provide access to each harvest area. The transportation problem for all the harvest areas must be solved in its entirety because the permanent roads provide access to more than one harvest area and could be re-used over a period of time. On the other hand, temporary roads are considered to have a useful life of only one entry and are built for an individual harvest area.

Using these definitions, a network representation of the transportation alternatives can be prepared (Figure 2). Nodes of the network are defined as:

$E_{ij}$  = Entry node for harvest area  $i$  in period  $j$

$TY_i$  = Transfer Yard for harvest area  $i$

AM = Auction Market

$i$  = Entry point from harvest area  $i$  to the proposed permanent forest road

$F_k$  = Nodes on existing or proposed permanent roads

Permanent roads in the above figure have

been designed in such a manner that all the three roads coming out of the (unit) areas coincide at a point from where a common road leads to the asphalt road. Values calculated according to this figure (Appendix - II) were incorporated in the *LINK* file of the NETWORK<sup>1</sup>.

### c) Model Inputs

The inputs necessary to solve this transportation problem can be summarized in two lists of the links with their variable and fixed costs (Table 1). Variable cost for each link between a timber entry node and the transfer yard for the temporary road alternative is the sum of the costs for transport on the temporary road, unloading and re-loading (on standard truck) at the transfer yard. In addition, a 10% value loss due to wood deterioration is added to these links as a variable cost for the temporary road alternative following estimates by Stoehr (1987). The fixed cost for each of these links is the sum of the construction cost to build temporary roads, their maintenance cost, the cost to hire a transfer yard and personnel cost. It has been assumed that temporary roads are completely rebuilt and the transfer yard is leased for each entry. Fixed cost for each potential permanent road is equal to the construction cost plus the discounted sum of periodic maintenance costs. Fixed and variable costs of dummy links are ZERO.

Costs in this programme are based on the prevailing market rates and personal experience of the author.

<sup>1</sup> A computer software developed by Dr. John Sessions, OSU Corvallis, OR, USA.

Permanent Road  
Temporary Road

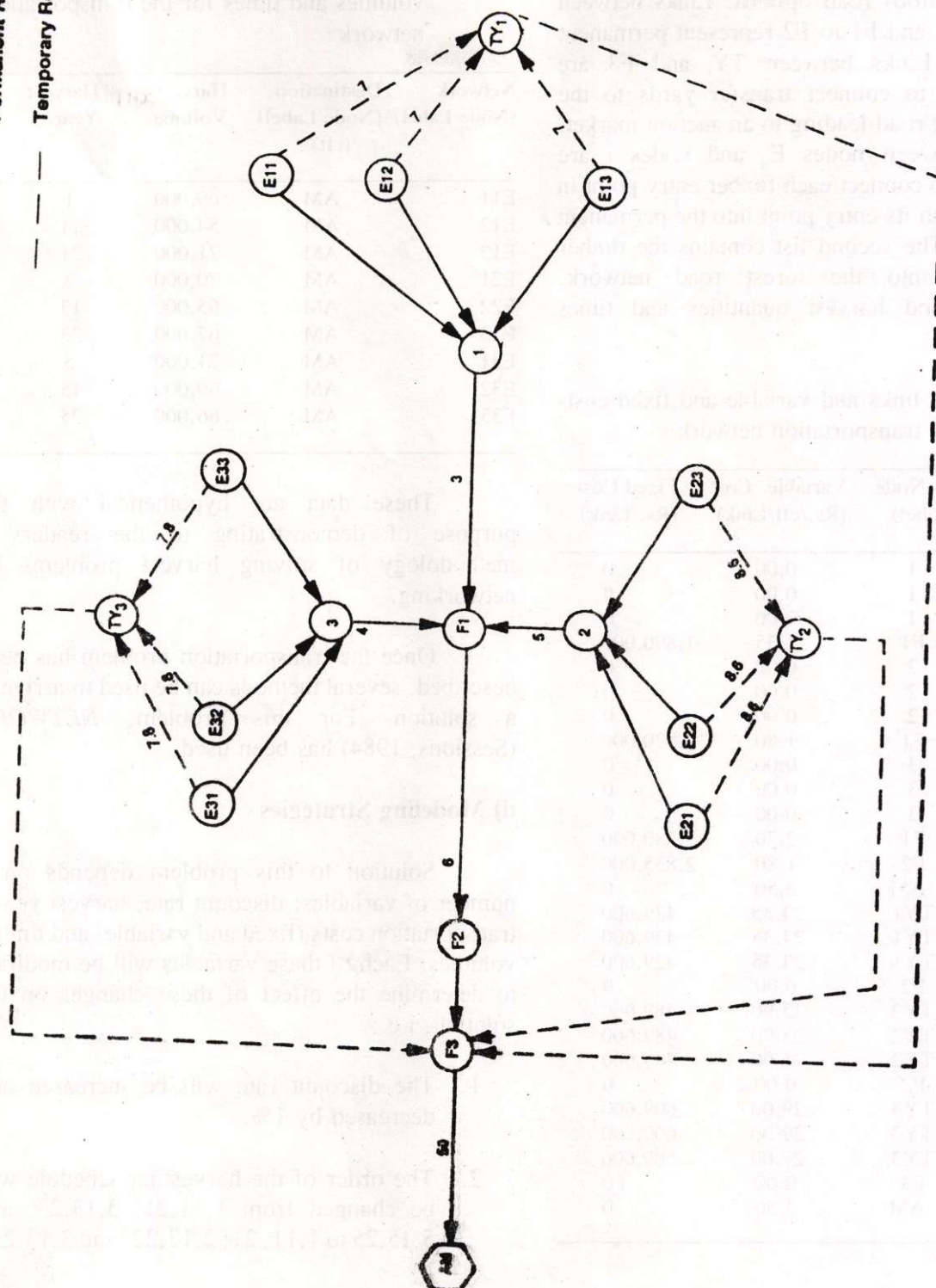


Figure 2. Network Presentation of Temporary and Permanent Road Transportation Alternatives



Links between nodes  $E_{ij}$  and  $TY_i$  represent temporary (Guttoo) road options. Links between nodes  $i$  and  $F1$  and  $F1$  to  $F2$  represent permanent forest roads. Links between  $TY_i$  and  $F3$  are dummy links; to connect transfer yards to the existing asphalt road leading to an auction market. The links between nodes  $E_{ij}$  and nodes  $i$  are dummy links to connect each timber entry point in each period with its entry point into the permanent road system. The second list contains the timber entry points into the forest road network, destination/s and harvest quantities and times (Table 2).

Table 1 List of links and variable and fixed costs for the transportation network

| From Node (Label) | To Node (Label) | Variable Cost (Rs./cft/Link) | Fixed Cost (Rs./Link) |
|-------------------|-----------------|------------------------------|-----------------------|
| E11*              | 1               | 0.00                         | 0                     |
| E12*              | 1               | 0.00                         | 0                     |
| E13*              | 1               | 0.00                         | 0                     |
| 1                 | F1              | 1.35                         | 1,890,000             |
| E21*              | 2               | 0.00                         | 0                     |
| E22*              | 2               | 0.00                         | 0                     |
| E23*              | 2               | 0.00                         | 0                     |
| 2                 | F1              | 1.80                         | 2,520,000             |
| E31*              | 3               | 0.00                         | 0                     |
| E32*              | 3               | 0.00                         | 0                     |
| E33*              | 3               | 0.00                         | 0                     |
| 3                 | F1              | 2.70                         | 3,780,000             |
| F1                | F2              | 1.80                         | 2,835,000             |
| F2                | AM              | 2.50                         | 0                     |
| E11               | TY1             | 24.35                        | 429,600               |
| E12               | TY1             | 24.35                        | 429,600               |
| E13               | TY1             | 24.35                        | 429,600               |
| TY1*              | F2              | 0.00                         | 0                     |
| E21               | TY2             | 25.90                        | 489,600               |
| E22               | TY2             | 25.90                        | 489,600               |
| E23               | TY2             | 25.90                        | 489,600               |
| TY2*              | F2              | 0.00                         | 0                     |
| E31               | TY3             | 29.00                        | 609,600               |
| E32               | TY3             | 29.00                        | 609,600               |
| E33               | TY3             | 29.00                        | 609,600               |
| TY3*              | F3              | 0.00                         | 0                     |
| F3                | AM              | 3.50                         | 0                     |

\* dummy links

Table 2 Entry points, destinations, harvest volumes and times for the transportation network

| Network (Node Label) | Destination (Node Label) | Harvest Volume (cft) | Harvest Year |
|----------------------|--------------------------|----------------------|--------------|
| E11                  | AM                       | 69,000               | 1            |
| E12                  | AM                       | 54,000               | 11           |
| E13                  | AM                       | 71,000               | 21           |
| E21                  | AM                       | 70,000               | 3            |
| E22                  | AM                       | 65,000               | 13           |
| E23                  | AM                       | 67,000               | 23           |
| E31                  | AM                       | 71,000               | 5            |
| E32                  | AM                       | 69,000               | 15           |
| E33                  | AM                       | 66,000               | 25           |

These data are hypothetical with the purpose of demonstrating to the readers a methodology of solving harvest problems by networking.

Once the transportation problem has been described, several methods can be used to arrive at a solution. For this problem, *NETWORK* (Sessions, 1984) has been used.

#### d) Modeling Strategies

Solution to this problem depends on a number of variables: discount rate, harvest years, transportation costs (fixed and variable) and timber volumes. Each of these variables will be modified to determine the effect of these changes on the solution, i.e.:

1. The discount rate will be increased and decreased by 1%.
2. The order of the harvesting schedule will be changed from 1,11,21; 3,13,23; and 5,15,25 to 1,11, 21; 2,12,22; and 3,13,23.



3. Fixed and variable costs will be increased by 5%.
4. Timber volumes will be increased by 10%.

## RESULTS AND DISCUSSIONS

Using a 4% real discount rate (Appendix - IV), the results suggested that for the costs and harvest schedule in this study, the present system of temporary roads was the best (Table 3).

Table 3 Solution to transportation problem using the information from Table 1 and Table 2 and a 4% discount rate

| Sale Entry | Timber Volume (cft) | Harvest Year | Path          |
|------------|---------------------|--------------|---------------|
| E11        | 69,000              | 1            | E11-TY1-F3-AM |
| E21        | 70,000              | 3            | E21-TY2-F3-AM |
| E31        | 71,000              | 5            | E31-TY3-F3-AM |
| E12        | 54,000              | 11           | E12-TY1-F3-AM |
| E22        | 65,000              | 13           | E22-TY2-F3-AM |
| E32        | 69,000              | 15           | E32-TY3-F3-AM |
| E13        | 71,000              | 21           | E13-TY1-F3-AM |
| E23        | 67,000              | 23           | E23-TY2-F3-AM |
| E33        | 66,000              | 25           | E33-TY3-F3-AM |

The path from each harvest area went through a Transfer Yard (TY<sub>i</sub>) on the way to the Auction Market (AM). This indicates a preference for the existing system of transportation. The total discounted cost for harvesting 602,000 cft for three entries and over three time periods was Rs.12,201,410 or Rs.20.27 per cft.

From the sensitivity analysis, a 1% increase in discount rate resulted in a 10% decrease in harvesting cost per cft. A 1% decrease caused a 5% increase in harvesting cost. When the order of the harvesting schedule was changed, harvest costs decreased by 2.6%. A significant change occurred when the dirt road costs were

increased by 5%: the analysis showed a preference for the proposed system with a nominal increase in harvest costs. When variable costs for the existing system were increased by 5%, there was again a switch-over to the proposed system.

When timber volumes were increased by 10%, the resulting optimal network was entirely different (Table 4). Now the permanent road system becomes more efficient.

Table 4 Solution to transportation problem using information from Table 1 and Table 2, a 4% discount rate and a 10% increase in the timber volume at each entry

| Sale Entry | Timber Volume (cft) | Harvest Year | Path           |
|------------|---------------------|--------------|----------------|
| E11        | 75,900              | 1            | E11-1-F1-F2-AM |
| E21        | 77,900              | 3            | E11-2-F1-F2-AM |
| E31        | 78,100              | 5            | E11-3-F1-F2-AM |
| E12        | 59,400              | 11           | E12-1-F1-F2-AM |
| E22        | 71,500              | 13           | E12-2-F1-F2-AM |
| E32        | 77,000              | 15           | E12-3-F1-F2-AM |
| E13        | 78,100              | 21           | E13-1-F1-F2-AM |
| E23        | 73,700              | 23           | E13-2-F1-F2-AM |
| E33        | 72,600              | 25           | E13-3-F1-F2-AM |

The total discounted cost for harvesting 663,300 cft of timber over the three time periods was Rs.12,515,587 or Rs.18.87 per cft. If the temporary road system had been used for these higher harvest volumes, the total discounted cost would have been 5.1% higher than using permanent forest road system. Had the harvest volumes been 20% higher, the discounted cost of using the temporary road system would have been about 11% higher.

It appears that the system is affected by changes in all the above variables particularly by discount rate. It is therefore, concluded that the



best transportation strategy will depend upon the discount rate, harvest schedule, timber volumes and road costs for a specific area. In some situations, a permanent road system or even a combination of temporary and permanent roads will be superior. In other cases, the status quo will yield better results.

## CONCLUSIONS

A methodology for analyzing transportation opportunities in the coniferous forests of Pakistan has been simulated and discussed. The procedure was first, to prepare a network representation of the transportation possibilities and second, to prepare two lists of information:

- i) a list of the transportation links, and
- ii) a list of the harvest times and entries into the transportation network.

Once the network model inputs have been organized, a number of methods can be used to solve the problem. For small problems involving less than 50 links with fixed costs, the optimal solution can be found. For larger problems, approximate methods using heuristics can provide good solutions rapidly while sensitivity analyses can be performed to test the results.

## LIMITATIONS

This analysis has only considered direct road construction, transport and maintenance costs; forest/dirt road construction costs may vary considerably from area to area. To be more exact, the analysis should consider a wider range of costs and benefits including environmental costs of temporary and permanent roads, benefits of permanent forest road for the efficient management of forests, fire protection, defence needs, the extent and time span of silt load transported down

streams and the potential social benefits such as recreation and access to market for the villagers.

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## APPENDIX-I

### FIXED AND VARIABLE COSTS

| Sl. No. | Works  | Unit       | Cost       |
|---------|--|------------|------------|
| 1.      | Dirt road construction cost                  | Rs/km      | 50,000.00  |
| 2.      | Dirt road maintenance cost                   | %age       | 20%        |
| 3.      | Forest road construction cost                | Rs/km      | 450,000.00 |
| 4.      | Forest road maintenance cost                 | %age       | 5%         |
| 5.      | Haul cost, dirt road                         | Rs/cft/km  | 0.80       |
| 6.      | Haul cost, permanent road                    | Rs/cft/km  | 0.30       |
| 7.      | Haul cost, asphalt road<br>(present system)  | Rs/cft/km  | 0.07       |
| 8.      | Haul cost, asphalt road<br>(proposed system) | Rs/cft/km  | 0.05       |
| 9.      | Unloading cost, transfer yard                | Rs/cft     | 0.25       |
| 10.     | Land rent, transfer yard                     | Rs/acre    | 1,200.00   |
| 11.     | Personnel cost                               | Rs/harvest | 8,400.00   |
| 12.     | Re-loading at transfer yard                  | Rs/cft     | 0.50       |

Based on the above costs, a model was written in the BASIC to compute the variable and fixed costs for the study under review (Appendix-II).

## APPENDIX - II

### A PROGRAMME TO DETERMINE FIXED AND VARIABLE COSTS FOR NETWORK ANALYSIS

```

100 '
110 '
120 '
130 '
140 '
150 DATA 7,4.5,8,6,10,9
160 FOR I = 1 TO 3
170     READ LD, LF1 'LENGTH OF DIRT ROAD: LANDING TO T.Y. FOREST ROAD: LANDING TO JN.
180     LF2 = 6 'LENGTH OF FOREST ROAD: JUNCTION TO ASPHALT ROAD
190     LA = 50 'LENGTH OF ASPHALT ROAD (KM)
200     DRC = 50000! 'DIRT ROAD COST (RS/KM)
210     FRC = 450000! 'FOREST ROAD COST (RS/KM)
220     TPF = 135 '(AVERAGE) TIMBER PRICE, FRESH (RS/CFT)
230     LF = .1 'LOSS FACTOR
240     LTV = TPF*LF 'LOSS IN TIMBER VALUE, PRESENT SYSTEM (RS/CFT)
250     DRCC = LD*DRC 'DIRT ROAD CONSTRUCTION COST, TOTAL (RS)
260     DRMC = DRCC*.2 'DIRT ROAD MAINTENANCE COST (@ 20% OF DRC) (RS)
270     PC = 8400 'PERSONNEL COST AT TRANSFER YARD
280     LR = 1200 'LAND RENT: TRANSFER YARD
290     FCD = DRCC+DRMC+PC+LR 'FIXED COST, DIRT RD. SYSTEM (RS)
300     FRCC1 = LF1 * FRC 'FOREST ROAD CONSTN COST, LANDING TO JN. (RS)
310     FRCC2 = LF2 * FRC 'FOR. RD. CONSTN COST, JN. TO ASPHALT RD. (RS)
320     FRMC1 = FRCC1 * .05 'FOR. ROAD MAINT. COST (@ 5% OF FRC) (RS)
330     FRMC2 = FRCC2 * .05
340     FCTT1 = FRCC1 + FRMC1 'FIXED COST, TRUCK-TRAILER: LNG. TO JN. (RS)
350     FCTT2 = FRCC2 + FRMC2 'FIXED COST, TRK-TRAILER: JN. TO ASP. RD (RS)
360     HCD = .8*LD 'HAUL COST, DIRT RD. SYSTEM (RS)
370     UCD = .25 'UNLOADING COST, DIRT RD. SYSTEM (RS/CFT)
380     LCD = .5 'LOADING COST, DIRT RD. SYSTEM (RS/CFT)
390     VCD = HCD+UCD+LCD+LTV 'VARIABLE COST, TOTAL; DIRT RD. SYSTEM
400     HTTF1 = .3*LF1 'HAUL COST, TRUCK-TRAILER: LNG TO JN. (RS/CFT)
410     HTTF2 = .3*LF2 'HAUL COST, TRUCK-TRAILER: JN. TO ASPHALT ROAD
420     HTA = .07*LA 'HAUL COST, TRK ON ASP ROAD, TOTAL (RS/CFT/LINK)
430     HTTA = .05*LA 'HAUL COST, TRUCK-TRAILER, ASPHALT ROAD (RS/CFT)
440     VCTT1 = HTTF1 'VARIABLE COST, TRUCK-TRAILER: LANDING TO JN (RS)
450     VCTT2 = HTTF2 'VARIABLE COST, TRUCK-TRAILER: JN TO ASP ROAD (RS)
460     PRINT "DIRT ROAD LENGTH....." =";LD "KM"
470     PRINT "FOREST ROAD LENGTH: LANDING TO JUNCTION....." =";LF1 "KM"
480     PRINT "FOREST ROAD LENGTH: JUNCTION TO ASPHALT RD....." =";LF2 "KM"
490     PRINT "-----"
500     PRINT USING "VAR COST, PRESENT SYSTEM: LANDING TO T.Y....." = RS. ###";VCD
510     PRINT USING "VAR COST, PRESENT SYSTEM: T.Y. TO AUCTION MARKET....." = RS. ###";HTA
520     PRINT USING "FIX COST, PRESENT SYSTEM: LANDING TO T.Y....." = RS. ###,###.###";FCD
530     PRINT "-----"
540     PRINT USING "VAR COST, PROPOSED SYSTEM: LANDING TO JN" = RS. #.###";VCTT1
550     PRINT USING "VAR COST, PROPOSED SYS: JN. TO ASPHALT RD" = RS. #.###";VCTT2
560     PRINT USING "VAR COST, PROPOSED SYSTEM: ASPHALT ROAD.." = RS. #.###";HTTA
570     PRINT USING "FIX COST, PROPOSED SYSTEM: LANDING TO JN..." = RS. #,###,###.###";FCTT1
580     PRINT USING "FIX COST, PROPOSED SYS: JN TO ASPHALT RD" = RS.#,###,###.###";FCTT2
590     PRINT "-----"
600 NEXT I
610 END

```



Dimensions of the variables in the programme are based on the following assumptions:

1. **Dirt road:** For dirt road, three lengths have been assumed: 7, 8 and 10 km.
2. **Forest road:** It is assumed that the average adverse gradient of dirt road is 18% against which the average adverse gradient of forest road has been taken as 12%. This gradient may apparently be on higher side, considering climatic conditions in the hilly areas of Pakistan (long dry spells followed by heavy rains: up to 80 mm an hour). But a properly gravelled and well compacted forest road is expected to last considerably, provided regularly maintained. Accordingly, permanent road lengths corresponding to the assumed dirt road stretches will be 10.5, 12 and 15 km. Assuming that a 6 km of this will be shared by all the three harvest units, the individual units will need independent sections of 4.5, 6 and 9 km of permanent road.
3. **Maintenance cost:** Dirt roads being poor in quality, need frequent maintenance. A 20% of construction cost as maintenance cost is considered to be a safe assumption. A good quality forest road would need not more than 5% of its construction cost as maintenance cost.
4. Loading, un-loading, transfer yard rent, personnel cost and haul cost on dirt road and asphalt road under the existing system are based on transaction evidence. Haul costs on proposed roads are calculated on the basis of capacity of truck-trailer combination.

After running this program, the following results were obtained:

|  |                   |
|--|-------------------|
| RUN  |                   |
| DIRT ROAD LENGTH.....                        | = 7 KM            |
| FOREST ROAD LENGTH: LANDING TO JN.....       | = 4.5KM           |
| FOREST ROAD LENGTH: JN TO ASPHALT RD.....    | = 6 KM            |
| <hr/>  |                   |
| VAR COST, PRESENT SYS: LANDING TO T.Y.....   | = RS. 19.85       |
| VAR COST, PRESENT SYS: T. Y. TO MARKET.....  | = RS. 3.50        |
| FIX COST, PRESENT SYSTEM: LANDING TO T. Y. = | RS. 429,600.00    |
| <hr/>  |                   |
| VAR COST, PROPOSED SYS: LANDING TO JN .....  | = RS. 1.35        |
| VAR COST, PROPOSED SYS: JN TO ASPHALT RD. =  | RS. 1.80          |
| VAR COST, PROPOSED SYS: ASPHALT ROAD.....    | = RS. 2.50        |
| FIX COST, PROPOSED SYS: LANDING TO JN.....   | = RS.2,126,250.00 |
| FIX COST, PROPOSED SYS: JN TO ASPHALT RD...  | = RS.2,835,000.00 |
| <hr/>  |                   |
| DIRT ROAD LENGTH.....                        | = 8 KM            |
| FOREST ROAD LENGTH: LANDING TO JN.....       | = 6 KM            |
| FOREST ROAD LENGTH: JN TO ASPHALT RD.....    | = 6 KM            |
| <hr/>  |                   |
| VAR COST, PRESENT SYS: LANDING TO T.Y.....   | = RS. 20.65       |
| VAR COST, PRESENT SYS: T. Y. TO MARKET.....  | = RS. 3.50        |
| FIX COST, PRESENT SYSTEM: LANDING TO T. Y. = | RS. 489,600.00    |
| <hr/>  |                   |
| VAR COST, PROPOSED SYS: LANDING TO JN .....  | = RS. 1.80        |
| VAR COST, PROPOSED SYS: JN TO ASPHALT RD. =  | RS. 1.80          |
| VAR COST, PROPOSED SYS: ASPHALT ROAD.....    | = RS. 2.50        |
| FIX COST, PROPOSED SYS: LANDING TO JN.....   | = RS.2,835,000.00 |
| FIX COST, PROPOSED SYS: JN TO ASPHALT RD...  | = RS.2,835,000.00 |
| <hr/>  |                   |
| DIRT ROAD LENGTH.....                        | = 10 KM           |
| FOREST ROAD LENGTH: LANDING TO JN.....       | = 9 KM            |
| FOREST ROAD LENGTH: JN TO ASPHALT RD.....    | = 6 KM            |
| <hr/>  |                   |
| VAR COST, PRESENT SYS: LANDING TO T.Y.....   | = RS. 25.25       |
| VAR COST, PRESENT SYS: T. Y. TO MARKET.....  | = RS. 3.50        |
| FIX COST, PRESENT SYSTEM: LANDING TO T. Y. = | RS. 609,600.00    |
| <hr/>  |                   |
| VAR COST, PROPOSED SYS: LANDING TO JN .....  | = RS. 2.70        |
| VAR COST, PROPOSED SYS: JN TO ASPHALT RD. =  | RS. 1.80          |
| VAR COST, PROPOSED SYS: ASPHALT ROAD.....    | = RS. 2.50        |
| FIX COST, PROPOSED SYS: LANDING TO JN.....   | = RS.4,252,500.00 |
| FIX COST, PROPOSED SYS: JN TO ASPHALT RD...  | = RS.2,835,000.00 |

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## Appendix - IV

### DISCOUNT RATE

Row et al (1981) state that public forestry requires expenditures that produce benefits many years into the future. To compare these benefits over time, a standard analytical procedure discounts them to present values. The Sum of these discounted costs measure the economic value of an investment.

The USDA, Forest Service uses a discount rate of 4% for evaluating long-term investment in (forest) resource management. This rate approximates the long-term measures of the opportunity cost of capital in the private sector of the USA. This seems to be a slightly conservative rate and has therefore been adopted for the investments in public forests in Pakistan.