BIBLIOGRAPHIC DATA SHEET	1. CONTROL NUMBER PN-AAJ-294	2. SUBJECT CLASSIFICATION (695) DP00-0000-G136

3. TITLE AND SUBTITLE (240) Ethiopia road maintenance study: final report

4. PERSONAL AUTHORS (100)

5. CORPORATE AUTHORS (101)

Harris (Frederic R.), Inc.

6. DOCUMENT DATE (110)	7. NUMBER OF PAGES (120)	8. ARC NUMBER (170)
1973	481p.	ET625.76.H317

9. REFERENCE ORGANIZATION (130)

Harris

10. SUPPLEMENTARY NOTES (500)

(Appendix, 228p.: PN-AAJ-295)

11. ABSTRACT (950)

12. DESCRIPTORS (920)		13. PROJECT NUMBER (150)	
Ethiopia Highways	Roads Maintenance	14. CONTRACT NO.(140) Ethiopia	15. CONTRACT TYPE (140)
		16. TYPE OF DOCUMENT (160)	

AID 590-1 (10-70)

ETHIOPIA

ROAD MAINTENANCE STUDY

FINAL REPORT

IMPERIAL ETHIOPIAN GOVERNMENT

IMPERIAL HIGHWAY AUTHORITY

JUNE 1973

PREPARED BY

FREDERIC R. HAR

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June 6, 1973

Ato Abashawl Woldemarian
General Manager of Highways
Imperial Highway Authority
Imperial Ethiopian Government
P.O. Box 1770, Addis Ababa, Ethiopia

Dear Ato Abashawl:

In accordance with our contract of February 29, 1972, we are pleased to present herewith our Report on Highway Maintenance and Rehabilitation with the primary objective of developing a Five Year Plan of action for the improvement of highway maintenance and the rehabilitation of road sections requiring urgent attention.

As a result of our studies, it was concluded that while the Imperial Highway Authority is using basically sound procedures, there is an urgent need and adequate justification for additional capital investment for maintenance equipment and that this will have to be acquired in the immediate future.

The benefits that this investment is expected to produce will create economies to both users of highways and to the nation. In addition, it will result in improved capabilities of greater productivity within the Imperial Highway Authority.

We wish to take this opportunity to extend our sincere thanks to the personnel of the Imperial Highway Authority, the USAID Mission and all those who have so eminently, graciously and generously provided us with their continued cooperation and valuable assistance throughout the study.

Respectfully submitted,

FREDERIC R. HARRIS, INC.

by Zachary de Gaster

Zachary de Gaster

ETHIOPIA

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June 1973

IMPERIAL ETHIOPIAN GOVERNMENT
IMPERIAL HIGHWAY AUTHORITY

Prepared By

FREDERIC R. HARRIS, INC.
Consulting Engineers

Supported By:

ECONOMICS RESEARCH ASSOCIATES
Transportation Economists

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ACKNOWLEDGMENTS

The Ethiopia Road Maintenance Study was conducted by Frederic R. Harris, Inc., Consulting Engineers, and supported by Economics Research Associates, Transport Economists, both subsidiary firms of Planning Research Corporation.

The study was conducted under the administrative supervision of Zachary De Gaster. Frederic R. Harris, Inc. wishes to acknowledge the efforts of the project team, especially Marshall Pentecost, Project Manager, and Frank Hahn, Transport Economist for the project. Additionally, the project was significantly assisted by the counterpart support of the Imperial Highway Authority and the coordination and comment by the U.S. Agency for International Development. Frederic R. Harris, Inc. wishes to express appreciation for the cooperation and assistance of the many other individuals and agencies who contributed to the study.

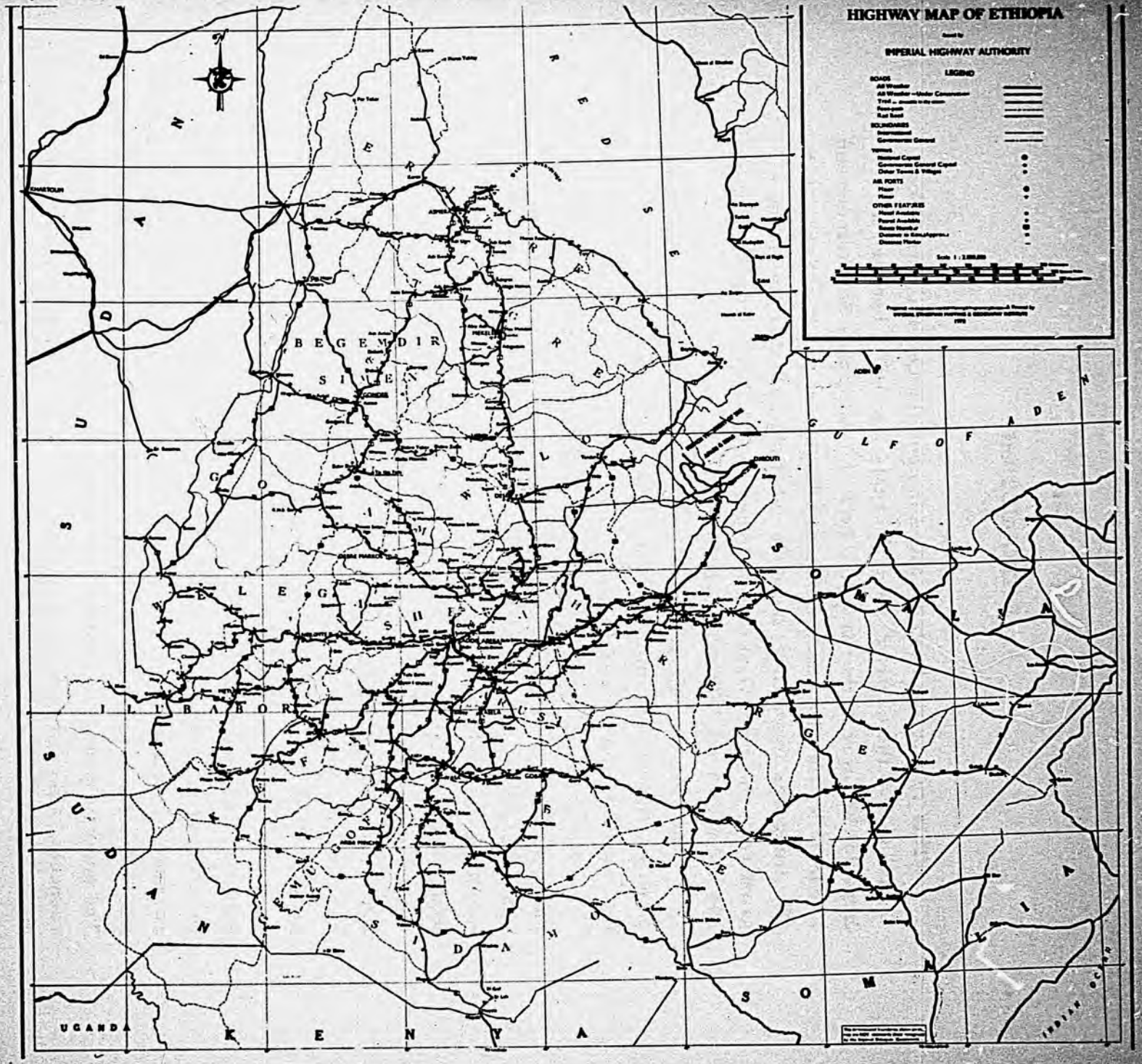
INTRODUCTION

This report has been prepared in compliance with Article X, Clause C-3 of the contract dated February 29, 1972, between the Imperial Highway Authority of the Imperial Ethiopian Government and Frederic R. Harris, Inc., Consulting Engineers, of New York, N. Y. The study was financed by the Imperial Highway Authority and by a grant from the U. S. Government under USAID Project Agreement No. 294 and PIO/T No. 663-155-3-20009.

The primary objective of this study was to develop a five-year plan of action for the improvement of highway maintenance, and for the rehabilitation of road sections requiring urgent attention.

The contract scope of work indicated that all aspects of maintenance were to be evaluated; organization, administration, operations, and work practices. The roads themselves had to be examined in detail, to assess their standards, record their condition, and determine what work was necessary and justified. An inventory of physical and human resources was required, to see what could be accomplished with those now available, and what changes or additions might be needed to carry out the programs which were found to be essential and economically justified.

The requirements of the study emphasized the economic feasibility aspects of maintenance and rehabilitations, to be expressed primarily in terms of cost savings to road users. This emphasis required, in a real sense, an extension of critical analysis into fields of highway activity where decisions have, by tradition, been guided by engineering fact alone. The analysis procedures conceived during the study are new in some respects, although they are based on familiar and established concepts. This chance to test the further uses of economic evaluation was accepted with keen interest and, hopefully, the results will add some clarity to the cost-effects of maintaining or not maintaining roads. The general utility of the procedures will have to be established by further studies of a similar kind, perhaps with alternative variations of analysis methods and assumptions.


HIGHWAY MAP OF ETHIOPIA
IMPERIAL HIGHWAY AUTHORITY
LEGEND
ROADS
All Weather
All Weather – Under Construction
Trail
Footpath
Rail Road
BOUNDARIES
Regional
Commission General
Towns
Regional Capital
Commission General Capital
Other Towns & Villages
AIR PORTS
Major
Minor
OTHER FEATURES
Rural Anabiba
Rural Anabiba
Bana Bashi
Chicken or Kina(Approx.)
Chicken Factor
Scale 1 : 3,000,000
KHARTOUM
ADDIS ABABA
DIRE DAWA
DJIBOUTI
ASMARA
BEGEMDIR
GONDER
GOJJAM
WELLO
SHEWA
ILLABOR
KEFFA
GEMU GOFA
SIDAMO
HARERGE
ARUSI
BALE
GULF OF ADEN
INDIAN OCEAN
SUDAN
UGANDA
KENYA
SOMALIA

Section I

SUMMARY OF FINDINGS

A. Organization

The administrative and supervisory structure of the Imperial Highway Authority was examined in close detail. The full discussion of the review appears in Report Section II, of this same volume. Recommendations are also presented in Section II, but some of the organizational charts are to be found in the Administrative Appendix, as indicated in the text of Section II.

In evaluating the IHA organization structure, the Consultants adopted the basic position that no changes should be considered unless they would result directly in improvement of highway maintenance and rehabilitations.

With this in mind, a review was conducted of the overall administration of the Highway Agency, but with a final emphasis on the Office of the Chief Engineer, the Operations Division, and the District offices. Attention was given to the special problems of the Supply and Equipment Division and to operations planning. Finally, personnel management and the Training and Testing Branch were examined.

1. It was concluded that the present organization structure is basically sound and easily capable of providing direction for the highway programs of Ethiopia. Throughout the IHA the existing administration was found to be generally capable, energetic and dedicated. As always, the study disclosed some instances where improvement could be achieved.

In the opinion of the Consultants the Office of the Chief Engineer was not, at the time of the study, adequately staffed and organized for its important role.

It is recommended that:

a. The Office Engineer be assigned specific responsibilities and a corresponding authority, as detailed in Report Section II.

b. A small office unit be added to the Office of the Chief Engineer. A suggested staffing and work function appear in Section II.

2. Concerning the Operations Division, it was felt that a rather serious problem exists in the line and staff relationships between headquarters and the district offices. Severe effects are avoided by the current practices and interpretations within the division, but the formal relationships should be clarified and made more workable.

It is recommended that:

a. Only the head of the Operations Division have line authority over the District Engineers. Other professional staff in the division headquarters should be limited to staff authority in their relationships with the districts. The steps needed to accomplish this are described in Section II.

3. District office administration appeared to be adequate in concept. The Consultants concurred with the IHA thinking and Public Administration Service (PAS) recommendations in this area.

It is here recommended that:

a. The IHA pursue its effort to obtain qualified professional engineers for all District Engineer positions.

b. Professionals should also be assigned to the Assistant District Engineer positions as this becomes possible.

c. On a conservative and selective basis, "Maintenance Sub-Districts" should be created where justified by the size of present districts, length of road to be maintained, and logistics or communications problems. Sub-Districts are further discussed in Section II and other portions of the report.

4. It was noted that the existing supply and Equipment Division has an unusual placement in the IHA organization structure. The history of this function in Ethiopia was reviewed, and the Consultants agreed that the PAS decisions were probably necessary, and the results obtained (improved equipment availability) justify the present organizational position.

It is recommended that:

a. No change be made now in the level and function of the Supply and Equipment Division, or its line authority over the district shops and warehouses. However, it is suggested that at an appropriate future time the IHA should consider placing the supply and equipment activity in the General Services Division, where the other support and service functions are grouped.

b. After some years of continued operation in the present manner, line authority over the district shops and warehouses should be transferred to the district engineers. Immediate actions are suggested in Section II which could improve cooperation between engineering operations and equipment management.

5. Some weakness was observed in the IHA's methods of developing programs for maintenance and rehabilitations. One basic problem identified was the mixing of program planning with budget anticipations. While monetary limitations are a very real constraint on the volume of work which can be done, it was felt that it would be preferable to separate the maintenance planning project from the budget process. Personnel should be assigned to the specific task of defining the necessary minimum programs using rational engineering/economic procedures, and estimating program costs. The best location for this function would be in the same organizational unit which has responsibility for overall IHA program development.

It is recommended that:

a. A new position of "Operations Planning Engineer" be created for assignment to the Planning and Programming Division. The division should, with the addition of this position, accept responsibility for maintenance planning as an integral part of its function.

6. The Consultants were favorably impressed with the organization and achievements of the Personnel Services Division. Report Section II mentions several specific accomplishments of the division. No recommendations are offered with regard to the Personnel Division in general.

The training and testing branch of personnel was evaluated separately because of its size and importance. It was concluded that the programs of the branch have been quite successful and very beneficial to the IHA. Continuation and some expansion of this effort should be supported.

It is recommended that:

a. The Training Center explore every possibility of developing programs in the "supervision" and "management" areas. Suggestions for pursuing this are offered in the report.

b. The Training Center should initiate an "administrative intern" program modeled after its "engineer-in-training" program.

c. Efforts in this field should include some recruitment and training of students graduating from the university in public administration, business management, or other appropriate fields.

d. Favorable consideration should be given to providing the Training Center with necessary equipment, tools and training aids.

B. Road Maintenance

The technical substance of the study was organized in what seemed to be the most logical progression. The basic rationale and the sequence of steps for the overall study can be inferred from the table of contents. The first requirement of this phase was a quantification of maintenance needs and costs.

1. Roads Considered

All existing routes under the jurisdiction of the IHA in fiscal year 1972/73 were identified, and were found to total 7,355 km. This consisted of 2,488 km of paved roads and 4,867 km with gravel or earth surfacing.

Routes under construction or reconstruction at the time of the study were identified. Information was also obtained on future programs, and estimates were made of all the new or revised length which would become maintenance responsibility by the fiscal year 1977/78. The total for these two categories was 3,811 km. A part of this represented paving

of existing gravel roads, which would not increase maintenance kilometers. By agreement with the IHA and other appropriate agencies, the system to be analyzed was confined to the sub-systems described in the preceding page.

2. Road Types for Maintenance

A determination was made of the factors which would cause significant variations in maintenance costs. The major parameters for Ethiopian roads were found to be surface type, climate, topography, and road standards (related to traffic volume). From these factors a general classification of roads was developed which recognized six different physical types, each of which might be found in any one of three kinds of climate and in any one of three conformations of topography. This produced 54 basic classifications of road for maintenance. The results are shown in Exhibit III-A of the report (see Section III). The exhibit is also reproduced here.

All roads to be analyzed were divided into short segments having homogenous characteristics. The segment lengths normally ranged from 5 to 50 km. The individual segment termini were chosen so that within the length there would be no important variations in surface type, surface width, traffic volume, climate or topography.

Each segment of existing road was classified as being in one of the 54 types according to its characteristics. This was done by means of field inventories and data on record.

Each segment of road under construction or programmed was classified through the use of survey data and by consultation with IHA personnel.

These classifications of individual segments by maintenance type appear in Exhibits III-D and III-E of the Engineering Appendix.

3. Maintenance Effort

"Maintenance" was defined and the various kinds of work necessary in Ethiopia were established. The amount or frequency of maintenance work which would be justified for different types of road was considered,

EXHIBIT III-A

ROAD TYPES FOR MAINTENANCE

Road Type	Description	Dry Weather Zones			Moderate Rainfall Zones			High Rainfall Zones		
		F	R	M	F	R	M	F	R	M
		Number and Letter Designations								
1	Asphalt-surfaced, less than 10 years old	1-DF	1-DR	1-DM	1-MF	1-MR	1-MM	1-HF	1-HR	1-HM
2	Asphalt-surfaced, 10 or more years old	2-DF	2-DR	2-DM	2-MF	2-MR	2-MM	2-HF	2-HR	2-HM
3	Gravel-surfaced, ADT 100 or more (primary)	3-DF	3-DR	3-DM	3-MF	3-MR	3-MM	3-HF	3-HR	3-HM
4	Gravel-surfaced, ADT less than 100 (primary)	4-DF	4-DR	4-DM	4-MF	4-MR	4-MM	4-HF	4-HR	4-HM
5	Gravel-surfaced, Feeder standard	5-DF	5-DR	5-DM	5-MF	5-MR	5-MM	5-HF	5-HR	5-HM
6	Gravel-surfaced, Service to Traffic standard	6-DF	6-DR	6-DM	6-MF	6-MR	6-MM	6-HF	6-HR	6-HM

F = Flat, R = Rolling, M = Mountain

Note: For road sections in those areas of Ethiopia where desert allowance is paid, a lower-case "d" is added to the above designations.

Examples: 1-DFd or 6-MRd. See Report Section III-G "Maintenance costs"

and the best means of doing the work (labor-intensive versus machine-intensive). From this base, a detailed analysis was made of the annual maintenance effort needed for each of the 54 types of Ethiopian road, in terms of annual crew-days per kilometer for specified crews of men and machines on the different maintenance operations. This analysis was a major effort of the study and is discussed at considerable length in Section III of the report.

4. Maintenance Costs

Crew-day costs for the various operations were estimated by combining labor, equipment rental, materials (purchased or produced) and overheads. Briefly, these were obtained as follows:

a. The IHA monthly pay scales, by classifications, using step "C". These rates were increased by 20.47 percent to cover social benefits, and were converted to hourly labor costs by assuming a calculated average of 159.5 applied working hours per month. Contract labor was computed separately. "Desert allowance" was added to produce a second set of labor rates for use where applicable.

b. Equipment rental rates per hour for the various machines, with values estimated to include depreciation plus all operating, repair and servicing costs except operator's wages.

c. Material costs at established average market prices or estimated unit costs for production by IHA crews.

d. An overhead percentage calculated to cover the remaining undistributed costs of maintenance operations, including a portion of district-level administrative costs but excluding IHA headquarters administration.

The crew-day costs, in conjunction with the earlier estimates of annual maintenance effort, produced a table of maintenance costs per km per year for each of the road types. These are summarized in Exhibit III-C of the report, and the table is also reproduced here. All values are financial (not economic) costs in 1972 Ethiopian dollars. The financial cost to maintain the existing (1972/73) road segments is shown by the figures of the last column of Exhibit III-D, found in the Engineering

EXHIBIT III-C

SUMMARY OF ESTIMATED BASIC ANNUAL MAINTENANCE COST PER KM BY MAINTENANCE TYPE

FINANCIAL COSTS IN 1972 ETHIOPIAN DOLLARS

Road Type	Dry Weather Zones			Moderate Rainfall Zones			High Rainfall Zones			Dry Weather Zones With Desert Allowance			Moderate Rainfall Zones With Desert Allowance		
	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M
1	1-DF $1,745	1-DR $1,785	1-DM $1,885	1-MF $2,960	1-MR $3,040	1-MM $3,250	1-HF $3,320	1-HR $3,430	1-HM $3,660	1-DFd $1,785	1-DRd $1,830	1-DMd $1,940	1-MFd $3,020	1-MRd $3,105	1-MMd $3,335
2	2-DF $2,060	2-DR $2,105	2-DM $2,200	2-MF $3,705	2-MR $3,780	2-MM $3,995	2-HF $4,380	2-HR $4,490	2-HM $4,720	2-DFd $2,130	2-DRd $2,170	2-DMd $2,275	2-MFd $3,800	2-MRd $3,890	2-MMd $4,120
3	3-DF $4,745	3-DR $4,240	3-DM $3,975	3-MF $4,745	3-MR $4,255	3-MM $4,080	3-HF $5,615	3-HR $5,010	3-HM $4,830	3-DFd $4,815	3-DRd $4,310	3-DMd $4,050	3-MFd $4,820	3-MRd $4,325	3-MMd $4,165
4	4-DF $2,840	4-DR $2,500	4-DM $2,475	4-MF $2,965	4-MR $2,635	4-MM $2,700	4-HF $3,850	4-HR $3,520	4-HM $3,470	4-DFd $2,885	4-DRd $2,545	4-DMd $2,530	4-MFd $3,015	4-MRd $2,685	4-MMd $2,765
5	5-DF $1,250	5-DR $1,145	5-DM $1,200	5-MF $1,360	5-MR $1,260	5-MM $1,405	5-HF $1,725	5-HR $1,630	5-HM $1,735	5-DFd $1,270	5-DRd $1,165	5-DMd $1,235	5-MFd $1,385	5-MRd $1,290	5-MMd $1,450
6	6-DF $ 855	6-DR $ 790	6-DM $ 850	6-MF $ 925	6-MR $ 865	6-MM $1,000	6-HF $1,175	6-HR $1,110	6-HM $1,210	6-DFd $ 870	6-DRd $ 805	6-DMd $ 830	6-MFd $ 950	6-MRd $ 895	6-MMd $1,035

F = Flat, R = Rolling, M = Mountain

Appendix. The maintenance type and cost per km are given in Columns 7 and 8 of that exhibit.

The incremental annual costs for future years, through 1977/78, are obtained from Exhibit III-E of the Engineering Appendix. The figures of the column headed "total annual cost change" in Exhibit III-E indicate, for existing routes, the net effect on maintenance cost of scheduled improvements. For new roads, the column gives the added maintenance cost. This was due primarily to the high unit price of the material needed for spot re-graveling and periodic resurfacing of these high-type gravel routes. The use of "processed" select material had been projected by the Consultants to obtain normal vehicle operating costs for the public.

Information was collected from all IHA districts on the sources, quality and quantity of materials for surfacing. The data are presented in Exhibit III-F of the Engineering Appendix.

Searching for a means of reducing the annual costs, comparative estimates were made of both maintenance and vehicle operating cost (VOC) using pit-run gravels, processed select materials, and crushed stone for replacement surfacing. Where applicable, unit prices were estimated for production by crushing and screening plants of two different sizes.

The conclusion was reached that unprocessed pit-run gravels from the known sources would not, in the majority of cases, be an economical choice for surfacing Type 3 and 4 roads, because the higher VOC would more than offset the savings in material costs. It was concluded that crushed stone would not be an economical substitute because there would be no significant reduction in VOC (over processed select material) and insufficient increase in wearing quality to make up for the higher unit price.

Nevertheless, the Consultants did not feel that the IHA should accept indefinitely the abnormal maintenance costs for primary gravel roads which would result from the projected use of processed select material. Instead, it was their view that acceptable natural materials must exist in many areas where surfacing is needed, and that a

comprehensive exploration program should be conducted, with technical assistance, to search for new sources. Based on experience with this same problem in other nations, it was estimated that exploration could probably discover suitable natural surfacing to care for 60 percent to 70 percent of the length of Type 3 and 4 roads. This could lower the overall average cost per cubic meter of replacement surfacing needed on these roads by about 45 percent.

Pending completion of a materials search, it would be advisable to defer a part of the capital investment needed to fully implement an adequate maintenance program.

C. Effects of Not Maintaining Roads

Section IV of the report assesses the physical changes which take place on a road if maintenance is inadequate or is stopped. The report establishes qualitative scales of condition (separately for paved and gravel surfaces) and then relates these to incremental increases in vehicle operating cost. A rationale for "maintenance priority ranking" is discussed and, finally, estimated lives are set for different classes of road under conditions of zero maintenance.

After a general review of vehicle operating costs in Ethiopia, a decision was made to employ the accepted working assumption that as highways deteriorate the VOC will rise from that normal for the road's surface type to that higher cost per km which is normal for the next simpler type of surface. That is, as paved routes deteriorate from good to bad condition, the VOC increases until it eventually reaches that for a good gravel surface.

Four condition ratings were selected and defined for pavements, and seven were established for gravel surfaces. These condition ratings and the corresponding VOC levels were used for two distinct purposes in the report. First, all existing roads of the 1972 IHA system were rated for observed condition, segment by segment. This rating appears in Column 6 of Exhibit III-D in the Engineering Appendix. The observed condition (and related VOC) was subsequently used in Report Section XIII to compute the benefits which could be obtained from better maintenance of the system.

Secondly, the condition ratings were used to fix a hypothetical scale of VOC increases which would occur if maintenance were interrupted on a particular segment of road, and the surface quality allowed to decline. The lives of different surfaces were estimated if given zero maintenance. The two sets of data formed the basis for the maintenance priority calculations of Section V.

D. Maintenance Priority Ranking

After considering the various factors which, taken together, fix the general importance of a road and therefore its priority for maintenance, it was concluded that there was no practical means of introducing broad considerations such as regional access or foreign exchange generation. A ranking methodology was therefore developed based on the one common and quantifiable variable of differential costs incurred by the users of the road.

Vehicle operating cost tables were developed, by analyzing those of the 1969 General Road Study and modifying those values as necessary. This extensive work is described in Report Section V.

Shadow price factors for maintenance were produced next, to convert this input from financial to economic cost. An opportunity cost of capital was selected.

In a major effort of the study, traffic forecasts were developed by areas, count stations, routes and individual road segments. Detailed computer analysis was utilized in the United States for this phase.

With all data prepared, the ranking methodology and sequence of steps can be described as follows:

1. The road systems were classified by segments. Each segment was identified as to location, length, surface standard, topography and climate zone.

2. Routine, periodic and special maintenance costs were developed for each segment.

3. The life of each surface type to deteriorate from the best potential condition to the next surface type was determined.

4. The economic vehicle operating cost range on each surface type was determined (dependent on type of surface and terrain). The range varied from Condition 1 to Condition 4 on paved surfaces, from Condition 2 to 6 on gravel roads of primary or feeder standard, and from Condition 3 to 7 on service to traffic roads.

5. The traffic forecast by vehicle type was determined on each segment.

6. Shadow cost factors for the maintenance cost were derived.

7. Utilizing a computer program and the above inputs, the following calculations were made (see Economics Appendix for program inputs and program):

a. Total annual economic maintenance cost by segment.

b. Total annual incremental economic VOC by vehicle type and total VOC by segment.

c. The difference between the total economic maintenance costs and the incremental economic VOC. This was termed the "net benefit".

d. The present value of the net benefit at the opportunity cost of capital.

8. Segments were then grouped into maintenance sections, and the net benefit and the present value net benefit summed for each section. (The groupings on the existing system are shown in Exhibit V-24 of Report Section V.)

9. Utilizing a second computer program, maintenance sections were then ranked in order from the highest present value net benefit to the lowest. Also, the sections were ranked from the highest present value net benefit per kilometer to the lowest.

The results of the ranking were found to be of interest and significance, though there were indications that they should be used with some care. The indices given by the process provide only a relative ranking of the system, with indications of which sections should be maintained to provide the greatest benefit to the actual users of the road. From another view, the rankings show where, given some resource constraint, maintenance could be delayed or stopped at the least cost to the users of the

system. However, it should be noted that if maintenance were actually stopped on any segment, new patterns of movement would evolve and the entire ranking order would then change.

With respect to traffic patterns and surface types, the present system was ranked assuming completion of scheduled and funded improvements to the primary network.

The candidate roads of the existing system were divided into viable routes, sections and links by grouping the appropriate route segments. Exhibit V-24 of Report Section V shows this grouping into analysis sections, and Exhibit V-25 (reproduced here) repeats the same list of sections, but ordered by their comparative rankings of present value net benefit (PVNB) per kilometer, from highest to lowest. Exhibit V-25 shows that, in general, the high commercial-traffic roads rank first. Next are the gravel roads with high traffic, then the paved roads with medium traffic. These are followed by the gravel and paved roads with light traffic.

Exhibit V-26 illustrates the priority ranking of future additions to the present road system, computed in the same manner. Of these routes and sections, only 20.5 percent of the total kilometers of proposed new road have a positive net benefit. This is because the majority of the new projects consist of feeder or service to traffic roads which are extensions to the present system and are on the fringes of traffic. Most of the new roads are justified on the basis of agricultural output or other objectives, such as national unity and access. Caution must be used in applying the rankings since they do not fully reflect the importance of the road segments in the national economy. They provide a basis for judging where maintenance expenditures are most effective in slowing or preventing increases in vehicle operating costs.

E. Rehabilitation Needs and Costs

Definitions were chosen for "normal" and "urgent" work, and the term "rehabilitation" was applied to all proposed work in excess of normal maintenance requirements. The condition ratings referred to in

EXHIBIT V-25

RELATIVE MAINTENANCE RANKING OF ROAD SECTIONS

EXISTING HIGHWAY SYSTEM (1972/73)

Route Sections	Segments	PVNB* E$ per km @ 10%	Ranking
Jct. Rte. 18 (near Tendaho) - Asseb	02007 - 02013	76,203	1
Addis Ababa - Jct. Rte. 18 (Awash Sta.)	04001 - 04012	72,597	2
Dengego - Dire Dawa	04401 - 04402	50,366	3
Yergalem Spur	06101	28,186	4
Asmara - Massawa	01067 - 01072	26,411	5
Modjo - Shashamane	06001 - 06004	22,738	6
Alemgena - Kersa R. Bridge	09001	15,069	7
Nazreth - Assela	08001 - 08006	8,693	8
Dessie - Quiha	01019 - 01046	8,446	9
Addis Ababa - Jimma	07001 - 07015	8,208	10
Shashamane - Sodo	41001 - 41004	7,368	11
Massawa - Gurgussum	01301	6,330	12
Harer - Jijiga	04037 - 04043	5,277	13
Addis Ababa - Combolcia	01001 - 01016	4,770	14
Addis Ababa - Lekempty	05001 - 05008	4,759	15
Mekele - Maimekden	01201	3,987	16
Jct. Rte. 18 - Harer	04015 - 04036	3,787	17
Shashamane - Dilla	06005 - 06008	3,398	18
Adigrat - Asmara	01057 - 01066	2,509	19
Gonder - Axum	03033 - 03054	2,423	20
Keren - Teseney Jct.	11006 - 11012	1,674	21
Shashamane - Dodola	40001 - 40003	1,635	22
Lekempty - Ghimbi	05009 - 05013	451	23
Bonga Spur	07201	204	24
Teseney Access	11101	84	25
Jimma - Bedele	43002 - 43009	62	26
Axum - Asmara	03055 - 03072	46	27
Mieso - Dire Dawa	20003 - 20004	(181)**	28
Massawa - Agip	12001	(190)	29
Adi Abun - Adwa	03401	(399)	30
Ghimbo Access Road	07101	(595)	31
Asmara - Keren	11001 - 11005	(677)	32
Combolcia - Dessie	01017 - 01018	(1,631)	33
Dejen - Bichena	23001	(1,891)	34

EXHIBIT V-25
(Continued)

Route Sections	Segments	PVNK* E$ per km @ 10%	Ranking
Debre Markos - Bahir Dar	03009 - 03022	(1,914)	35
Addis Ababa - Debre Markos	03001 - 03008	(2,580)	36
Jijiga - Degenbur	30001	(2,771)	37
Jimma - Bonga Junction	07016 - 07020	(3,184)	38
Quiha - Adigrat	01047 - 01056	(3,193)	39
Mukutere - Alem	03101	(3,237)	40
Bahir Dar - Tis Abat	51001	(3,620)	41
Terramini - Decamere	50001 - 50002	(3,659)	42
Wondo - Negele	44001 - 44005	(4,155)	43
Gonder - Setit	33001 - 33002	(4,330)	44
Dodola - Goba	08025 - 08028	(4,454)	45
Cement Quarry Road	03301	(4,649)	46
Debre Berhan - Jihur	28001 - 28002	(5,325)	47
Adi Ugri - Areza	17001 - 17005	(5,503)	48
Tarmaber - Seladengie	49001 - 49003	(5,602)	49
Kuni - Gelemso	35001 - 35007	(5,771)	50
Debre Berhan - Ankober	16001	(5,835)	51
Sodere Spur	08101	(5,928)	52
Azezo - Gonder	03031 - 03032	(6,069)	53
Tarmaber - Molale	14001 - 14002	(6,370)	54
Mehal Meda Road	14101	(6,907)	55
Quiha - Mekele	01101 - 01102	(6,957)	56
Kobo - Deder	04301	(8,011)	57
Bahir Dar - Azezo	03023 - 03030	(8,169)	58
Sodo - Arbaminch	09030 - 09034	(8,335)	59
Asseb Airport Road	02101	(8,801)	60
Bonga Jct. - km 485	07021 - 07022	(8,967)	61
Combolcia - Jct. Rte. 18 (Tendaho)	02001 - 02006	(10,240)	62
Gonder Airport - Gorgera	27001 - 27005	(11,259)	63
Adigrat - Adi Abun	15001 - 15005	(11,361)	64
Debre Libanos Road	03201	(12,668)	65
Nefasit - Decamere	10001 - 10003	(13,468)	66
Koka Dam Access Road	14101	(13,734)	67

* PVNB - Present Value Net Benefit
** Parentheses indicate negative PVNB

EXHIBIT V-26

RELATIVE MAINTENANCE RANKING OF ROAD SECTIONS
FUTURE ADDITIONS

Route Sections	Segments	PVNB* E$ per km @ 10%	Ranking
Relocation (Akaki-Nazreth)	04006	83,041	1
Awash River Br. - Tendaho	18001 - 18011	20,131	2
Butajira - L. Zuway	09101 - 09102	18,184	3
Alemgena - Hosaina	09002	3,822	4
Aseela - Dodola	08007 - 08011	2,504	5
Gelemso - Mechara	35008 - 35009	(804) *	6
Jimma - Suntu	37001	(1,393)	7
Kebre Dehar - Ferfer	30006 - 30009	(1,511)	8
Teseney - Humera-Royan	25001 - 25003	(1,606)	9
Babile - Fik	04701 - 04707	(1,617)	10
Areza - Barentu	17006	(1,622)	11
Degenbur - Kebre Dehar	30002 - 30005	(1,634)	12
Azezo - Metema	21001 - 21005	(1,961)	13
Bonga - Mizan Teferi	07023 - 07027	(1,990)	14
Ghimbi - Kurmuk	05014	(2,210)	15
Agaro - Chira	43101	(3,015)	16
Welkite - Hosaina	13001 - 13009	(3,184)	17
Goba - Meslo	36001 - 36002	(3,959)	18
Modjo Access	01501	(5,276)	19
Bichena - Mota	23002 - 23003	(5,538)	20
Robey - Ghinir	08029 - 08034	(5,539)	21
Mega - Moyale	06025 - 06029	(7,246)	22
Yabello - Mega	06020 - 06024	(7,273)	23
Local Access Road	04601	(9,135)	24
Agere Maryam - Yabello	06016 - 06019	(9,450)	25
Bedele - Metu	43010 - 43017	(9,699)	26
Dilla - Agere Maryam	06009 - 06015	(9,736)	27
Butajira - Hosaina	09003	(11,454)	28

* PVNB - Present Value Net Benefit
** Parentheses indicate negative PVNB

Paragraph I-C above were examined to identify all segments of existing road which should be considered for rehabilitation. On these, the potential project limits were set and the types and quantities of work were estimated using the Consultants' field notes, IHA "Condition Surveys", and data from the General Road Study.

Eleven possible projects were established; five on paved routes totaling 707 km, and six on gravel roads with a combined length of 968 km. Other segments with equally poor ratings were considered. Some were too short to make viable projects; others were in a borderline condition which could be corrected by ordinary maintenance methods. Some additional sections were already scheduled for improvement by the IHA, or work was already in progress.

Two sets of unit prices were established; one for work by contract and the other by IHA forces. Cost analyses were made on each proposed project to determine the most economical and feasible means of doing the required work. From these comparisons it was concluded that all gravel road rehabilitations and all base repairs and other preparation on paved routes should be done by force account, but with purchased materials. Bituminous surfacing could be done more economically by contract.

Using this division of the work, it was estimated that the total cost of all the candidate projects would be E$39,430,200, distributed over three years. Descriptions of the projects, work quantities and estimates of costs are given in Report Section VI.

F. Rehabilitation Ranking

Although highway rehabilitations are usually programmed by administrative decision, in this study the projects were examined for economic justification, based primarily on VOC effects. This presented some rather difficult problems to which standard economic analysis could not be applied, but a ranking procedure was developed consisting of the following steps:

1. Road segments identified as needing rehabilitation were grouped into rehabilitation sections. This was based on engineering judgment.

2. The associated surface classifications, lengths and other data for each segment were taken from Exhibit III-D of the Engineering Appendix.

3. Traffic estimates and the annual traffic growth rates were then taken from the forecasts as described in Report Section V-F.

4. The incremental VOC was calculated for each surface type and range of conditions, assuming that the existing condition was improved to the best condition which would result if rehabilitation occurred, and that recommended maintenance would then be initiated.

5. The incremental vehicle operating cost savings were calculated for each rehabilitated segment for a period of ten years.

6. The present value of the incremental VOC was calculated for each segment at the opportunity cost of capital for each of the ten years.

7. The present value of the incremental VOC was summed for all the segments of a rehabilitation section, by years.

8. The yearly present values of the incremental VOC for a section were summed from the initial year forward until the sum of the present value net benefit was equal to or greater than the rehabilitation costs.

9. The number of years it would take for the present value of the incremental VOC to be equal to or greater than the rehabilitation cost was evaluated, in engineering terms.

10. If the number of years was considered to be within the engineering life of the rehabilitation for a specific section, considering such factors as the age of the road, traffic, and so on, then the project was considered for ranking.

11. Rehabilitation projects were then ordered in terms of the time it would take to achieve the above described equality. For the purposes of this analysis, projects for which more than 10 years were required to achieve equality were considered unacceptable.

The following list shows, for the paved roads, the rehabilitation cost, the present value of the incremental VOC for approximate equality, and the year in which that incremental VOC is achieved.

Section	Rehabilitation Cost E$	Present Value Incremental VOC	Year Achieved
Addis Ababa-Welkite	2,084,300	2,522,929	2nd
Addis Ababa-Agrehiwot	3,433,800	3,296,107	3rd
Tendaho-Asseb	3,216,000	3,459,240	4th
Addis Ababa-D/Berhan	4,530,600	4,776,882	6th
Addis Ababa-Dejen	4,845,700	--	12 plus

Of these sections, it can be seen that the last falls into the unacceptable category. It must be emphasized that acceptability is calculated solely in terms of savings to vehicle operators. This may or may not be the most important criteria for any specific segment.

The following list shows the gravel roads considered for rehabilitation, the rehabilitation cost, the present value of the incremental VOC which gives approximate equality, and the year in which this is reached.

Section	Rehabilitation Cost E$	Present Value Incremental VOC	Year Achieved
Tarmaber-Woldia	7,982,100	10,761,791	2nd
Shashamane-Sodo	3,187,700	4,107,634	3rd
Shashamane-Kofole	2,221,500	2,103,519	3rd
Wondo-Kebremengist	3,023,200	3,064,260	5th
Jimma-Bonga	3,169,800	3,049,771	5th
Kofole-Goba	1,735,500	--	20 plus

The last of these, Kofole-Goba, has an extremely long break-even period. This is due to the low traffic forecast on the section.

G. Resource Implications and Constraints

The work described in previous paragraphs provided a basis for estimating the costs of maintaining all existing system roads plus those planned for the near future, and for doing all justified rehabilitations. It was then necessary to ask what resources, financial and physical might be available to carry out the programs, and whether they would be sufficient.

The total financial cost to maintain the existing (1972/73) road system was derived by summing all figures of the last column of Exhibit III-D, found in the Engineering Appendix. The incremental annual costs for maintaining all roads planned in future years, through 1977/78, were obtained from Exhibit III-E of the same Appendix. The total financial costs by years for the maintenance of all candidate roads, with equipment depreciation costs included, would be as follows:

Fiscal Year		Total Annual Cost
Ethiopian	Gregorian	(1972 E$)
1965	1972/73	25,850,320
1966	1973/74	27,242,640
1967	1974/75	28,274,985
1968	1975/76	29,302,668
1969	1976/77	29,804,333
1970	1977/78	29,844,103

Discarding the two projects which were found to have very long payout lives (Addis Ababa-Dejen and Kofole-Goba) the proposed rehabilitation work which should be carried out if funds permit had an estimated total cost of E$32,849,000. A tentative schedule was worked out for the rehabilitations, beginning in July, 1973. This provided rounded estimates of expenditures by years for the work, as given on the following page. The combined maintenance and rehabilitation costs by years are then shown, for future years.

Fiscal Year Ethiopian	Fiscal Year Gregorian	Rehabilitation Costs by Years (1972 E$)
1966	1973/74	15,242,800
1967	1974/75	13,925,800
1968	1975/76	3,630,500

		Combined Program Costs
1966	1973/74	42,485,440
1967	1974/75	42,200,785
1968	1975/76	32,983,168
1969	1976/77	29,804,333
1970	1977/78	29,844,103

Data were collected on the past amounts and future projections of funds from those tax sources which are traditionally used to finance road maintenance and construction. The Imperial Ethiopian Government (IEG) currently imposes all of the common taxes on highway users and, historically, the revenues generated have been greater than the combined IHA expenditures for maintenance and construction.

Exhibit VIII-1 of Report Section VIII shows the historical growth of the principal road user charges in Ethiopia from 1956/57 to 1971/72 (Gregorian Calendar). Exhibit VIII-4 of the same section gives a projection of all user revenues through the year 1977/78, including municipal taxes.

Information was also gathered on past highway expenditures, and these are reported in Exhibits VIII-9 and VIII-10 of the report. The assembly and projection of all figures are discussed at some length in Section VIII.

Because the size of IHA budgets is not fixed by any allocation formula or "earmarking" of funds, it was considered that there is no determinate "constraint" which sets a limit to these budgets. It was

concluded that three separate avenues should be explored for guidance as to a rational financial constraint on maintenance spending.

The first was projection of the historical relationship of maintenance programs to total IEG expenditures. The second, a projection of the average past maintenance per km, applied to the growing system. The third would involve projecting maintenance as a percentage of gross road user revenues.

Exhibit VIII-12, reproduced below, shows a summary of past IHA expenditures and their percentages of tota IEG budgets. Disregarding 1968/69, the IHA total has had a fairly constant relationship with total government spending, averaging about 8.87 percent. Maintenance alone was even more uniform as a percentage of the IEG total, at about 3.18 percent.

The previous table is followed by Exhibit VIII-15, which gives a projection of the future maintenance amounts which would be generated by taking 3.18 percent of the estimated IEG budgets of the coming years (IEG budgets from Exhibit VIII-14 of the report). The 3.18 percent maintenance amounts are also compared with the required funds for the Consultants' recommended maintenance. The latter figures (last column of Exhibit VIII-15) were adjusted to exclude estimated equipment depreciation, to make them comparable with past expenditure reports of IHA maintenance, as used in Exhibit VIII-12 and subsequently projected at the 3.18 percent average.

As can be seen, the recommended maintenance exceeds the projected historical 3.18 percent of IEG expenditures in all future years, and by substantial amounts. The significance is clear; if the forecast of IEG budgets is reasonably correct, and the historical-share for road maintenance is continued as a constraint, then the necessary maintenance of all candidate roads cannot be funded.

The second approach to establishing a possible limit consisted of calculating the average maintenance cost per kilometer for each of the past years 1964/65 through 1970/71, and then multiplying the overall average past expenditure per kilometer times the total future lengths of road proposed for maintenance. The resulting program amounts are

EXHIBIT VIII-12

COMPARISON OF IEG AND IHA ANNUAL EXPENDITURES
(Millions of Ethiopian Dollars)

	1965/66	1966/67	1967/68	1968/69	1969/70
IEG Expenditures*	394.4	416.8	442.2	454.5	473.6
IHA Expenditures:					
Construction	24.1	26.0	23.6	12.2	21.8
Maintenance	12.4	14.1	14.0	13.7	15.4
Total	36.5	40.1	37.6	25.9	37.2
IHA Total Expenditures As Percent of IEG Expenditures	9.3	9.6	8.5	5.7	7.9
IHA Maintenance as Percent of IEG Budget	3.1	3.4	3.2	3.0	3.2

*Includes salary and operating cost only.

Source: For IEG Expenditure, Central Statistical Abstract, 1970; for IHA Expenditure, IHA Planning and Programming.

EXHIBIT VIII-15

PROJECTED IHA EXPENDITURES AS A PERCENTAGE IEG, AND COMPARISON WITH RECOMMENDED MAINTENANCE (E$000,000)

Year	IEG Total	Total at 8.87% of IEG	Maintenance at 3.18% of IEG	Recommended Maintenance (Adjusted)
1972/73	548	48.6	17.43	20.81
1973/74	575	51.0	18.28	21.93
1974/75	604	53.6	19.21	22.76
1975/76	634	56.2	20.16	23.59
1976/77	666	59.1	21.18	23.99
1977/78	699	62.0	22.23	24.02

Source: Consultants' Analysis.

shown in Exhibit VIII-16. Note that this process generates numbers which are never more than 3 percent above or below those derived by taking 3.18 percent of assumed IEG expenditures. Therefore, it is apparent that projecting past IHA costs per kilometer would also fall short of financing the maintenance of all candidate roads. This is to be expected, if the maintenance effort during recent years has not been sufficient to prevent deterioration of the system. If the past maintenance cost per kilometer were to be adopted as a constraint, then further decline of the road system would follow, unless the operational efficiency could be raised substantially by some means.

The third approach to constraint-fixing was independent of the historical patterns of allocations and expenditures for maintenance. Instead, it related past programs and future needs to the receipts from road user charges. In Exhibit VIII-13 of Report Section VIII, combined IHA expenditures are shown as a percentage of past user revenue collections. The utilization by IHA has ranged from 52.1 percent to 97.2 percent, generally 80 to 90 percent. The construction portion of this cost has varied considerably, and if maintenance alone is expressed as a percentage of the same reported receipts, as in Exhibit VIII-17, it presents a much more uniform progression. In 1964/65, maintenance utilized 31.3 percent of user charge revenues. This remained about the same through 1967/68, then dropped to 27.6 percent and 27.5 percent for the next two years, then to 26.3 percent in the last year for which data were available (1970/71).

The projection of future user revenues Exhibit VIII-17, together with the estimated costs for maintaining all candidate roads (adjusted once more to exclude equipment depreciation) presents a rather clear picture of maintenance program costs rising, but more slowly than revenues, so that maintenance is a progressively lower percentage of the user charges. The maintenance, in this case, is that calculated to provide adequate protection for the roads. Furthermore, the projected revenues are not the totals shown in Exhibit VIII-4; they exclude those taxes which are municipal in origin.

EXHIBIT VIII-16

IHA PAST AND FUTURE MAINTENANCE
BASED ON COST PER KILOMETER

Year	Total Kms of Road	Maintenance (E$000)	E$/Km
1964/65	5,671	10,663	1,880
1965/66	5,855	12,397	2,117
1966/67	6,195	14,086	2,274
1967/68	6,826	13,982	2,048
1968/69	6,836	13,741	2,010
1969/70	6,848	15,832	2,312
1970/71	7,653	15,712	2,053
Approximate Average			2,100
Forecast			
1973/74	8,046	16,897	2,100
1974/75	8,834	18,551	2,100
1975/76	9,289	19,507	2,100
1976/77	9,708	20,387	2,100
1977/78	10,296	21,622	2,100

Source: IHA Maintenance Branch and Consultants' Analysis.

EXHIBIT VIII-17

PAST AND RECOMMENDED MAINTENANCE AS A PERCENTAGE OF USER REVENUES

Year	User Revenues* (E$000)	Maintenance Cost** (E$000)	Percent
1964/65	34,044	10,663	31.3
1965/66	40,165	12,397	30.9
1966/67	45,164	14,086	31.2
1967/68	47,021	13,982	29.7
1968/69	49,726	13,741	27.6
1969/70	55,838	15,382	27.5
1970/71	59,731	15,712	26.3
Forecast			
1971/72	64,505		
1972/73	73,366	20,809	28.4
1973/74	81,367	21,931	27.0
1974/75	85,030	22,761	26.8
1975/76	90,656	23,589	26.0
1976/77	96,125	23,992	25.0
1977/78	101,338	24,024	23.7

*Excluding Municipal Taxes
**Excluding Equipment Depreciation

Depreciation is a real cost of maintenance, and if the full program costs including this item are compared with the projected user tax receipts it can be seen that the total recommended maintenance costs for the candidate roads represent a somewhat higher percentage of the revenues, starting at 35.2 percent in 1972/73 (if the program were now in force) and declining to 29.4 percent in 1977/78. This is shown in Exhibit VIII-18 (see following page).

In the judgment of the Consultants, the historical levels of maintenance expenditure should not be imposed as a financial constraint on future programs, either in terms of controlled percentage of overall IEG budgets, or as a continuation of past average costs per kilometer. There does not seem to be any rational tie between overall government functions, comprised of a multitude of programs, and the maintenance of a defined system of roads. Regarding the established past expenditure per kilometer, there was no evidence that the cost had been related to actual needs by calculation and, on the contrary, the current condition of the highway system indicated that prior expenditures per kilometer had not been sufficient.

It appeared to the Consultants that there was no really definitive constraint on budget allocations to the IHA, except to the extent that there are never enough funds to meet all public requests and finance all desirable programs.

In the view of the Consultants, the total of <u>user revenues</u> might logically be adopted as a limiting financial constraint on <u>total</u> IHA expenditures. Within this limitation, it appeared reasonable to allocate to maintenance those funds estimated to be necessary for adequate minimum protection of the road investments, and service to the users. For the operational costs of maintenance, this would represent about one-third of user taxes in 1973/74, the initial program year of this study, and would decrease to less than 30 percent in the fifth year. The portion remaining available for construction and other IHA activities (including general administrative costs) would be from 65 percent to 70 percent of revenues, and increasing. It was the conclusion of the Consultants that no imperative financial constraint existed to prevent the adequate maintenance of all candidate roads.

EXHIBIT VIII-18

TOTAL RECOMMENDED MAINTENANCE AS A PERCENTAGE OF USER REVENUES

Year	User Revenues* (E$000)	Maintenance Cost** (E$000)	Percent
1972/73	73,366	25,850	35.2
1973/74	81,367	27,243	33.5
1974/75	85,030	28,275	33.2
1975/76	90,656	29,303	32.3
1976/77	96,125	29,804	31.0
1977/78	101,338	29,844	29.4

*Excluding Municipal Taxes
**Equipment Depreciation Included

The costs for the candidate rehabilitation projects were not included with the maintenance programs in the foregoing discussions. These costs are substantial, but the earlier analysis indicated that they would be favorable projects. Their further postponement would mean continuing abnormal costs to road users, and higher expense for eventual restoration. Since the distressed condition of these road sections is, in large part, due to curtailed maintenance effort in past years, with the required funds presumably put to other uses, it was considered appropriate to finance the rehabilitations now needed from general revenues or any other available sources. It was the opinion of the Consultants that no constraint should be placed on this necessary work.

An assessment was made of the adequacy of labor forces in the IHA, by work classifications, to see if this would impose a constraint on the work programs. Although there were minor shortages in some important groups, it was concluded that no critical constraint existed.

On the other hand, it was early apparent that lack of equipment would be a serious impediment to carrying out the proposed maintenance and rehabilitation programs. Evaluation of this factor was a major effort of the study.

After the assembly and review of record data on equipment, study personnel traveled more than 8,500 km to physically inspect the units in the field and shops, interview supervisors, operators and mechanics, and to examine repair and servicing facilities.

Excluding passenger cars, pickups and miscellaneous equipment, the records of the IHA Supply and Equipment Branch showed about 1,200 major units under the jurisdiction of the agency. Some 70 percent was assigned to maintenance in mid-1972, and the rest to the Direct Labor Construction Branch.

The Consultants' field inspections covered approximately 90 percent of the total listed equipment, or some 1,100 units. Many of these machines were classified as salvage on the rolls, but numbers of them were examined to see if they could be rehabilitated economically. This was not usually found to be feasible.

Some 825 major units of serviceable or repairable equipment were identified, of which 607 were assigned to maintenance. Notes were made on the make, model, age, utilization to date and condition. A judgmental estimate was made of the years of remaining life, assuming adequate minimum parts and servicing.

The present status of IHA equipment is discussed extensively in Report Section VIII. Some important conclusions were:

1. About 60 percent of the total IHA fleet is overage by ordinary standards, and much of it is in a poor state of repair.

2. Despite their ages in years, many units have had a low utilization in total hours worked, being deadlined for long periods due to a lack of spare parts and for other reasons.

3. The prevailing shortages cause the operable units to be overworked.

4. Servicing and preventive maintenance are not fully adequate.

5. Administrative difficulties exist in the control of the equipment.

6. As a part of the Highway Equipment Repair Facilities (HERF) Project in cooperation with USAID, new shops were being constructed and equipped in all nine of the IHA districts. Completion of these will provide much-improved and generally adequate repair facilities. However, another central rebuild shop will probably be needed in Asmara by 1975 or 1976.

7. The HERF Project, overall, has been of great assistance to the IHA in raising the availability of existing equipment and in training personnel.

8. Parts supplies are not sufficient. The procedures for ordering, stocking and issuing parts have not been effective, and this function has not been adequately funded.

9. The availability factor for normal mechanical equipment, taking all influences into consideration, was estimated to be about 65 percent.

The present maintenance fleet was evaluated to estimate by years the units which would remain in service through 1977/78. Equipment on order by the IHA in 1972 was taken into account. For future years, the totals by classes were reduced by the numbers of units expected to go out of service. The results are given in Exhibit VIII-20, reproduced on the following page.

H. Recommended Maintenance

To arrive at recommendations on the roads to be maintained consideration was given to costs, the meaning of the priority rankings, program constraints, and the broad national effects of including or excluding different routes and sections.

In the ranking analysis of Report Section V, it was found that the majority of existing roads (62.6 percent) had a present value net benefit (PVNB) which was positive, but some 37.4 percent of the system was negative. Nevertheless, the exclusion of those sections with a negative PVNB would mean the abandonment of maintenance on routes leading to Dire Dawa, Keren, Bonga, Arbaminch, Negele and numbers of smaller communities. The entire highway link from Addis Ababa to Gonder would be excluded, and long sections of other vital routes. It was apparent that this course would be politically untenable and economically disastrous.

Degrees of negative standing were of little assistance in attempting to define the best course of action. As an illustration, the Bahir Dar-Azezo section of Route 3 was 58th of the 67 sections ranked, despite the fact that it is obviously an essential artery for the nation. It was the conclusion of the Consultants that all segments of the present highway system should continue under IHA maintenance.

Most of the proposed future road improvements showed a negative PVNB. However, a majority of the future projects were for the paving of existing, presently-maintained gravel roads, on which maintenance should be continued, or were projects of the 4th and 5th highway programs. The latter, approved for financing from external sources, were supported

EXHIBIT VIII-20

PRESENT FLEET FORECAST
IHA EQUIPMENT UNITS ESTIMATED TO CONTINUE IN SERVICE
MAJOR MAINTENANCE ONLY, BY YEARS

Description	Existing	In Procurement	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Dump Trucks	272	--	272	227	183	139	139	139
Crawler Tractors	14	--	14	14	14	13	11	10
Motor Graders	74	--	74	74	74	74	74	74
Front-End Loaders	25	--	25	25	25	19	13	13
Rollers (over 5-ton rating)	13	4	17	17	17	17	17	17
Crushing/Screening Plants (50 TPH units)	10	--	10	10	10	10	10	10
Air Compressors (Equiv. 600 CFM units)	21	--	21	21	17	14	11	11
Wagon Drills	6	--	6	6	6	5	5	5
Asphalt Distributors	8	--	8	8	8	8	8	8
Asphalt Relay Trucks	2	--	2	2	2	2	2	2
Asphalt Kettles	52	15	67	67	61	55	49	49
Aggregate Spreaders	8	--	8	8	8	8	8	8

by feasibility studies which included calculations of their future maintenance costs. The obligation to preserve these roads was clear.

Fourteen future projects remained in question, and a check was made to see what maintenance cost they would add to the total for all candidate roads, by years. This was found to range from 0.78 percent to 2.35 percent, with an average over the five years of 1.59 percent.

All such projects were part of approved programs of the Direct Labor Construction Branch. Most were related to farm development and national integration. Construction had begun on numerous sections. Considering their minimal addition to total program costs, it was not considered logical to exclude them from IHA maintenance responsibility.

Considering all the facts, it is recommended that:

1. The IHA continue maintenance of all routes and sections now under its jurisdiction, as listed in Exhibit III-D of the Engineering Appendix.

2. The IHA undertake the future maintenance of all project sections shown in Exhibit III-E of the same appendix.

An alternate program level at 25 percent less than the above total was considered in the study, as required by the contract. However, it can be shown that if all the programmed future length were to be rejected for maintenance it would decrease the 1977/78 program cost by only 13.4 percent. If, in addition, the existing system were to be limited to only the primary highways and major secondary routes, discarding all spurs and side roads and all low-traffic feeder and minor access roads, the cost would only be reduced by another 5.0 percent. Together, these two drastic measures could only effect a saving of 18.4 percent. To achieve an alternative budget level 75 percent of that recommended would require elimination of some major, arterial route sections. It was concluded that this was not a realistic possibility, and that there was little purpose in attempting to establish which primary road sections might be abandoned.

I. Recommended Rehabilitations

The procedure outlined in Section VII indicates that candidate rehabilitations were ranked by a process of computing how long it would take for the savings in VOC to repay the cost of doing the work. The number of years required was used, on the basis of judgment, to decide whether the work should be done. The conclusion reached was that four of the five candidate paved-road projects should be programmed, and five of the six projects analyzed on gravel roads.

In the opinion of the Consultants, the following candidate projects should be programmed and carried out, with the priorities and estimated costs shown:

RECOMMENDED REHABILITATION PROGRAM

Section	Net Project Length (km)	Estimated Cost, E$	Priority
Paved Routes			
Addis Ababa-Welkite	97.0	2,084,300	1st
Addis Ababa-Agrehiwot	106.6	3,433,800	2nd
Tendaho-Asseb	120.0	3,216,000	3rd
Addis Ababa-Debre Berhan	102.4	4,530,600	4th
Gravel Routes			
Tarmaber-Woldia	367	7,982,100	1st
Shashamane-Sodo	140	3,187,700	2nd
Shashamane-Kofole	101	2,221,500	3rd
Wondo-Kebremengist	140	3,023,200	4th
Jimma-Bonga Junction	105	3,169,800	5th

J. Resource Requirements

After developing program recommendation on the basis of economic priorities and financial capacities, a study was made of the resources which would be needed to carry out these programs. The basic elements were the numbers and types of equipment units, the labor forces, and the quantities of purchased materials. The probable costs of all these

elements were assembled, including those for equipment acquisitions. The foreign and local components of cost were then derived.

The procedures used in quantifying the separate physical resource needs for maintenance and rehabilitation were different in detail, but similar in fundamentals. In substance, the method was the reverse of that employed to obtain maintenance costs per kilometer by road types.

After the recommended road system was established it was possible to go back through the crew-day calculations to get the resources needed. The total kilometers of each type of road were added up; that is, all of Type 1-DF, all of Type 3-MR, and so on. Knowing the kilometers of each type, and having the tables of crew-days for the maintenance of each type, it was then possible to multiply total kilometers times the tabular annual rates to get total crew-days per year for all kilometers of that road type, by maintenance activities. The total crew-days for each specific activity were then summed for all road types. From that data could be computed the numbers of annual work-hours for each personnel classification and each type of machine, plus the quantities of materials.

This was done first for the existing (1972/73) system, by districts and then by system totals. For subequent years, only the system revisions were considered.

The computations of labor, equipment and material quantities were complex and voluminous. The processes are described in Report Section XI, and the detailed findings are presented in Exhibits XI-1 through XI-21 of that section. In general, these give the requirements by individual districts for each program year, plus totals. Labor needs are shown as both man-days and numbers of men in the various job classifications; equipment as work-days and numbers of machines of the different types. Materials are tabulated by type.

The combined program financial costs were previously given in Section I-G above. For the later purposes of program analysis, it was determined that approximately 21.5 percent of maintenance would be foreign costs, and the other 78.5 percent local. The recommended mix

of contract and force account work on rehabilitations would result in 23.1 percent foreign costs and 76.9 percent local.

K. Programs and Budgets

1. Scheduling of Maintenance Program

This was considered to be comprised of two separate parts; the maintenance of the roads through regular and periodic activities, and the production and stockpiling of materials in support of those activities.

a. Regular Maintenance

In view of the present condition of the road system, it is recommended that the procedures and levels of effort described in this report be instituted as soon as practical. It was apparent that not all of the necessary steps could be completed by the end of the fiscal year in which the study was conducted, but equipment procurement and personnel training should be put in progress at the earliest date.

It was considered unlikely that all preparations could be made by the beginning of Fiscal Year 1973/74, and perhaps not even by the mid-point of the year, in January 1974. The competing demands of the rehabilitation program would be severe during that initial period. Every effort should be made, however; delay would clearly result in further deterioration of the roads.

b. Materials Production

One serious impediment to putting the maintenance program in full force was the uncertainty regarding the best means of providing gravel surfacing for Type 3 and 4 roads. Section III-H of the report discusses a possible means of lowering gravel-road maintenance costs to more normal limits, by conducting an organized search for better natural materials. It was considered reasonable to expect that such a search should be successful in discovering granular materials to take care of some 65 percent of the total length of Type 3 and 4 roads. The

Consultants concluded, after extensive calculation, that the most logical course of action would be to proceed immediately with the acquisition of one 225 ton per hour crushing and screening plant, with its auxiliary equipment, and to simultaneously start a program of materials exploration and research along the principal gravel roads.

Regardless of the solution finally adopted for the principal gravel roads, there is the separate need for a large annual quantity of lower-quality (pit-run) material to maintain the Type 5 and 6 roads and asphalt-highway shoulders. This indicates the need for 8 or 9 crawler tractors, and the immediate provision of 8 is recommended for this program.

New equipment acquisitions in general are discussed later, but the majority of machine requirements for materials production cannot be quantified at this time. A supplemental procurement will have to be defined at a later date.

2. Scheduling of Rehabilitations

Because of the urgency of this work, it is recommended that this program be started in July, 1973, in all four of the districts involved, and be prosecuted continuously until its completion in about April of 1976. Compliance with this timing will depend on the provision of funds, the arrival of equipment, and the efficient marshalling of all resources, but the need to begin is compelling.

a. Work Programs

Exhibits XII-1 through XII-4 of Section XII offer a tentative scheduling of the necessary rehabilitation operations, with the force account and contract phases identified separately. Work should begin immediately on the preparation of such simple plans and standard specifications as would be necessary for the contract portions.

b. Materials

It is indicated in Report Sections VI and XI that large volumes of granular materials would be employed in the force account phases of the rehabilitation projects, as follows.

Crushed aggregate base	261,400 m^3
Processed select material for surfacing	661,300 m^3
Pit-run select material for subbase, base and surfacing	428,600 m^3

Plainly, it will not be possible for the IHA to produce these quantities with its own facilities. The Consultants recommend that the furnishing of these rehabilitation materials be advertised for bid, to be stockpiled at suitable locations. Preparations for these contract purchases should begin at once.

3. Comparisons of Existing and Required Resources

Possible revisions in maintenance staffing and the scheduling of capital expenditures for new equipment are indicated by comparing the quantified needs with existing resources in these two categories.

a. Personnel

Exhibit XII-5 (reproduced on the following page) presents figures on the labor force required in the first program year, 1973/74, to the extent that these needs are defined by the study procedures. The numbers of personnel are given separately for regular maintenance, rehabilitations, and materials production, and then in a combined total. Also shown are the numbers officially authorized (Maintenance Branch only) and those actually employed in the corresponding classifications for the current year, 1972/73.

Obviously, the total initial requirements will be somewhat reduced as the rehabilitation projects are completed. The regular maintenance forces, however, will have to increase gradually as the system grows. The latter changes can be seen on Exhibit XI-10 of Report Section XI.

b. Equipment

Exhibit XII-6 (see following page) is a compilation of all relevant data on equipment, as viewed by the Consultants. The requirements by types are presented, separately for the different programs and for each of the five years 1973/74 through 1977/78.

EXHIBIT XII-5

COMPARISON, TOTAL IHA MANPOWER REQUIREMENTS FOR 1973/74 WITH EXISTING PERSONNEL, 1972/73

Position	Requirement				Authorized Force	Deficiency or (Excess)	Present Staff	Deficiency or (Excess)
	Regular Maintenance	Rehabilitation	Materials Program	Total				
Construction Foreman	17	5	0	22	4	18	9	13
Labor Foreman	108	10	15	133	197	(64)	145	(12)
Mason Foreman	8	0	0	8	9	(1)	5	3
Mason II	23	0	0	23	71	(48)	43	(20)
Mason I	40	0	0	40	--	40	--	40
Laborer II	63	12	0	75	629	(554)	540	(465)
Laborer I	285	0	28	313	1,533	(1,220)	1,358	(1,045)
Contract Laborer	618	64	66	748	--*	--	1,885**	(1,137)
Crusher Operator	0	0	12	12	48	(36)	36	(24)
Grader Operator	74	16	0	90	102	(12)	95	(5)
Dump Truck Driver	162	66	20	248	362	(114)	261	(13)
Truck Driver	20	0	0	20	9	11	6	14
Water Truck Driver	19	12	0	31	12	19	9	22
Roller Operator	42	24	0	66	62	4	26	40
Asphalt Distributor Operator	6	0	0	6	6	--	6	--
Asphalt Relay Truck Operator	6	0	0	6	7	(1)	6	--
Dozer Operator	6	8	22	36	19	17	19	17
Loader Operator	48	14	18	80	52	28	24	56
Quarry Supervisor	0	0	7	7	0	7	0	7
Quarry Foreman	0	0	11	11	17	(6)	13	(2)
Driller I	0	0	8	8	17	(9)	6	2
Powder Man	0	0	7	7	44	(37)	7	--
Helper I	0	0	5	5	--	5	--	5
Helper II	62	16	8	86	120	(34)	110	(24)

*Authorized "as needed"
**Average during year

EXHIBIT XII-6

COMBINED EQUIPMENT REQUIREMENTS
MAINTENANCE REHABILITATION AND MATERIALS PROGRAMS
Fiscal Years 1973/74 Through 1977/78

	Motor Grader	Dump Truck	Loader	2-1/2 Ton Truck	Roller	Water Truck	Crawler Tractor	Asphalt Heater	Asphalt Distributor
1973/74									
Requirements									
Maintenance	99	212	60	23	53	22	8	17	9
Rehabilitations	16	66	14	0	24	12	8	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/0	227/0	25/0	0/0	17/0	0/0	14/0	67/0	8/0
Deficiency or (Excess)	41	71	67	23	60	34	17	(50)	1
Recommended Purchase	40	70	65	15	60	30	15	0	1
1974/75									
Requirements									
Maintenance	103	225	64	27	61	29	8	20	10
Rehabilitations	12	66	14	0	24	12	6	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	183/70	25/65	0/15	17/60	0/30	14/15	61/0	8/1
Deficiency or (Excess)	1	58	6	12	8	11	0	(41)	1
Recommended Purchase	0	40	6	10	0	0	0	0	1
1975/76									
Requirements									
Maintenance	106	232	70	28	65	25	8	21	10
Rehabilitations	9	40	14	0	10	8	2	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/110	19/71	0/25	17/60	0/30	13/15	55/0	8/2
Deficiency or (Excess)	1	43	12	3	(2)	3	(3)	(34)	0
Recommended Purchase	0	10	12	0	0	0	0	0	0
1976/77									
Requirements									
Maintenance	105	236	79	29	68	24	8	21	10
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/120	13/83	0/25	17/60	0/30	11/15	49/0	8/2
Deficiency or (Excess)	(9)	(3)	1	4	(9)	(6)	(3)	(28)	0
Recommended Purchase	0	0	0	0	0	0	0	0	0
1977/78									
Requirements									
Maintenance	104	241	80	29	72	24	8	23	12
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/120	13/83	0/25	17/60	0/30	10/15	49/0	8/2
Deficiency or (Excess)	(10)	2	2	4	(5)	(6)	(2)	(26)	2
Recommended Purchase	0	0	2	0	0	0	0	0	2

EXHIBIT XII-6
(Continued)

	Asphalt Relay Truck	Aggregate Spreader	Conveyor	Compressor 600 C.F.M.	Wagon Drill	Crushing 225 T.P.H.	Screening Plants 50 T.P.H.	Truck Tractor and Trailer
1973/74								
Requirements								
Maintenance	9	9	0	0	0	1	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/0	8/0	0/0	21/0	6/0	0/0	10/0	7/0
Deficiency or (Excess)	7	1	4	(9)	6	1	0	0
Recommended Purchase	7	2	4	0	6	1	0	5
1974/75								
Requirements								
Maintenance	10	9	0	0	0	0	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/7	8/2	0/4	17/0	6/6	0/1	10/0	5/5
Deficiency or (Excess)	1	(1)	0	(5)	0	0	0	0
Recommended Purchase	1	0	0	0	0	0	0	5
1975/76								
Requirements								
Maintenance	10	9	0	0	0	0	10	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/8	8/2	0/4	14/0	5/6	0/1	10/0	3/10
Deficiency or (Excess)	0	(1)	0	(2)	1	0	0	0
Recommended Purchase	0	0	0	0	1	0	0	0
1976/77								
Requirements								
Maintenance	10	9	0	0	0	0	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/8	8/2	0/4	11/0	5/7	0/1	10/0	3/10
Deficiency or (Excess)	0	(1)	0	1	0	0	0	0
Recommended Purchase	0	0	0	1	0	0	0	0
1977/78								
Requirements								
Maintenance	12	11	0	0	0	0	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/8	8/2	0/4	11/1	5/7	0/1	10/0	3/10
Deficiency or (Excess)	2	1	0	0	0	0	0	0
Recommended Purchase	2	1	0	0	0	0	0	0

Following this, the existing fleet is shown, then the deficiency or excess of units, and finally the recommended procurement. The recommended purchase figures are intended to mean for delivery at the beginning of the fiscal year in which they are shown, to the extent that initial time and funding limitations will permit. For the years after 1973/74, the existing fleet is shown in two components, old and new. The "old" equipment is that shown in the appropriate-year columns of Exhibit VIII-20; that is, presently owned units (1972/73) expected to remain in service. The "new" equipment figures assume that the recommended acquisitions of prior years have been made.

c. Recommended Acquisitions

All of the recommended purchases are shown in Exhibit XII-7, by years, with the estimated unit prices and total procurement costs. An additional 15 percent is added for spare parts in each year's total. Exhibit XII-8 gives a summary for the five years. The two exhibits are reprinted on the following page.

4. Emergency Procurement

All of the equipment needs defined above would seem to fit the definition of "Urgent", but in view of the large capital cost for the initial year there may be a need to establish relative priorities.

The existing IHA-maintained highway system (1972/73) is generally in a deteriorated state, as established by the condition ratings of the individual segments. Those sections with the poorest ratings were, by definition, taken to be the ones most urgently in need of attention, and were evaluated for rehabilitation. It follows, therefore, that the equipment needed to carry out the force account portions of the rehabilitation program should have the higher priority in the procurement scheduling. As indicated by Exhibit XII-6, the numbers of units for this work are at their maximum in the first year. The first priority purchases should therefore, be as follows.

EXHIBIT XII-7

RECOMMENDED EQUIPMENT PROCUREMENT UNITS
ESTIMATED PRICES AND TOTAL COST
(1972 E$)

Description	Total Units	Unit Price E$	Total Cost E$
1973/74			
Motor Grader	40	75,600	3,024,000
Dump Truck	70	60,000	4,200,000
Front End Loader	65	75,000	4,875,000
2.5 Ton Truck	15	27,000	405,000
Roller	60	51,500	3,090,000
Water Truck	30	75,000	2,250,000
Crawler Tractor	15	110,100	1,651,500
Asphalt Distributor	1	76,500	76,500
Asphalt Relay Truck	7	56,500	395,500
Aggregate Spreader	2	15,900	31,800
Conveyors	4	18,000	720,000
Wagon Drill	6	30,000	180,000
225 T.P.H. Crushing and Screening Plant	1	700,000	700,000
Truck-Tractor and Trailer	5	180,000	900,000
Subtotal			E$22,499,300
Spare Parts @15%			3,374,895
Total			E$25,874,195
1974/75			
Dump Truck	40	60,000	2,400,000
Front End Loader	6	75,000	450,000
2.5 Ton Truck	10	27,000	270,000
Asphalt Distributor	1	76,500	76,500
Asphalt Relay Truck	1	56,500	56,500
Truck Tractor and Trailer	5	180,000	900,000
Subtotal			E$ 4,153,000
Spare Parts @15%			622,950
Total			E$ 4,775,950

EXHIBIT XII-7
(Continued)

Description	Total Units	Unit Price E$	Total Cost E$
1975/76			
Dump Truck	10	60,000	600,000
Front End Loader	12	75,000	900,000
Wagon Drill	1	30,000	30,000
Subtotal			E$1,530,000
Spare Parts @15%			229,500
Total			E$1,759,500
1976/77			
Compressor, 600 C.F.M.	1	65,000	65,000
Subtotal			E$ 65,000
Spare Parts @15%			9,750
Total			E$ 74,750
1977/78			
Front End Loader	2	75,000	150,000
Asphalt Distributor	2	76,500	153,000
Asphalt Relay Truck	2	56,500	113,000
Aggregate Spreader	1	15,900	15,900
Subtotal			E$ 431,900
Spare Parts @15%			64,785
Total			E$ 496,685

EXHIBIT XII-8

SUMMARY
RECOMMENDED EQUIPMENT PROCUREMENT
Total Cost by Years in 1972 Ethiopian Dollars

Fiscal Year	Amount
1973/74	E$25,874,195
1974/75	4,775,950
1975/76	1,759,500
1976/77	74,750
1977/78	496,685
Combined Total Cost	E$32,981,080

Description	Units Needed	Unit Price	Total Cost (1973 E$)
Motor grader	16	75,600	1,209,600
Dump truck	66	60,000	3,960,000
Loader	14	75,000	1,050,000
Roller	24	51,500	1,236.000
Water truck	12	75,000	900,000
Crawler tractor	8	110,100	880,800
Subtotal			9,236,400
Spare parts @15%			1,385,500
Total			10,621,900

5. Budgets

Exhibit XII-9 (see following page) presents the combined recommended budgets by years resulting from the findings of this study. These annual budgets are separated into line items, derived in the manner discussed in the paragraphs below.

a. Ordinary Budget Request

Normal Maintenance Program

Personal Services. These figures were obtained by taking all labor hours for regular maintenance and applying the hourly rates given in Section III for the various classifications, including fringe benefits and desert allowance where applicable. The total hours computed provide for the production of all necessary aggregates and surfacing materials by the means used as a basis for estimating in the original costing procedures of Section III.

Equipment Rentals. This line item was computed by multiplying all machine hours required for maintenance and materials production times the hourly rental rates for the various equipment types, as established in Section III. The annual amounts are therefore intended to include depreciation, fuels and lubricants, repairs and servicing, and all other costs of equipment usage excepting operator's wages.

Materials. The budget amount for this time covers the purchase of materials, especially bitumens, from outside sources, by contract or other means.

Others. This figure represents district-level overheads and other undistributed incidental costs, as defined in Section III, at 21.1 percent of the preceding categories.

Discrepancies in Totals. The annual budget totals for normal maintenance in Exhibit XII-9 are slightly different from the figures used in discussing funding requirements by years (Sections VIII and XI). This results from the use of engineering-based crew costs in one case and budgetary costs by fiscal categories in the other.

Emergency Rehabilitation. The annual amounts for the line items of this program were derived in a manner similar to that for normal maintenance, except that Contractual Services were added to cover work by contract, engineering supervision, and other engineering assistance from outside the Maintenance Branch. Some small arbitrary adjustments were made in the undistributed incidental expenses to make the totals by years agree with the figures given in earlier report sections.

b. Capital Expenditures

This budget category represents only the recommended annual procurements of equipment (plus spare parts), and the figures are taken directly from Exhibit XII-7.

c. Applicability of Budgets

It must be noted that the yearly amounts for normal maintenance in Exhibit XII-9 are founded entirely on the data and assumptions described in Section III of this study, and on the recommended road systems. Any change in these bases would result in altered budgets. The figures in the exhibit do not provide for small betterments, assistance to other agencies, or any activities not defined and quantified in the report. The final IHA maintenance budget for any year must be based on the

EXHIBIT XII-9

RECOMMENDED BUDGETS, IHA MAINTENANCE BRANCH
BY PROGRAMS AND FISCAL YEARS
(1972 E$)

Program and Item	1973/74	1974/75	1975/76	1976/77	1977/78	Total 5 Years
A. Ordinary Budget Request						
Normal Maintenance						
Personal Services	2,448,608	2,591,714	2,712,357	2,775,124	2,836,320	13,364,123
Equipment Rentals	18,091,408	18,604,893	19,136,095	19,182,553	18,883,124	93,898,073
Materials	2,097,502	2,351,892	2,553,684	2,686,203	2,902,138	12,591,419
Others*	4,776,516	4,968,733	5,148,851	5,199,859	5,195,154	25,289,113
	27,414,034	28,517,232	29,550,987	28,843,739	29,816,736	145,142,728
Emergency Rehabilitation						
Personal Services	400,032	417,343	106,615	--	--	923,990
Equipment Rentals	3,003,594	3,158,151	811,304	--	--	6,973,049
Materials	5,481,523	6,253,328	1,950,368	--	--	13,685,219
Contractual Services	4,495,749	2,216,168	287,429	--	--	6,999,346
Others*	1,861,902	1,880,794	524,752	--	--	4,267,448
	15,242,800	13,925,784	3,680,468	--	--	32,849,052
Subtotal, Ordinary Budget	42,656,834	42,443,016	33,231,455	29,843,739	29,816,736	177,991,780
B. Capital Expenditure Budget Request						
Equipment Acquisition	25,874,195	4,775,950	1,759,500	74,750	496,685	32,981,080
Total Budget Request for Maintenance Branch	E$68,531,029	E$47,218,966	E$34,990,955	E$29,918,489	E$30,313,421	E$210,972,860

*Overhead and undistributed incidental expenses.

programs which are actually adopted, with the real numbers of personnel employed, the equipment units to be operated, related materials, and the authorized capital expenditures.

L. Benefits of Improved Maintenance

Although the analysis used in Section V to establish priorities for maintenance was a hypothetical exercise, genuine economic benefits would result from applying the maintenance standards described in this report to the recommended highway system. The quality of the travelway surfaces would be improved on most of the highways, and vehicle operating costs would be reduced.

In Report Section V, relationships are established between road condition ratings and VOC. The levels of maintenance effort recommended in the study were designed specifically to preserve each road type in its standard state. The total potential user savings for the system are represented by the difference in total VOC between the existing (1972/73) condition and the condition to which the roads would be returned by adequate maintenance.

The costs of recommended maintenance would be higher than past and current expenditures for the present road system. This differential is the cost of obtaining the benefits. The only year in which it is possible to make a direct comparison of costs and benefits is the current year, with the roads in their observed condition. However, in order to derive a stream of net benefits by years, in the normal manner for economic analysis, it is logical to establish a comparative base by projecting current expenditures per kilometer for the pertinent road system, and assume that this will continue to cause equivalent sub-normal conditions on the roads. Sets of annual savings and costs can then be quantified, and the net differences converted to present worth.

1. Determination of User Savings

The benefits which can be derived from the implementation of the Consultants' recommended maintenance program are expressed in terms of reduced vehicle operating cost. As described in Section IV,

each segment of road was rated as to existing condition. Vehicle operating costs for each surface type and condition were derived in Section V. Adoption of the recommended maintenance practices would result in all roads being returned to their best condition, or being preserved in that state. Consequently, the vehicle operating costs for any segment in sub-normal condition would also be reduced by some range of values. The net system reduction in VOC represents the benefits of the recommended maintenance program. These benefits were calculated annually for the years 1972/73 through 1977/78. For each year the additional roads, changes in surface type and increasing traffic were taken into account. A stream of benefits was thus generated. Details of the method are given in the report.

2. Benefits from the Recommended Maintenance

The computer program to generate VOC savings by segment and for the total system is listed in the Economics Appendix, with the annual system totals presented in Exhibit XIII-2 (see following page). The results are shown at zero traffic growth and at the forecast traffic growth. The former is considered a "worst case" situation where traffic remains static. The predicted growth is about 6 percent annually, on a system basis. The exhibit includes the benefits which would occur if the recommended maintenance program were applied to the 1972/73 road system. This calculation is required as a point of reference for comparison and forecasting purposes.

Examination of the exhibit shows that the benefits decline annually, especially under zero traffic growth conditions. This is due to the fact that the new paved sections (new routes and former gravel), do not produce any benefits from improved maintenance, being always rated in condition one. The total savings do include the incremental VOC for new gravel roads because the present maintenance practices will not keep these roads in condition one. However, traffic volumes on the majority of these new gravel roads are low, and the total effect of such routes on the incremental VOC is minimal.

EXHIBIT XIII-2

ECONOMIC BENEFITS
FROM IMPROVED MAINTENANCE TOTAL
AND DISCOUNTED AT 10 PERCENT
(Thousands of 1972 E$)

Fiscal Year	Vehicle Operating Cost Savings			
	Zero Traffic Increase		Positive Traffic Growth	
	Total	Discounted	Total	Discounted
1972/73	18,817	18,817	18,817	18,817
1973/74	17,751	16,136	18,816	17,104
1974/75	16,438	13,578	18,460	15,248
1975/76	15,269	11,467	18,181	13,654
1976/77	13,187	9,007	16,642	11,366
1977/78	11,206	6,959	14,994	9,311
		75,964		85,500
Less 1972/73		18,817		18,817
Benefits, 1973/74-1977/78		57,147		66,683

3. Cost and Benefit Stream

The costs of obtaining the benefits shown in Exhibit XIII-2 are the annual differences between the Consultants' maintenance program costs and the projection of current IHA maintenance costs, assuming continuation of present operational conditions. The Consultants' costs were summarized by years in Exhibit VIII-18. They are repeated in Exhibit XIII-5 (see following page), together with a projection of IHA maintenance costs based on historical spending levels and the extent of the future system. It can be seen from the exhibit that the overall average cost of maintenance per km decreases over the years in both cases. This reduction is the result of an increasing proportion of paved surfaces in relation to high-type gravel roads, and the introduction into the system of more service-to-traffic and feeder roads.

Exhibit XIII-5 also shows the annual differences in financial cost of implementing the recommended program. These differences are in the range of 5.5 to 6.7 million dollars per year.

Exhibit XIII-6 (see page I-54) gives the annual cost and benefit stream for the years considered in the study, plus the present value of the net benefits to the IEG. As illustrated, the total present value of net benefits is E$53,200,000 for the period 1972/73 through 1977/78. These are the benefits which would be realized if the IHA could begin immediately to apply the recommended maintenance practices. This is an idealistic scenario. More likely, no significant improvement can be made during 1972/73. The total net benefits would therefore be reduced accordingly, to E$40.4 million for the five years 1973/74 through 1977/78, assuming that the program could be fully implemented in 1973/74.

M. Administrative Implementation

No large changes in the IHA administrative procedures are needed now to carry out the programs recommended in this study. Some added staffing at critical points could speed and improve the implementation.

The budgeting and accounting procedures are examined in Report Section XIV, plus some aspects of program funding.

EXHIBIT XIII-5

PROJECTED COST DIFFERENCE BETWEEN PRESENT AND RECOMMENDED MAINTENANCE PROGRAMS
(Financial Costs)

Year	Total kms of Road	Total Maintenance Costs (E$000) IHA*	Consultants	Difference
1967/68	6,826	16,020		
1968/69	6,836	16,780		
1969/70	6,848	16,983		
1970/71	7,024	18,866		
1971/72	7,257	19,054		
Forecast				
1972/73	7,355	20,373**	25,850	5,477
1973/74	8,046	21,086	27,243	6,157
1974/75	8,834	21,820	28,275	6,455
1975/76	9,289	22,573	29,303	6,730
1976/77	9,708	23,367	29,804	6,437
1977/78	10,296	24,183	29,844	5,661

*Includes Total Financial Costs for Equipment Use
**Source: IHA Cost Accounts Branch and Consultants' Analysis.

EXHIBIT XIII-6

NET BENEFITS OF
RECOMMENDED MAINTENANCE PROGRAM
(Thousands of 1972 E$)

Fiscal Year	Differential Maintenance Costs		Economic Benefits (A VOC)	Net Benefits	Present Value Net Benefits (@10%)
	Financial	Economic			
1972/73	5,477	6,025	18,817	12,792	12,792
1973/74	6,157	6,773	18,816	12,043	10,948
1974/75	6,455	7,100	18,460	11,360	9,388
1975/76	6,730	7,403	18,181	10,778	8,098
1976/77	6,437	7,081	16,642	9,561	6,530
1977/78	5,661	6,227	14,994	8,767	5,444
Total					53,200
Less 1972/73					12,792
Five-Year Net Benefits					40,408

*Financial to Economic Cost Factor = 1.1

The IHA budget process was reviewed in detail, including the planning, preparation and approval of the annual budgets, and the execution and control of programs was investigated. The latter took in the administrative and responsibility functions of program control, plus the general staffing and personnel factors.

A careful study was made of the accounting system--its past development, the expenditure records and reports now in use, and the present cost accounting system.

It was the opinion of the Consultants that some rather serious weaknesses exist in these administrative procedures. The evaluation is presented in Report Section XIV-C. The condensed recommendations for improvement are repeated below, and the details of the recommendations are to be found in Section XIV-D-2.

It is the view of the Consultants that as soon as circumstances permit the IHA should:

1. Develop budget proposals and monitor progress on the basis of a maintenance program designed to yield costed quantities of maintenance functions completed.

2. Upgrade the budget function to assure positive response to planning responsibilities.

3. Seek IEG authorization for special funding of repairs to roads damaged by unusually severe flood or slide conditions.

4. Establish a capitalized working fund for the receipt, custody and issue of materials, supplies and parts.

5. Provide organizational recognition of the fiscal systems functions within the Fiscal Services Division. Develop the function at a high level of experience and demonstrated competency.

6. Establish cost determination procedures to govern input of overhead costs and costs of production operations and service centers into the IHA cost accounts.

7. Design and institute a program analysis and reporting system within the Operations Division based on field input of resource utilization data and computer application of related pricing data.

8. Establish capability within the Operations Division to execute and monitor the program analysis operation.

The current provisions for recovery of equipment investment are discussed in Report Section XIV-E, with the conclusion that these funding procedures have not brought about replacement of equipment items at the expiration of their useful lives. It is believed that the IEG and IHA should consider alternatives to initiate a more orderly equipment acquisition program.

The requirements of a capital working fund were examined, and are treated in both the body of the report and in a special section of the Administrative Appendix. A modified version of such a fund is presented in Section XIV, identified as a "Capital Equipment Fund" (IEG). The Consultants recommend that the national government and the IHA consider the creation of a fund having the same general characteristics.

Section XIV-F of the report sounds a cautionary note on Ethiopia's debt service position and the impact of capital expenditures recommended in this study.

Section XIV-G discusses dedicated funds in general, and offers the opinion that there are special and persuasive arguments for insuring that highway agencies have known and predictable sources of funds.

N. Engineering Implementation

Road maintenance in Ethiopia is functioning well considering the limited resources available and the great geographic obstacles which exist. Various measures would help to improve efficiency, and other steps will have to be taken to carry out the recommendations of this report.

1. First in order of importance, the administrative staffing for maintenance should be strengthened to give it a better chance of controlling and implementing programs.

It is recommended that a full-time authorized position be established to provide the Chief Maintenance Engineer with an office engineer assistant who would deal with the large volume of reports, correspondence, data assembly, and work program preparation necessary to maintenance administration. At least one clerical aide should also be authorized.

If the Area Engineer now stationed in Asmara fills an important role in the supervisory chain for maintenance, then this position should not be disturbed. It is recommended, however, that in addition to this individual, or in lieu of the Area Engineer scheme, the Chief Maintenance Engineer be provided with an assistant engineer for field operations. The duties of such a field engineer are described in the report.

2. Improvement is desirable in the flow of information within maintenance; outward in the form of clear instructions and policies, inward as accomplishments and costs are reported.

3. Maintenance practices in Ethiopia were found to be based on sound, established methods. Only three specific problems of general scope are commented on in the report (Section XV-A-3).

4. Regarding overall maintenance supervision and methods, the Consultants did not identify any areas where technical assistance was required. It appeared that it might later be very useful to organize some "Pilot Programs" with professional guidance by Consultants. Work-training projects on representative asphalt and gravel roads could be set up in selected districts and observed by supervisors and operators from adjacent districts. Such demonstrations would have to wait until adequate equipment was on hand.

5. Responsibility for local roads of low standards is a subject of growing concern in Ethiopia. Some of the legal and technical aspects are discussed in Report Section XV-A-5. In the opinion of the Consultants, minor roads and access routes should be under the jurisdiction of local governments. Authority and sources of revenue would have to be provided by the IEG. The IHA responsibility should be limited to technical assistance. The report presents a rudimentary basis for estimating maintenance costs on seasonal roads and trails.

6. With respect to equipment use and repair, minor reorientation of operator training is suggested, and greater emphasis on equipment servicing and inspection. Continued improvement is expected in shop repairs and machine availability but better spare parts management will be a critical need.

7. Equipment standardization is the subject of Report Section XV-C. Analysis showed that essentially the IHA has only two makes of motor graders, two of crawler tractors, and four of dump trucks. Other units have come from more sources, but not excessively. The variety of makes is not extreme for a fleet the size of the IHA's, and there are only limited opportunities for greater standardization.

8. One crucial need to implement the recommended maintenance program is a materials search and improved production. An exploration program is briefly described in Section XV-E, with an estimated cost of E$211,500.

O. Estimated Additional Benefits

The scope of work for the road maintenance study called for an evaluation of benefits which might be realized by postponing maintenance and rehabilitations. It was the conclusion of the study that such postponements would result in disbenefits rather than savings. It was not found practical to quantify these absolutely in economic terms.

Prior deferment of maintenance on the roads has led to the present need for restoration of the surfaces, at exceptional costs. High vehicle operating costs have also been imposed on the public. It is not likely that the savings in maintenance expense have been sufficient to outweigh these two factors. Further deferral of maintenance can be expected to cause diversions or reductions of traffic and increases in freight charges. While these effects are not quantifiable they are obviously adverse in their nature.

The postponement of rehabilitations would result in constantly rising costs for the eventual repairs, estimated at about 25 percent per year. Abnormal and increasing vehicle operating costs would apply until the work was done. The breakeven periods for the recovery of the rehabilitation costs, now mostly favorable, would become excessively long.

The effects of increased equipment availability were examined, and a revised acquisition schedule explored, based on a 75 percent

availability factor. No great saving was considered to be possible because most of the equipment purchases (over 78 percent) are necessary in the first program year. Capital outlays could be reduced somewhat for 1974/75 and later years by improved machine servicing, parts supplies and so on.

Exhibit XVI-1 (see following page) shows a revised equipment scheduling with the 65 percent factor used in 1973/74 and the higher (75 percent) availability for the succeeding years. This table can be compared with the earlier Exhibit XII-6, for the most common equipment types.

With the quantities remaining unchanged for 1973/74, the tables display significant differences for the years 1974/75 through 1977/78:

1. The number of graders required drops from 103 to 86 in 1974/75, and changes little after that.

2. The fleet requirement and deficiency for dump trucks would decrease by 32 units in 1974/75, so that purchase of 26 trucks would meet the full needs.

3. The recommended provision of 65 new front-end loaders for 1973/74 would give a surplus of 2 the next year, instead of a shortage of 6.

4. Exhibit XII-6 called for 25 cargo trucks (2-1/2 ton) to be procured for the five years, and this left continuing shortages in all years. A 75 percent availability would permit all needs to be met (after 1973/74) by the purchase of only 22 units.

5. Provision of sufficient rollers in the first year again results in excesses through the final 3 years, and in greater numbers.

6. A similar situation exists for water trucks, with no reduction possible in capital costs and excess numbers resulting from better equipment maintenance over the years.

7. The acquisition of crawler tractors would be unchanged, but the 75 percent factor would cause excess numbers to occur one year earlier and continue in somewhat greater numbers.

EXHIBIT XVI-1

REVISED PARTIAL EQUIPMENT REQUIREMENTS FOR MAINTENANCE, REHABILITATION AND MATERIALS PROGRAMS BASED ON 65% AVAILABILITY FACTOR FOR 1973/74 AND 75% FOR SUBSEQUENT YEARS

Description	Motor Grader	Dump Truck	Leader	2-1/2 Ton Truck	Roller	Water Truck	Crawler Tractor	Asphalt Distributor	Asphalt Relay Truck
1973/74									
Requirements:									
Maintenance	99	212	60	23	53	22	8	9	9
Rehabilitations	16	66	14	0	24	12	8	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/0	227/0	25/0	0/0	17/0	0/0	14/0	8/0	2/0
Deficiency or (Excess)	41	71	67	23	60	34	17	1	7
Recommended Purchase	40	70	65	15	60	30	15	1	7
1974/75									
Requirements:									
Maintenance	86	193	56	20	50	19	5	6	6
Rehabilitations	12	66	14	0	24	12	6	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	183/70	25/65	0/15	17/60	0/30	14/15	8/1	2/7
Deficiency or (Excess)	(16)	26	(2)	5	(3)	1	(3)	(3)	(3)
Recommended Purchase	0	26	0	5	0	0	0	0	0
1975/76									
Requirements:									
Maintenance	88	198	61	21	54	20	5	6	6
Rehabilitations	9	40	14	0	10	8	2	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/96	19/65	0/20	17/60	0/30	13/15	8/1	2/7
Deficiency or (Excess)	(17)	23	9	1	(13)	(2)	(6)	(3)	(3)
Recommended Purchase	0	0	5	1	0	0	0	0	0
1976/77									
Requirements:									
Maintenance	89	202	63	22	55	19	5	7	7
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/96	13/70	0/21	17/60	0/30	11/15	8/1	2/7
Deficiency or (Excess)	(25)	(13)	2	1	(22)	(11)	(6)	(2)	(2)
Recommended Purchase	0	0	0	1	0	0	0	0	0
1977/78									
Requirements:									
Maintenance	87	206	65	22	58	18	5	8	8
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/96	13/70	0/22	17/60	0/30	10/15	8/1	2/7
Deficiency or (Excess)	(27)	(9)	0	0	(19)	(12)	(5)	(1)	(1)
Recommended Purchase	0	0	0	0	0	0	0	0	0

8. Improved availability of the asphalt distributor trucks and relay trucks would allow these acquisitions to be decreased by three units each, according to the tables. The feasibility of this full reduction was open to some question, considering the age and condition of the existing distributors and the practicality of shuttling them long distances for work scheduling.

Utilizing the foregoing comparison, and adjustments in purchases as described in Report Section XVI, the achievement of a 75 percent availability factor through better equipment repair and servicing would permit a reduction of capital costs as shown below:

Description	Units Eliminated	Unit Cost	Total Cost Reduction (1972 E$)
Dump Truck	24	60,000	1,440,000
Loader	15	75,000	1,125,000
2-1/2 Ton Truck	3	27,000	81,000
Asphalt Distributor	3	76,500	229,500
Asphalt Relay Truck	3	56,500	169,500
Total			3,045,000

The potential benefits from reduced material costs were quantified. A successful search for better natural materials would substantially lower the maintenance costs for Type 3 and 4 roads; the costs for other road types would not be significantly affected.

If the materials program recommended in Section XII-A-2 were to be adopted and the described results achieved, then the composite unit cost for the required surfacing would be approximately E$4.80 per m^3. Both the E$9.67 of the basic maintenance estimates and the above E$4.80 include overheads at the time of production so the difference of E$4.87 can be used directly in computing potential savings.

Exhibit XI-21 of the report shows the annual quantities of processed select material required, and these amounts reflect the changes in

kilometers of Type 3 and 4 road, year by year. Therefore, the system-wide cost savings by years are derived as follows:

Year	Quantity (m^3)	Savings (E$000)
1972/73	850,367	4,141
1973/74	863,494	4,205
1974/75	835,839	4,070
1975/76	815,908	3,973
1976/77	779,093	3,794
1977/78	680,284	3,313

The above financial cost reductions are converted to economic cost differences by again applying the factor of 1.1. The resulting figures represent the added annual maintenance benefits from the proposed materials program. These, and the corresponding present values, are given in Exhibit XVI-2 (see following page). Once more, the benefits shown for 1972/73 cannot be realized, and they are deducted from the total.

It must be noted that the benefits indicated in the exhibit can only be obtained by expenditures which have not been taken into account, both for the exploration and for the acquisition of further equipment. However, the unadjusted benefits as shown in Exhibit XVI-2 indicate a potential increase of more than 40 percent over the basic benefits of the recommended maintenance program.

EXHIBIT XVI-2

ADDITIONAL NET BENEFITS OF PROPOSED MATERIALS PROGRAM
(Thousands of 1972 E$)

Year	Financial Savings	Economic Benefits*	Present Value of Benefits at 10%
1972/73	4,141	4,555	4,555
1973/74	4,205	4,626	4,205
1974/75	4,070	4,477	3,700
1975/76	3,973	4,370	3,283
1976/77	3,794	4,173	2,850
1977/78	3,313	3,644	2,263
TOTAL			20,856
Less 1972/73			4,555
Five-Year Net			16,301

* Financial Savings times 1.1

Section II

IHA ORGANIZATION

A. Introduction

Article III of the Contract Provides that the Consultants shall identify and recommend any organizational changes that should be introduced in order to improve the efficiency of road rehabilitation and maintenance. To assimilate historical and background information, the Consultants carefully reviewed the following reference material:

1. The Organization and Management of the Imperial Highway Authority; A Survey Report for IBRD by the Public Administration Service - October 1966.
2. Ethiopia General Road Study (Draft Final Report); Vol. 5, Chapter II prepared by Rendel, Palmer and Tritton, Consulting Engineers, and the Economist Intelligence Unit, Ltd. November 1969.
3. Various other manuals developed by the Public Administration Service in cooperation with the staff of the Imperial Highway Authority.

It is appropriate to state here that the Consultants found the background material to be very complete and informative. The conclusions concerned with organization structure and alignment of functions appeared to be well-considered. The Consultants were in almost total agreement with the basic organizational changes which were recommended by the Public Administration Service. However, as the IHA's program and professional strength evolves, it is believed some additional organizational improvements should be considered. These will be discussed in later paragraphs.

Following the review of the available reference material, the Consultants interviewed key officials and staff of the IHA both in the Central Office and representative District Offices. These discussions included, but were not limited to:

- Delegations of Authority
- Staff and Line Authorities
- Staff and Line Responsibilities
- Staff and Line Inter-relationships
- Logistics Support
- Suggestions for Improvement

The Consultants found all of the IHA officials and staff very cooperative in this effort and the information obtained was helpful in understanding the available reference material, the current situation, and the problems which appear to exist.

In the task of evaluating the IHA organization structure, the position was taken that no changes should be recommended unless it was believed they were essential and would result in major improvement of the organizational effectiveness related to highway maintenance and rehabilitations. This basic position and philosophy was adopted in recognition of the fact that almost since its creation, the Imperial Highway Authority has been suffering the pains of growth, development, organization and reorganization.

This has been particularly true since 1964, at which time the intensive study of IHA's organization and management was initiated. As a result of that study a major reorganization was implemented in 1970, and this was followed by continuing significant changes in policies and procedures. It was inescapable that this would have a disruptive impact on day-to-day operations and interpersonal relationships. For these reasons, the Consultants have approached the consideration of any further organizational change with caution.

B. Office of the Chief Engineer

This discussion relates only to the immediate office of the Chief Engineer, and specifically does not include the Operations Division, covered in later paragraphs.

Obviously the Office of the Chief Engineer is one of the single most important organizational elements of the IHA, since it is in effect the

"program execution" wing of IHA, including as it does the, (1) Operations Division, (2) Design Division, and (3) Contract Construction Division. This structure is shown graphically in Exhibit II-1. The Office has an extremely important responsibility in the overall direction, supervision and coordination of these three large divisions.

It is the Consultants' judgment that at present the Office of the Chief Engineer is not adequately staffed and organized to carry out the important role it has been assigned. The authorized staffing includes an Office Engineer, a Secretary, and clerical staff as required. When the study was initiated the Office Engineer position was filled by an American expatriate, who left the IHA in June, 1972. An Ethiopian Engineer had been working with the Office Engineer, as an "understudy" and assistant. In addition, there was a Secretary and a Driver. No other engineering, technical or administrative staff were identified.

It is apparent that the Chief Engineer, in these circumstances, cannot adequately administer, coordinate and monitor the wide-spread operations under his jurisdiction. Frequent consultations and contacts with the General Manager and other staff officials are called for, certain "external" contacts cannot be avoided, a considerable amount of travel to the Districts and construction projects is desirable, and frequent day-to-day contacts with his Division Chiefs are absolutely essential. In addition, there are numerous engineering reports, documents, and correspondence that should be reviewed and acted upon.

The expatriate Office Engineer did not have any significant formal delegations of authority or responsibility, and actually served more in the nature of a "general assistant" or expeditor. The Office has no administrative or clerical staff to review such administrative documents as budget estimates, payroll data, supply requests, cost reports, etc.

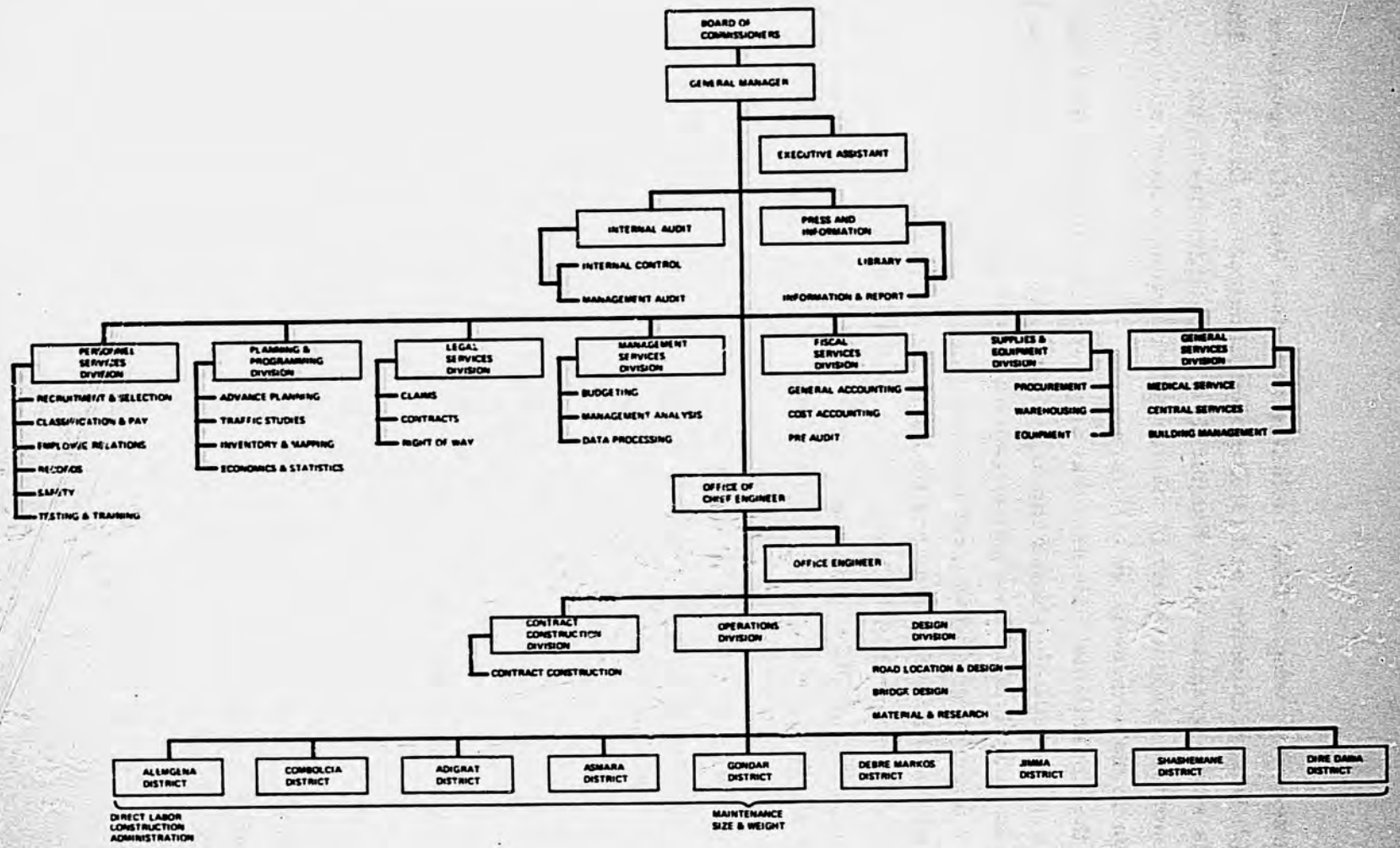


EXHIBIT II-1 IMPERIAL HIGHWAY AUTHORITY FUNCTIONAL ORGANIZATION, EXISTING JUNE, 1972

Recommendations

It is recommended that the Office Engineer should be assigned specific responsibilities and corresponding authority. His role should include, but not be limited to: continuing liaison with the Planning and Programming Division regarding normal programs plus changing priorities and emergency requirements; coordinating and scheduling with the Division Chiefs on route studies, location surveys, materials investigations, preliminary and final design and preparation of estimates; scheduling of advertising, progress schedules on all work underway, and compliance with those schedules; review of all engineering reports and documents requiring the Chief Engineer's approval. In summation, the Office Engineer should in effect be the nerve center and control point in the coordination, continuity scheduling and follow-up of all work which flows to and from the divisions in the Office of the Chief Engineer. It is also expected that he would maintain continuing liaison with the Legal Services Division in matters concerning right-of-way acquisition and contract claims.

It is further recommended that a small office unit be added to the Office of the Chief Engineer consiting perhaps of an Account Clerk III, a Clerk II and a Clerk-Typist I. This small unit should serve primarily for handling the numerous administrative and fiscal documents that must flow in both directions between the Office of the Chief Engineer and its three divisions. It is emphasized that the recommended office unit in the immediate Office of the Chief Engineer should not duplicate work done at the division level, but rather should monitor "due dates" and deadlines, review material for general adequacy and completeness, bring questionable material to the attention of the Office Engineer, and consolidate material from the Divisions as required.

C. Operations Division

Exhibit II-2 (see the Administrative Appendix) reflects the existing (June, 1972) organization structure of the Operations Division; its internal "line" and "staff" relationships; and its external relationships with the other Divisions and elements of IHA. The Consultants wish to emphasize that Exhibit II-2 has been prepared on the basis of the IHA Administrative Manual, the IHA Manual of Organization Charts and the Operations Division Technical and Administrative Procedures Manual (which includes well-prepared position descriptions for most of the key positions in the Operations Division). The point to be brought out is that, while the structure itself is accurate, some of the line and staff relationships are, in actual practice, not rigidly followed. Actually this is fortunate, because reference to the exhibit shows that the District Engineers are subject to direct line authority from five officials in the headquarters Operations Division:

Operations Engineer (Operations Division)
Maintenance Engineer (Maintenance Office)
Construction Engineer (Direct Labor Construction Office)
Bailey Bridge Engineer (Direct Labor Construction Office)
Supervisor Clerical Service (Clerical Services Section)

In addition, the District Engineer is in the awkward position of having his "Office Unit" subject to direct technical supervision from the supervisor of Clerical Service in the headquarters Operations Division.

The District Engineer's administrative authority is further complicated (and diluted) by the fact that three of the "professional staff specialists" in the headquarters Operations Division, the Quarry Supervisor, the Size and Weight Engineer and the Asphalt Engineer, are officially (in their position descriptions) given strong "staff" authority over their respective counterpart activities in the Districts.

While Exhibit II-2 displays a complex and almost unworkable web of authorities, in function it isn't as bad as it looks. Admittedly, some of the District Engineers feel they have "too many bosses" but on the other hand

it seems that the various supervisors and staff specialists in headquarters recognize that they are only representatives of the Operations Engineer. It appears that this attitude varies considerably from man to man, but it is appropriate to single out, and compliment, the Chief Maintenance Engineer (who is of particular importance in this study) as one staff official who is making every effort to respect the integrity of the District Engineer's position. In other words, the Maintenance Engineer understands the full meaning of the "staff" concept and tries to practice it notwithstanding the "line" authority he is given through his position description and delegated authority.

The Operations Division is vested with functional responsibility for all of the following activities:

1. Highway and structure maintenance
2. Direct labour construction
3. Quarry and crusher operations
4. Provincial and other cooperatively-funded local roads (as specifically authorized)
5. Signs and markings
6. Size and weight control

In addition, Operations has line responsibility for insuring the coordinated execution of these programs through the District Engineers. It follows then that the Operations Division must be organized to provide the necessary staff specialists in the various areas of functional concern. The only other alternative would be to provide such professional staff in each District, and obviously this is unrealistic.

Accordingly, it is the judgment of the Consultants that the problem which exists with respect to the Operations Division is not one of organization, but rather its line and staff relationships with the districts.

Recommendations

It is recommended that only the head of the Operations Division have line authority over the District Engineers. On this basis all other professional staff in the Operations Division should be limited to staff authority in their relationships with the District Engineers.

To accomplish this change several actions should be taken:

1. The IHA administrative Manual, page A.M. No. 155.10 should be revised under 155.12 to read --

   "Authority - The Professional Staff is limited to the exercise of staff authority over field operations. This staff authority is exercised in behalf of the Operations Engineer and shall extend to include coordination of field activities, providing technical leadership, guidance, consultative assistance and monitoring for compliance with prescribed policies, standards and procedures."

2. The "Operations Division Technical and Administrative Procedures Manual," which contains the position descriptions for the principal positions in the Division, should be screened and revised to make the minor changes that are necessary to change the authority of the professional staff specialists from "line" to "staff." The supervisor of the Clerical Services Office can make these changes with very little time and effort.

3. A formal notification should be prepared by the Operations Engineer to his professional staff and the District Engineers advising them of the change, including an expression of his concept of the relationships his professional staff should have with the District Engineers. For example, he should point out that, within their functional areas, the professional staff specialists are acting for and in behalf of the Operations Engineer in providing leadership, technical guidance, assistance in resolving technical problems, and evaluation of compliance with technical policies, standards and procedures, but not in the sense of directing or supervising work operations.

The above recommendation should not be viewed as any major change. Some of the professional staff in the Operations Division are practicing these principles now. The change is intended to formalize a relatively simple change in attitudes and relationships between the District Engineers and the

staff of the Operations Division. Exhibit II-3 reflects the recommended change (see Administrative Appendix).

A recommendation appears later in the report under the heading "Operations Planning Engineer" which relates very closely to the work of the Operations Division.

D. District Offices

Exhibit II-3 referred to above reflects, in the lower portion, the existing structure of the IHA District Offices. In the design of the organization structure as recommended by PAS, it was planned that each District would be headed by a professional engineer and that there would be a second engineer in each District who would serve as the Assistant District Engineer and also supervise Maintenance Operations. Unfortunately, the shortage of professional engineers in IHA has made it impossible to meet this staffing plan. As of June, 1972, only three District Engineers were in fact professional engineers, and none of the Districts had been assigned the second, lower-grade, engineer.

As a temporary solution to the District staffing problem, a new position of "Maintenance Superintendent" has been added to the District organization structure. In the larger Districts a second or third maintenance superintendent has been informally added as deemed necessary.

The Consultants concur with the original PAS recommendation that each District be headed by a professional engineer, and that eventually a second professional engineer be assigned as the "assistant." However, the alternate solution adopted by IHA is both logical and realistic.

Officials of the Central Office Operations Division have expressed their belief that the district operations could be improved considerably by the creation of one or more "Maintenance Sub-Districts" in most, or all, of the districts. This is because of the geographic remoteness of any maintenance sections (and section camps) from the district headquarters. This geographic separation is felt in several ways: distance in terms of kilometers, sometimes amplified by the standard and condition of the roads and

by weather; difficulty of communications; infrequency of technical guidance and direction; and the length of the all-important "supply-line" for equipment repair service, parts replacements and other requirements.

The Consultants believe all of the above are valid problems and that they justify serious consideration of the proposal that small "Sub-District" stations be created.

Recommendations

It is recommended that the IHA make every possible effort to place well qualified professional engineers in the positions of District Engineers, with the possible exception of any unusually qualified and outstanding men who have demonstrated their full capacity to handle all aspects of the position.

Once the District Engineer positions have been satisfactorily filled, it is recommended that priority be given to placing professional engineers in the Assistant District Engineer positions. Consideration might well be given to placing young engineers who are in IHA's "Engineers-in training" program in these positions for a period of approximately six months as a regular part of their rotational training.

It is recommended that on a conservative and selected basis, "Maintenance Sub-Districts" be created in those large districts where one or more of these units are justified in remote locations. When such Sub-District stations are created it is recommended that they be headed by a "Maintenance Superintendent" on a "resident" basis and that one or two "General Foremen" be assigned to assist him in supervising the Section Foremen who are in charge of the maintenance sections.

It is further recommended that each such Sub-District station be staffed with an all-purpose clerk (Clerk II level), a Clerical-Aide and one or two men of appropriate mechanical level to service equipment and make minor emergency repairs that can be made with hand tools. The specific position types and grade levels for the equipment repair activities should be determined after careful consideration jointly by the District Engineer and the District Shop Superintendent, and should be subject to a certain flexibility depending on the complement of equipment that may be assigned to the Sub-District at any given time.

Exhibit II-4 reflects the organization structure of the Districts as they would appear in cases where Maintenance Sub-Districts are authorized.

E. Existing Supply and Equipment Division

When the IHA reorganized in early 1970, in general accord with the recommendations of the PAS, a major change was made in the management and administration of all phases of the equipment and supply function, including procurement and both central Office and field operations.

For a period of about 14 years before the reorganization, the administration and operations of the equipment and supply functions were fragmented.

Procurement was under the Director of Administration. The Parts and Supplies Division, which operated the Central Warehouse, reported to the Chief Engineer. The Equipment Division reported to the Chief Engineer, and was responsible for writing specifications for new equipment purchases, the assignment of equipment, the operation of the Central Shop, field inspections of equipment and facilities, and property and cost recording. The District Equipment Repair Shops and District Warehouses reported directly to the District Engineers.

It is reported in the PAS study report that once equipment was assigned, it passed from the control of the Equipment Engineer (the head of the Equipment Division). It was further stated in the PAS report that, "...about 25 percent of the fleet is deadlined for repair and over 20 percent is in storage. Equipment problems constitute one of the major problems in the maintenance of the highway system and in the construction of new roads by direct labor." And again, later, "The effectiveness of equipment management is reduced due to lack of coordination among Procurement, Supply, and Equipment Maintenance Operations; due to inadequate repair facilities and personnsl; and due to misuse and abuse of equipment. Equipment shorages are critical."

It is clear that, on the basis of the PAS findings, drastic action was mandatory. The proposed solution, (stated in over-simplified terms) which was adopted by the IHA was to put all procurement and equipment and supply functions - management, administration and operations, both office and field - within a single Supply and Equipment Division in the Central Office, reporting

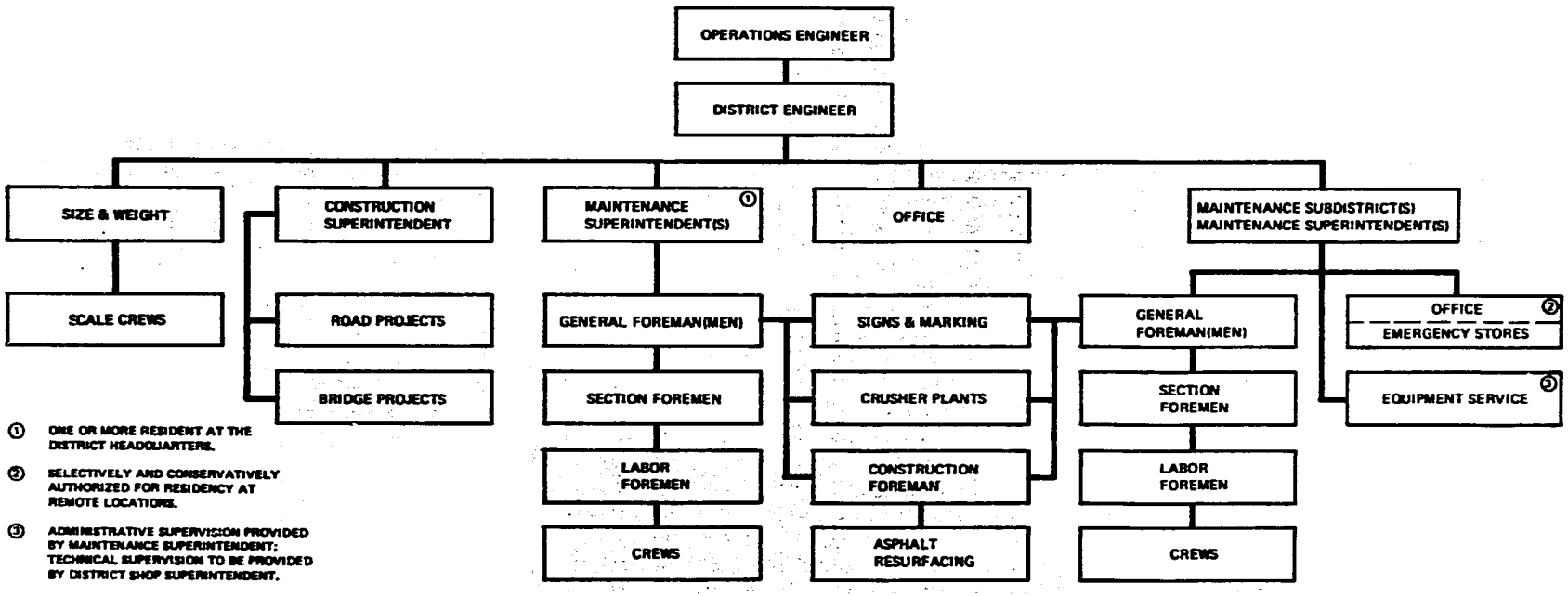


EXHIBIT II-4 PROPOSED ORGANIZATION CHART

directly to the General Manager. Originally, there was one exception to this plan; the district warehouses were to be a part of the district office organization, under the line authority of the District Engineer. However, this too was subsequently changed and the District Warehouses were all placed under the line authority of the Parts and Supplies Branch of the Supply and Equipment Division in December, 1971.

Obviously, one of the main objectives of this change was to eliminate the serious lack of coordination between functions. This was to be accomplished by creation of the new Division consisting of three major branches:

1. Equipment Branch
2. Procurement Branch
3. Parts and Supplies Branch

Exhibit II-5 has been prepared to show the organizational structure of the Supplies and Equipment Division as it existed in June, 1972. The exhibit also reflects the relationships with the Operations Division and the field districts (see the Administrative Appendix).

A number of other actions were taken to "up-grade" and strengthen the management and effectiveness of the consolidated Supply and Equipment Division. These included the following measures:

1. Development of formal Policy and Procedure Manuals (cooperatively by PAS and IHA):
   a. Equipment Management Manuals
   b. Warehouse Policies and Procedures
   c. Procurement Branch Policies and Procedures
   d. Property Records Manual
2. Development of staffing standards for the Division and its Branches; the Central Warehouse, the Central Shop, the District Shop and Warehouses.
3. Conversion of the old Central Shop to essentially a "Component Rebuild Shop," and establishment of policies and standards for substitution of rebuilt component units in lieu of district repair.

4. Employment of a highly-qualified expatriate to administer the new Supply and Equipment Division.
5. Assignment of an Ethiopian Equipment Engineer to serve as the "understudy" to the expatriate Chief of the Division.
6. In cooperation with USAID, 10 expatriate shop specialists were employed for assignment to each of the 9 district shops, with the Team Leader in the Central Office Supply and Equipment Division. These specialists have no organizational status within IHA, but advise and provide technical support to the District Shop Superintendents in expediting the repair and rehabilitation of deadlined equipment.

It is the opinion of the Consultants that, overall, these various efforts to strengthen and improve the effectiveness of the procurement, supply and equipment functions have been highly successful. Further, on the basis of figures which were quoted to the Consultants, the average percentage of deadlined equipment has been reduced from 70-80% before the reorganization to about 20% currently. Progress has certainly been made in returning equipment to service, and the effectiveness of the district shops and warehouses has been improved considerably.

It is the view of the Consultants that the basic cause of the original problems in the procurement, supply and equipment functions was probably a lack of professional leadership and guidance at the Central Office level, coupled with the fact that the staff direction of the three functions was fragmented, with a resulting lack of coordination. Obviously, the above problems were recognized in the original study and actions were taken to cure them.

The Consultants agree that the actions recommended by PAS to resolve the three problems cited above were proper and necessary at that particular time, to ensure that coordinated corrective action would be initiated and vigorously pursued, with the support of the General Manager.

However, one general policy established in the new equipment management plan appears to be subject to question; the rule that no skilled

mechanical staff will be assigned to any Maintenance Section or Direct Labour Construction project. This policy is not intended to be inviolate, as indicated by the November 20, 1970 memorandum from the Acting General Manager to all supervisors which said, in part, that the district Equipment Superintendents "are to do everything possible to comply with operational requirements of the District as given by the District Engineer or District Superintendent." In accordance with the quoted statement, it is permissible for the Shop Superintendent to comply with a request from the District Engineer that mechanical help be assigned to a Maintenance Section. However, it is apparently rarely done, even in the case of remote sections, because of the general policy and the "veto" power vested in the Shop Superintendent. The Consultants feel that the policy should be interpreted and applied much more liberally, with the benefit of the doubt being given to the District Engineer to avoid the possible risk of delaying maintenance or construction operations and the cost of idle crews.

Recommendations

It is recommended that no change be made now in the organization structure of the Supply and Equipment Division and its existing line authority over the district shops and warehouses.

However, the Consultants suggest that at an appropriate time in the future, when the equipment and supply management functions in the IHA are fully effective and matured to the point where all affected staff (both in equipment and supply and in the engineering area) have been fully trained and developed in the proper management and operation of equipment and supply activities, that consideration be given to reducing the horizontal organization level of the Supply and Equipment Division by placing that unit within the "General Services Division" where the rest of IHA's general support and service divisions are grouped. Such an action would place the "equipment and supply" functions at the same horizontal level as the "engineering operations" functions within the "Office of the Chief Engineer." This is suggested because the supply and equipment functions in a highway organization

are an essential support and service activity to the basic operating functions. On this basis, it is organizationally unrealistic to permanently place the service and support activity on a higher horizontal plane than the organizational unit which it serves and exists for.

It is further recommended that after an additional period of operation in the present manner for several more years, direct line authority for the operations of the district shops and warehouses be transferred to the District Engineers. This should not diminish in any way the policy and staff authority which should be exercised by the Central Office Supply and Equipment Division.

Immediate actions which are suggested to achieve better understanding and cooperation between the engineering operations and equipment management people are:

1. Scheduling of a meeting of the principal staff of the Office of the Chief Engineer with the principal staff of the Supply and Equipment Division (chaired by either the General Manager or the Executive Assistant) at which all participants would be encouraged to air all their complaints, criticisms and suggestions for better understanding and cooperation.
2. Following the above meeting, another should be scheduled to include all District Engineers and all District Shop Superintendents (chaired jointly by the Operations Engineer and the Chief of the Supply and Equipment Division) at which, again, all participants would be encouraged to air all their complaints, views and ideas for improvement.
3. The key staff of the Supply and Equipment Division should carry out an intensive orientation effort in their frequent contacts with the District Shop Superintendents to impress them with the fact that they are a "service" activity to the District operations and that they should make every reasonable effort to resolve all district equipment problems in an efficient and cooperative manner.

wish to point up here is that budgetary constraints - whether they be the result of the traditional system or inadequacy of revenues - will usually have a negative impact on bona fide program planning.

Assuming that there is a weakness in IHA's maintenance planning, not due to neglect or lack of desire, then how best can the problem be resolved? Two basic courses of action appear necessary: (1) Separate the annual and multi-year maintenance planning process from the budget process; and (2) assign one or more persons, as necessary, solely to this function, but expanded to include the development of estimates of resource requirements for the alternate program levels considered.

It is the judgment of the Consultants that the ideal location for the function of IHA maintenance program planning is in the same organizational unit that is responsible for the agency's regular annual and multi-year program planning. Unfortunately, unless special precautions are taken, maintenance planning tends to become the "orphan child," almost ignored and left to the Maintenance Engineer to worry with.

To achieve for maintenance planning the same degree of sophistication in modern methods of current and advance planning that is applied to highway system development and improvement, many of the same skills, techniques and alternate analyses are needed. It is not essential that the individual responsible for maintenance planning be personally skilled in all the techniques of modern planning, but it is desirable that he be familiar with the processes, and have access to the specialized skills that are normally available in a "planning" organization, e.g., economists, statisticians, planning engineers and computer (or data processing) capabilities. In addition, he should have a reasonable depth of experience in highway maintenance operations and be qualified to work closely with the officials charged with the responsibility for maintenance operations.

The Consultants recognized that, with a high degree of skill and effort, an effective job of maintenance planning can be done by an engineer on the staff of the Chief Maintenance Engineer. However, it is believed that a much better result could be obtained if the maintenance planning were done by a

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The Consultants recognized that, with a high degree of skill and effort, an effective job of maintenance planning can be done by an engineer on the staff of the Chief Maintenance Engineer. However, it is believed that a much better result could be obtained if the maintenance planning were done by a

maintenance specialist within the staff of the Planning and Programming Division. Within the environment of say, the advance planning branch, maintenance and direct labor planning can be approached without the immediate constrictions of budget considerations; optimum and various alternate levels of programs can be evaluated in cost-benefit and traffic service terms, and there is a much stronger possibility that "maintenance planning" will be taken seriously as a basic and important segment of IHA's total planning and programming responsibility.

2. Recommendations

It is recommended that a new position of "Operations Planning Engineer" be created for assignment to the Planning and Programming Division, in the Advance Planning Branch.

It is further recommended that the Planning and Programming Division, with the addition of this position, recognize and accept the responsibility for treating "Operations Planning" as a basic, integral part of the total planning and programming function it must perform for IHA. Within this "recognition and acceptance," it should be understood that this means applying the full resources, capabilities and planning techniques of the Division to the "Operations Planning" just as it does to its "Capital Development" (new works) planning.

Under Article III, section E, paragraph 4 of the study contract it is provided that the Consultants shall propose:

"4. a program for periodic updating of

(a) .....

(b) IHA's maintenance plan, and recommendations for the organizational arrangements for updating the maintenance plan."

It is believed that the Planning and Programming Division should be charged with the future responsibility for periodic updating of IHA's maintenance plan, and that the creation of the proposed "Operations Planning Engineer" position in that Division should be the initial action to develop the function and its future capability.

If the above recommendations are adopted, it is essential that the Operations Division recognize its responsibility to work cooperatively with the Operations Planning Engineer in providing timely and accurate highway condition surveys, maintenance work program data, cost information, and any other data and reports necessary to the process.

G. Personnel Management

1. Observations

The Consultants were favorably impressed with the organization and operations of the personnel management and administration side of the Personnel Services Division. The leadership of the Division has a strong determination to pursue a modern and effective program, and appears to be making commendable progress in all areas that were suggested for improvement in the PAS study report.

Perhaps the most important basic action that has been taken is the development of a "Revised Personnel Manual" in January 1972. The manual was prepared by the Personnel and Training Services Division in cooperation with the Public Administration Service. In the opinion of the Consultants, the manual is quite complete and will adequately serve the needs of the IHA. It is prepared in "loose-leaf" form so that revisions can be readily made as necessary.

A comprehensive "Imperial Highway Authority Classification Plan - 1970" has been completed, issuedand is in regular use. The Classification Manual was prepared by PAS in cooperation with the Personnel and Training Division staff. The Manual consists of a complete set of position specifications for all occupational titles utilized by IHA.

A formal Salary Plan, tied to the classification plan, was adopted by the IHA in July, 1970. The pay plan consists of 46 grade levels, each divided into six steps. Again, the pay plan was developed by the PAS in cooperation with the IHA personnel staff.

In the development of the salary plan there were two major efforts involved: (1) evaluating all the positions contained in the class specifications

against each other to determine their relative level in the proposed pay structure, and (2) the conduct of a salary survey in representative private and charter agencies in order to determine local prevailing rates for positions which were similar in duties, responsibilities and requirements to those of the IHA. Because the IHA staff were involved in these efforts, a high level of understanding and training was achieved.

A concerted effort is being made to convert as many as possible of the "day-labor appointment" personnel to regular monthly type positions. This is not being done haphazardly; a careful review of each individual's education, experience and qualifications is being made against the class specifications for vacant positions, and where "matches" can be made, the conversion to regular monthly positions will be initiated. In April, 1972, a "mass conversion" action was in process, awaiting only perfunctory Central Personnel Agency (IEG) approval, for a total approximately 2,500 persons who would then become regular monthly employees.

As of approximately May 1, 1972, the staffing figures for all divisions of the IHA were:

Regular monthly employees	3358
Day labor employees	5205
Total employees	8563

When the "mass conversion" of day labor people is completed, the approximate figures will be:

Regular monthly employees	5858
Day labor employees	2705
Total employees	8563

Efforts will continue to convert day labor people into regular positions but only when it is possible to match their qualifications with vacant authorized positions. It is recognized that there is, and will be for some time, a surplus of day labor people who cannot be legitimately placed in regular monthly authorized positions. The plan is to gradually reduce this surplus of low-skill help by: (a) attrition; (b) terminations where successful appeals are unlikely, and; (c) expected program expansion which would increase the

number of opportunities to place "low-skill" people in open authorized positions.

The 1966 PAS study Report indicated that the total employment of IHA at that time was approximately 11,500 employees, of which about 3,300 were regular montly staff and 8,200 were of the day-labor type. Accordingly, the figures cited earlier indicate that there has been a total reduction of staff amounting to approximately 3,000 people, almost entirely in the day-labor category.

The Personnel Services Division has an admirable record of attracting a high percentage of the annual production of graduating Civil Engineers in Ethiopia. While the figures have not been verified, it is understood that the number of graduates has been averaging about 20 each year. Of that number, IHA has been successful in employing some 10 to 12, and occasionally more. Certainly a much better record could not be expected. In May, 1972, the Personnel Services Division was conducting an "advertising" campaign to attempt to attract candidates for the Engineer I, II, and III levels. In addition to the outside recruiting efforts, the division also makes an effort to fill vacancies "from within," utilizing its Training Branch in many cases to develop promising people for career advancement.

The Personnel Services Division is making excellent progress, in cooperation with the Data Processing Unit, in converting its employment records to mechanized data processing methods.

In summary the Consultants feel that the IHA personnel management has been energetic and effective, and no recommendations are offered for its improvement.

H. Training and Testing Branch

The Training and Testing Branch is being treated separately in this report because of its importance and size within the Personnel Services Division.

Regarding the IHA's Training Center (a separate physical facility), the past and current programs of the Branch and its leadership and direction,

it can be said that the IHA should be proud of what it has achieved in this area.

In other reports and material which has previously been published, such as the 1966 PAS study and the periodic reports which have been issued by the Training Center itself, complete descriptions of the types of programs and statistics on training and testing are readily available, so there is no purpose in repeating them here. Some new observations and, later, recommendations are presented.

The Training Center Management has recently come to the conclusion that their past program emphasis on what might be called "mass training" of a maximum number of people in the skilled, technical and mechanical trades and fields (including equipment operators) is now in need of close review and possible revision.

During the period of the IHA's rapid growth it was essential that large numbers of people be trained in technical skills because sufficient numbers of qualified people of this type simply were not available. The situation has changed considerably in recent years - total IHA employment has actually declined and there is a recognition of the need to change the direction and emphasis of the programs.

Currently, the Training Center is placing its major emphasis on "refresher" courses. The approach has been to develop a series of "Inventory of Training Need" forms for each of the occupational classes trained in the past, such as Equipment Mechanic, Welder, Equipment Operator, Engineering Aide, etc. Supervisors have been requested to fill out these forms for each of their employees and to rate the employees' skills and knowledge requirements for the various jobs. These forms are consolidated and analyzed to identify the types of refresher or "specialized re-training" courses that are needed to correct deficiencies among existing employees. A major part of the Training Center's 1972 program will be taken up in this innovative effort. As needed, the Training Center is continuing its "full training courses" for new employees and those who are being trained for promotion or reassignment.

The Training Center is also aware that a major weakness lies in not having developed any significant programs for supervisory and management training, or for intermediate and higher level administrative, accounting and clerical personnel. The awareness of this deficiency is the first essential step toward developing a solution.

The Training Center is actively continuing its Scholarship Program through which higher level professional engineering and management staff are sent to developed nations for extended periods of training and orientation in modern methods and advanced technology. The Center is also continuing its program of paying the tuition and other direct costs of night school or special courses for a limited number of employees who apply and are approved.

Early in May, 1972, the Chief of the Personnel Services Division had the Training Center develop a comprehensive list of the "Equipment, Tools, and Training Aids" that are considered necessary for the Training Center to expand, improve and modernize its capabilities. The list was broken down into the needs for:

1. Technical Section
   a. Mechanic Training
   b. Electrical Training
   c. Welding and Bodyman Training
   d. Machinist Training
   e. Carpentry Training
2. Equipment Operation Section
3. Engineering Section
4. Administrative Section
5. Programmed Instruction Books

A summary of the estimated cost of the total requirements is:

Equipment	US$390,422
Tools	12,977
Books	3,803
Audio-Visual Aids	18,572
Total	$425,774

By way of clarification, a substantial part of the "equipment" category represents ordinary highway maintenance equipment such as 1 grader, 1 front end loader, 1 compressor, etc. Also included in the "equipment" category are shop tools such as an arbor press, boring machine, drill press, electric welder, milling machine and a shaper, plus some engineering equipment; transits and levels, a plane table, drafting instruments and so on.

It was assumed that the list of training needs was developed for possible financing as part of the fifth highway program.

Recommendations

It is recommended that the Training Center explore every possibility of developing programs in the "supervision" and "management" areas. It is rather unlikely that it will be possible to develop any strong capability within the Training Center itself, or even within IHA, to actually develop the details and do the instruction in such courses. However, there are possibilities that can be explored cooperatively with local university officials and by other means.

There are good "correspondence-type" courses available through the United States Department of Defense, particularly for first-line supervisors. It is believed that good material might also be obtained through the U.S. Civil Service Training Institute or the U.S. General Services Administration Training Institute. Another source of excellent audio-visual training aids is the American Management Association in New York City. Excellent video-tapes and sound films can be purchased from this organization.

Highway-management training is offered in a course, (about 6 weeks in length) conducted once each year by the Highway Management Institute of the University of Mississippi. This particular course might be very valuable for several people at the highest level of the IHA's management structure.

It is recommended that particularly close scrutiny be given the types of programs that are proposed for the "external" scholarship program overseas. It is the Consultants' belief that the most valuable types are those involving "academic graduate study" in new technologies that have application

to highway planning, design, construction and maintenance, and those that are intended as "refreshers." Where scholarship programs involve visits to to other overseas highway departments, care should be taken to avoid short visits to a number of organizations because such programs do not permit any real "in-depth" learning. These are often valuable for high-level officials, providing a broader perspective of developments and practices in other countires, but the limitations of their training value should be recognized. In the case of intermediate and lower level professionals, it is believed more value can be obtained from continuous assignment to one carefully selected overseas highway department within the functional area of the employee's interest.

It is recommended that the IHA Training Center develop and initiate an "administrative intern" program modeled after its "engineer-in-training" program. The Consultants believe there is a shortage of professional level administrative people in the IHA. This shortage appears in the fields of financial management, accounting, auditing, personnel management and training, equipment and supply management, data processing and computer technology, and others.

To provide more professional administrators, a modest program of recruiting and training students graduating from the University in public administration, business management or other appropriate fields is recommended. The program should consist of from 18 to 24 months of rotational assignments (similar to the engineer-in-training program) in the various administrative divisions and at least one field district office.

Finally, it is recommended that favorable consideration be given to providing the Training Center with the equipment, tools and training aids needed to strengthen and modernize the Center's facilities and programs.

Section III

ROAD MAINTENANCE

A. Roads Considered

A central objective of the present study was development of a practical plan for the regular maintenance (and necessary rehabilitation) of the most important roads in Ethiopia. The procedure adopted was to identify those highway routes and sections which should logically be considered for inclusion in the plan, and to estimate the annual costs of adequate maintenance for them, together with the costs of rehabilitating any sections which were seriously deteriorated. This would produce a "candidate" list of roads for economic analysis, in which the estimated benefits to road users could be compared with the required expenditures on the roads. A comparative ranking of all highway sections would result, and those routes having the best relative indices would be recommended in the final plan.

1. The Road System Presently Maintained

It was apparent that all routes now under IHA jurisdiction and maintained by that Agency should be included in the candidate list for economic analysis. These roads were identified from the program control lists of the IHA Maintenance Branch, in consultation with the Chief Maintenance Engineer. The initial system defined was that under maintenance in Fiscal Year 1965, Ethiopian Calendar, corresponding to the period July 8, 1972 through July 7, 1973 of the Gregorian Calendar.

This was found to consist of 2,488 km of paved roads and 4,867 km with gravel-surfaces, for a total of 7,355 km. These are shown, separately by IHA Districts, in Exhibit III-D in the Engineering Appendix. An explanation of the route identification and other information in the exhibit is given in Paragraph A-4 below, and in other sections of this report.

2. Scheduled Revisions and Additions to the Present Highway System

In addition to the kilometerage being maintained by the IHA in 1972/73, other sections of road were under construction (or reconstruction) at the time of the study, by contractors or by the IHA Direct Labor Construction Branch. Further, new projects to extend the highway system were funded for construction within the time span of the study, and it was anticipated that funds would be approved for certain other routes proposed for early construction.

Altogether, some 3,811 km of current and future road improvements were identified which would probably be completed at some time in the calendar years 1972 through 1976, or early in 1977, so that they might be taken over for maintenance by the IHA in one of the Fiscal Years 1973/74 through 1977/78. These included all projects of the Fourth and Fifth Highway Programs, some of the Sixth Highway Program, and projects of the IHA Direct Labor Construction Branch (represented in some sections of this report by the symbol "D/L"). Some improvements administered by the D/L Branch would utilize equipment acquired under specific external loan agreements, and other D/L projects were actually being built by Engineer Battalions of the Ethiopian Armed Forces, under agreements with the IHA.

The 3,811 km of the above programs are listed, section by section, in Exhibit III-E in the Engineering Appendix. While most of this length is made up of new routes, some represent the paving of gravel roads already maintained by the IHA in 1972/73. These projects would result in a change in surface type and maintenance cost, but without altering the maintenance length significantly. Three short sections of the present paved highway between Addis Ababa and Nazreth would become local access roads after relocation of the main highway along that route, and would be additional maintenance length, while the main highway distance would be shortened by about 5 km.

3. Road System for Economic Analysis

The foregoing selection process provided a list of existing and scheduled road sections totaling 11,166 km. This was viewed as

including all routes which would fall under a clearly defined national responsibility, by virtue of prior IHA acceptance or construction under IHA programs. All other existing roads were believed to be local in function or of such limited usage as to have only minor significance in the national economy. Early in the study, it was assumed that some of the more important existing roads of relatively low standards (and not now maintained by the IHA) should be included in the candidate list and subjected to analysis for maintenance priority. However, essential data was usually unavailable on such roads, and consultation with the IHA, the National Planning Commission and the Ministry of Finance indicated that separate preparatory studies and accords between those agencies to clarify the jurisdictional status of local roads could not be completed in time to serve as a guide to selection. In view of this it was agreed that the candidate list should be limited to the systems described in the above paragraphs and the cited exhibits.

4. Explanation of Tables

Exhibits III-D and III-E were devised to portray much more data than a simple listing of candidate road sections, and will be referred to often in other parts of this report. However, the first few columns of the exhibits describe, in considerable detail, the present IHA maintained system and the anticipated revisions and additions.

The "Route and Segment Number" column consists of a 5-digit identification, in which the first two numbers indicate the IHA route number (see "Highway Map of Ethiopia," Imperial Highway Authority, 1970). Roads without official designations were assigned numbers in which the first two digits indicated the main route from which they branched and the third digit the sequence along the main road, or the individual identification. For all officially-numbered routes, the third digit in the exhibits is zero. The fourth and fifth digits were used to identify segments of the routes. These are sometimes discontinuous, as when there is no maintenance through a city, or some part of the route itself is not presently constructed and the number of segments ultimately required could not be determined.

The route sections within the IHA Districts are described in the second column, with principal points located and other clarifying information given. The limits of each segment are shown next, from beginning to end of the segment, usually in kilometers as measured from Addis Ababa or Asmara. This is the practice normally followed by the IHA in describing the roads, and is the one most familiar to maintenance personnel. In some cases, the segments are shown as starting from km 0 at a road junction. For all segments, the length is given following the limits.

The "1972 ADT" (average annual daily traffic) is that estimated for the segment, discussed elsewhere in the report. Descriptions of the entries in other columns of the exhibits will also be presented in later sections, but it may be of immediate value to state that under "Maintenance Type" the numbers 1 and 2 indicate paved sections, while the others (3 through 6) refer to gravel surfaces of successively lower standards. The first letter of the maintenance type designates climate (dry, moderate or high rainfall) and the second letter the topography of the segment (flat, rolling, or mountainous). These are sometimes followed by a lower-case "d, " in areas where "desert allowances" are paid to IHA maintenance personnel.

B. Road Types for Maintenance

To establish a basis for estimating annual maintenance costs for each road section of the candidate list, and for the recommended system of the final plan, a classification of roads by maintenance type was developed. This was a separation into types according to those distinct characteristics or conditions which determine the kinds and amounts of maintenance work which must be done.

With all road sections classified by type, the work and cost for each could be examined in some detail. This method was chosen over the use of a maintenance formula for several reasons. First, it would provide a broader scale of typical maintenance costs, with greater sensitivity to the physical variations which actually occur on the roads.

Second, the estimation of average costs by specific work activities, such as asphalt patching or culvert cleaning, would permit a review of work practices and the levels of effort necessary to a satisfactory road condition. Third, having the quantities of man-days, equipment hours, and materials from the basic estimates would offer a means of approximating, for any particular road system or subsystem, the resources needed for the maintenance program.

1. Distinction by Surface Type

The first separation of highway types for maintenance purposes was by surfacing, since paved, gravel, and earth roads would obviously require different methods and expenditures. It was determined that the paved types would consist only of asphalt surfaces, since there were no significant lengths of Portland Cement concrete, cobblestone, or other types. The principal unpaved sections, existing or programmed, had surfaces of crushed aggregates, natural granular materials, or admixtures of the two.

For the initial classification, the only cost-effects considered were those related to the travelway, since the maintenance requirements for other elements, primarily shoulders and drainage facilities, would be largely independent of surface type.

a. Paved Highways

Considering first the asphalt surfaces, it was assumed, as a point of departure, that maintenance cost would vary with the pavement width, the age, climatic conditions, traffic volume, and the structural adequacy of the pavement (consisting of surface, base, subbase if any, and the subgrade soils).

The principal source used for information on pavement widths was the "Condition Survey" made by the IHA District Engineers in July and August, 1971. This covered all roads under IHA maintenance, and included essentially all the non-urban paved sections of Ethiopia. The widths were almost always recorded as 6.0, 6.5, or 7.0 meters. Some short sections were shown as being 5.5 or as little as 5.0 meters in

width, while others were up to 8.0 meters wide. Near Addis Ababa there are even divided highway sections of short length, with two separate roadways. After careful investigation, it was concluded that an average width of 7 meters could be used for all paved routes, and that separate classifications by width would not be needed. In terms of maintenance cost, the variations from this average would not cause significant errors.

Considering pavement age as a maintenance-cost variable, it was assumed to be generally agreed that all pavements deteriorate with time, suffering a progressive loss of surface integrity due to cracking, raveling, local failures of pavements and base, and settlement or expansion of subgrade soils. Normal maintenance procedures can correct most of the effects, but the repairs themselves are usually less smooth and uniform than the original surface. The increasing roughness may not cause measurable changes in vehicle operating costs, but the maintenance effort required to prevent large changes becomes gradually larger. At first glance it might seem desirable to classify surfaces into 2-year or 5-year age groups, but general experience shows that such refinement is not especially useful, since the effects of age alone are less important than, and obscured by, the damages from other variables. Furthermore, the ages of many Ethiopian pavements are not known. Few records are available on pavements consutructed during the Italian military occupation, or on most of the extensive system in Asmara District. Naturally, various sections of these pavements have been rebuilt or reinforced with additional layers since their original construction (other long sections have reverted to gravel because it was impossible or uneconomical to maintain them). The pertinent age for maintenance cost estimating is that of the last surface placed (excluding simple seal coats) and the date of first construction is less significant. Since there is a large kilometerage of indeterminate age in the system, it was decided to fix one classification of pavement as "10 or more years old," covering all sections known to be constructed before 1962.

During the past decade, approximately 1,000 km of asphalted highway have been added to the IHA maintenance responsibility,

representing about 40 percent of the present pavement. Examination of the reported work on these roads did not show any meaningful correlation between age and current levels of surface maintenance. Instead, it appeared that most of the areas of abnormal surface failure on newer roads were related to inadequate strength designs, poor subgrade soils, large volumes of heavy truck traffic, and insufficient engineering control during construction or reconstruction, all of which are partially interrelated. In view of this, it was decided that no subdivision should be made of the first 10 years of pavement life as a classification for maintenance type.

Another important variable affecting asphalt surface maintenance is that of climate, especially rainfall. The effects of weather were considered, and a means of reflecting differences in annual costs for different climatic zones was introduced by the subdivision of all surface type classifications into three subclasses by annual rainfall. This is described later in Paragraph B-2.

It is apparent that asphalt maintenance is affected by traffic volumes. Based on the findings of pavement design studies and experiments during the past 20 years, and particularly the AASHO Road Test conducted in Illinois during 1959 and 1960, it was taken as fundamental that structural damage to pavements over time results primarily from the repeated application of vehicle axle loadings of significant weight. The studies have indicated that light vehicles (i. e., autos, jeeps, and pickups) have little effect, and that the heavy component of total traffic is most important in surface (and base) deterioration. The load applications from what are usually called "commercial" vehicles determine, in a large measure, the pavement maintenance required.

However, the studies have also shown that the rate of deterioration is not a function of traffic volume alone, but of cumulative axle loadings in relation to pavement bearing value. Pavements which are under-designed or poorly constructed, or which carry commercial traffic greater in volume, heavier in axle weights, or more rapid in annual growth than was anticipated, will show more distress and higher maintenance costs. Unfortunately, there is no practical means of

relating these factors to abnormal failure rates on existing roads, unless there is very good data on the entire engineering history of the road sections and the kinds of traffic they have carried. The projection of future failure over a period of years is even more problematic. The AASHO Road Test and subsequent investigations made it possible to forecast pavement performance under predicted traffic, but only for pavement designs known in detail including the characteristics of the subgrade soils and all subbase, base and surface layers. It is apparent that the traffic projections would also have to be reasonably accurate. The road tests and later experiments even provided a means of estimating probable future performance on the basis of existing pavement condition, but the meaning of "condition" was carefully defined, and required extensive programs of measurements of surface irregularities by means of the "Roughometer" or similar devices, or of pavement deflections under load by use of the Benkelman Beam.

The Consultants felt it would be desirable to have some classification of asphalt surfaces by commercial-traffic/bearing-strength relationship, but no practical means was found for collecting or correlating the necessary quantities of data. Instead, it was decided that all existing sections showing a very serious surface condition would be considered for rehabilitation and treated as abnormal cases. For all other sections of pavement, the assumption was made that the bearing strength was reasonably adequate for the current and future traffic.

In summary, the evaluation of Ethiopian paved roads resulted in a differentiation into two basic types by age (less than or more than 10 years old) which would later be subdivided according to climate zones.

b. Gravel Roads

Going next to the highest type of unpaved surfaces, the distinction between crushed stone and natural gravel was considered. Some sections originally built with crushed material of controlled gradation were subsequently maintained by adding selected pit-run gravels. The difference between the two types was therefore obscured. In all the cases where this was avoided, and the quality of

crushed surface material was preserved, the routes in question were scheduled for early paving with asphalt, which would remove them from the gravel classification. Consequently, only a single type, identified as "gravel surface" was adopted. This was defined as including all good-quality granular surfaces, non-plastic and therefore stable under all moisture conditions, whether initially built with crushed aggregates or other materials.

The category of all-weather, non-paved roads was intended to apply only to engineered and constructed routes with reasonably complete drainage facilities and other normal elements, requiring all the usual maintenance activities. Consequently, the classification of "gravel surfaced" was restricted to roads with those characteristics. Their widths would normally range from six to seven meters, excluding any unsurfaced "shoulder" areas of the roadbed.

When appreciable volumes of traffic are carried on gravel roads the cost of surface maintenance is increased, because more frequent blading or shaping of the travel way becomes necessary, and the loss-rate of surfacing is greater. This is especially true of roads with good geometrics, since higher vehicle speeds contribute to both factors. The variation in cost is significant, but not large enough to justify any elaborate categorization by traffic volume. A simple statistical review was made of the 1971 traffic volumes on major existing unpaved roads. It was found that a majority of sections of primary and secondary standard had volumes in the general range from about 40 to 100 ADT, and several carried from 100 to 300 vehicles per day. A very small number had higher volumes. It appeared reasonable to establish only two classifications for these roads; those having an ADT of 100 or more, and those with less than 100 vehicles per day. These were identified as road types 3 and 4, respectively, with average surfaced widths of seven meters.

A few of the presently-maintained roads, and numerous future gravel routes of the candidate list, were designed to "Feeder" and "Service to Traffic" standards. These were successively more modest in geometric and other characteristics. Also, a review of available

traffic projections showed, as would be expected, that the traffic volumes for these roads would generally be less than for types 3 and 4, and more in consonance with their standards. According to IHA design practice, the width of surfacing for either class would be six meters, but thickness and quality would be less for the Service to Traffic. Maintenance costs would vary with traffic volume and other factors, and it was thought necessary to make two further distinctions within the general classification of "gravel-surfaced. ". Feeder roads were designated as Type 5, and Service to Traffic Type 6.

It was necessary to assume, for uniform analysis, that all-weather gravel highways were engineered and fully constructed, although it was recognized that in some cases this was not true. Any road which had originally been designed or intended for ultimate construction to an all-weather surface and adequate drainage facilities was classified in the group into which it would fall if the additional investment were made to complete it. In this way, the later steps of estimating normal maintenance costs would determine what its annual maintenance would be if completed to its intended standards. The costs of finishing the construction could not be included since they would be capital investment, and would distort comparative maintenance costs in varying degrees.

2. Distinction by Climatic Zone

Having set up a first classification of roads by surface type and the subordinate variables related to travelway maintenance, each of these was then subdivided into three subclasses according to annual rainfall. This was considered necessary because some maintenance activities, especially brush control and asphalt patching, are greatly affected by the humidity of the climate.

In other areas of the world additional climate factors must sometimes be taken into account, such as low temperatures where snowfall and freezing occur, or wind-temperature-soil combinations which result in dune formations. However, examination of the conditions in Ethiopia indicated that annual precipitation would be the only major factor, except for some low or moderate rainfall areas where the high intensity of seasonal storms would cause increased costs.

After study of specific roads and work activities in the IHA Districts, the following categories were adopted:

Dry Weather Zones--Up to 400 mm. rainfall per year.

Moderate Rainfall Zones--400 to 1,000 mm. per year.

High Rainfall Zones--More than 1,000 mm. per year.

As a general guide in determining which category would apply to any particular road, the 400 mm. and 1,000 mm. Isohets (of the National Climatological Service) were plotted on a map of the present highway network. In the later classification of specific road sections, adjustments were made for known local conditions.

3. Distinction by Topography

With six basic surface types, each of which might occur in any of three rainfall zones, there were 18 classes of road type for maintenance purposes. As a final separation, each of these was again subdivided into three topographical classes; flat, rolling, and mountain. This was believed necessary because terrain determines the extent of some maintenance operations, especially ditch and culvert maintenance.

For the purpose of maintenance effects, roads would be classed as flat if grades were generally zero percent to three percent in flat or gently undulating terrain, or following wide valleys. Sections would be called rolling if grades were three percent to five percent in undulating to heavily rolling country, with numerous through cuts where the highway crossed rounded ridges, and with embankment sections between the ridges. The mountain classification would apply to roads with grades averaging more than five percent, or in any case where constructed in high, steep-sided landforms, with sidehill cuts predominating.

4. Summary

The foregoing procedure resulted in 54 road classifications, permitting assessment of average annual maintenance costs for the basic surface types under varying conditions of climate and topography. Provision was also made for quantifying the effects of unusual variations in different factors. The number and letter designations assigned to all 54 classes for their identification in later processing are given in

Exhibit III-A. The second column of the exhibit shows the descriptions of the basic surface types.

It was realized that this process might provide more classifications than were needed for the actual road types in existence and that, for present roads, the differences in annual costs between types might be small, suggesting that some might be eliminated or combined. However, the complete exhibit would provide a category for average standard maintenance cost on any kind of Ethiopian road now projected, and an estimated cost would be available for any construction now scheduled.

Consideration was also given to possible maintenance requirements for lower-standard unconstructed roads, and this is discussed elsewhere in the report. However, no designations were assigned beyond those described above.

C. Maintenance Effort

After establishing the candidate list of roads for analysis, and the classifications which would permit a distinction of the kinds of work required on each road type, attention turned to how that work should be done and how much of it would be needed. This involved the definitions of the maintenance activities, the necessary or justified levels, and the methods and resources to be employed.

Each kilometer of road has its individual characteristics, so that the attention which must be given to that particular section by maintenance forces will depend on the landforms, geology, climate, vegetation, and other factors. Although the roadway itself may be uniform in width and surfacing, it represents an intrusion into a natural balance of forces, causing subsoils to settle under fills, and cut slopes to react to the change in lateral support. Surface conditions are also changed, with rainfall runoff diverted to artificial channels, the velocities of flow sometimes speeded and sometimes slowed. Different soils are exposed, and the vegetation which was disturbed tends to regenerate itself in ditches and on slopes. From one kilometer to the next there may be large differences in the culvert cleaning to be done or the pavement failures from localized soil variations or subsurface moisture. Maintenance superintendents and foremen are aware of these differences on the sections

EXHIBIT III-A

ROAD TYPES FOR MAINTENANCE

Road Type	Description	Dry Weather Zones			Moderate Rainfall Zones			High Rainfall Zones		
		F	R	M	F	R	M	F	R	M
		Number and Letter Designations								
1	Asphalt-surfaced, less than 10 years old	1-DF	1-DR	1-DM	1-MF	1-MR	1-MM	1-HF	1-HR	1-HM
2	Asphalt-surfaced, 10 or more years old	2-DF	2-DR	2-DM	2-MF	2-MR	2-MM	2-HF	2-HR	2-HM
3	Gravel-surfaced, ADT 100 or more (primary)	3-DF	3-DR	3-DM	3-MF	3-MR	3-MM	3-HF	3-HR	3-HM
4	Gravel-surfaced, ADT less than 100 (primary)	4-DF	4-DR	4-DM	4-MF	4-MR	4-MM	4-HF	4-HR	4-HM
5	Gravel-surfaced, Feeder standard	5-DF	5-DR	5-DM	5-MF	5-MR	5-MM	5-HF	5-HR	5-HM
6	Gravel-surfaced, Service to Traffic standard	6-DF	6-DR	6-DM	6-MF	6-MR	6-MM	6-HF	6-HR	6-HM

F = Flat, R = Rolling, M = Mountain

Note: For road sections in those areas of Ethiopia where desert allowance is paid, a lower-case "d" is added to the above designations.

Examples: 1-DFd or 6-MRd. See Report Section III-G "Maintenance costs"

of road which they travel constantly, and make use of their forces accordingly.

However, in viewing large road systems and maintenance programs, these peculiarities of specific sections cannot be taken into consideration. For the purposes of evaluation, analysis and program development on a large scale, the needs must be generalized, for basic types of roads and for broadly defined conditions. The procedure must necessarily deal in averages. The use of maintenance cost formulae takes this generalization to the extreme limit, assuming, in effect, that all sections of asphalt surfacing, for example, require the same maintenance effort except as reflected by a very few variables introduced. The procedure adopted for this study reflects more of the natural differences than is possible in a formula of manageable length, but still requires that work quantities be averaged within the classifications used. Many of the individual lengths of road will not conform to the types and amounts of effort estimated for the class, but such errors will diminish as numerous sections are grouped for the analysis of an entire route, district or system. In any event, the averaging is a necessary compromise.

1. Definition of Maintenance

The normal concept of the meaning of maintenance was applied in the study, that of preserving the facility as nearly as possible in its original condition, and keeping the traffic moving. Any work which would increase the capacity of the road was classed as betterment, and excluded. This meant any improvement of width, line or grade, any substantial addition to the original thickness of surfacing, or any provision of structures not built in the initial construction. Betterment was considered to be an additional investment for which there would be some compensating benefit, to be determined by feasibility analysis. It was assumed that the function of maintenance was not to lower the basic user costs, but to prevent them from rising significantly above the level normal to the type and standard of road which was first constructed.

This distinction is always crucial in highway administration, and was considered to be especially important in Ethiopia. Some betterment

work is almost always included in highway operations. Small programs are often desirable and reasonably economical, and occasionally a specific improvement is essential, as when a natural drainage channel diverts and a new culvert must be added. Nevertheless, betterment work should always be recognized and charged as such, or the process of accounting cannot show the true cost of maintenance, which is a vital administrative tool. Further, if the practice of making improvements with maintenance resources is not controlled, it often leads to expenditures without adequate planning, engineering, or consideration of alternative priorities, and often to the detriment of needed maintenance.

Regardless of the governmental decision on the proper extent and control of betterment work, it was believed essential to exclude it entirely from estimated maintenance costs in this study. This because one of the prime objectives, and a basic requirement of the contract, was the comparative economic ranking of roads for maintenance. If the effort applied to one section of road included the placement of culverts and surfacing left out of the original construction, while the effort on a similar road built to normal standards was limited to ordinary maintenance, it was obvious that the ranking of the first would be prejudiced even if the two were actually equal in traffic volume and general economic importance. It was also apparent that the economic analysis would involve a mixture of maintenance ranking and construction feasibility in such cases. Consequently, the work functions quantified for the various road classes were limited to those necessary for the preservation of the facilities already constructed, and these were assumed to be reasonably adequate in drainage provisions and in surfacing in relation to traffic loads.

2. Work Categories

Maintenance work was divided into three broad groups of activities:

a. Those of a routine nature, performed throughout the year or at least once annually.

b. Periodic maintenance, consisting of surface restorations at intervals of several years; and

c. Special maintenance.

The last was primarily a means of providing extra work or cost for sections of road known to have exceptional requirements beyond the normal ones for the classification, such as abnormal brush. Emergency operations were also classed as special maintenance, and estimated for those road sections subject to slides and repeated flooding.

3. Specific Work Functions

a. Routine Surface Maintenance

The first activity considered was that of surface maintenance. For asphalt pavements (road types 1 and 2) this consisted mostly of surface patching, to include the preparation and filling of pavement breaks with pre-mixed material, and skin patching and leveling with applications of heated bitumen and aggregates. Other work items would be crack sealing, limited base corrections followed by surface patching, and limited edge rebuilding. For gravel roads (types 3 through 6) the routine surface maintenance included two operations:

(1) Surface grading; the shaping of the travelway (and shoulder area) at intervals during the year.

(2) Spot regraveling, the addition of surfacing material in moderate quantities each year to fill depressions and cover worn or unstable sections.

b. Brush Control

It was assumed that brush would have to be cleared regularly from the ditches, shoulders and other areas of road types 1 through 6. This would be necessary at least annually in all climate zones, but with large variations in the effort and cost, depending on rainfall.

c. Culvert Maintenance

Two routine activities were identified for all the roads:

(1) The removal of silts and trash from the culverts themselves and cleaning around the end sections.

(2) The repair or replacement of small drainage structures, including the headwalls, aprons, and so on. The latter would be mortared masonry work for the most part. It was estimated to be different for the three topographical classes, but about equal for all road types 1 through 6 within a topographic class. On lower-standard roads (types 5 and 6), the maintenance of fords would sometimes be substituted for ordinary work on culverts.

d. Ditch and Shoulder Maintenance, Asphalt Roads

This would consist of the regular cleaning of:

(1) Primary (longitudinal) ditches.

(2) Secondary ditches (crown, outer longitudinal, and lead-off or furrow ditches, plus some culvert channels). An additional item (3) was estimated for the shaping and replacement of material on the untreated shoulders adjacent to pavements.

e. Ditch Maintenance, Gravel Roads

For road types 3 and 4, this work was identical to items (1) and (2) on asphalt roads, as in the previous paragraph. For types 5 and 6, effort and cost for ditch maintenance would be less.

f. Miscellaneous Routine Maintenance

Two items were included in this category:

(1) Bridge and channel maintenance.

(2) Other miscellaneous, covering signs, markers, guard railings, fences, etc.

Since the occurrence of bridges follows no rule, no attempt was made to estimate this cost by road classifications. It was assumed that the relatively small annual cost was most likely to be related to the total

for the two activities of item C-3-c, culvert maintenance, and could be expressed as a percentage of the item's cost for all six of the road types.

The annual cost per kilometer for "other miscellaneous maintenance" was estimated as a small percentage of the total cost for all normal routine maintenance activities. The same percentage was used for road types one through four, but the item was eliminated for Feeder and Service-to-Traffic roads.

g. Periodic Maintenance

Aside from the regular surface patching and shoulder conservation on paved roads, and the shaping of gravel surfaces, it was determined that all types would need restoration of the roadway surface at intervals of several years. For types one and two, this would consist of seal-coating, or a leveling course and seal coat, on the asphalt travelway (plus reconstruction of the outer shoulder and fill slopes in some special cases). Types three and six would require replacement of the gravel surfacing lost through traffic effects and surface erosion.

h. Special Maintenance

Several classes of extra work or cost were provided to cover, where necessary, some activity or anomalous condition not usually encountered. These were:

(1) Retaining wall repair, for those road sections with extensive lengths of masonry wall constructed to retain cut and fill slopes, and requiring significant annual maintenance effort.

(2) Excess brush growth. Some areas were known to have a special annual clearing problem greater than the normal range for the classification.

(3) Slide control and removal. Limited sections of road were known to have unstable slopes and a recurring need for slide clearing to prevent closure of the road.

(4) Flood repair. Other highway sections were subject to frequent inundation, and damage from flood waters passing over the road or scouring the adjacent channels.

i. Intermittent Maintenance, Other Roads

No unconstructed trails, seasonally passable tracks or low-standard penetration or access roads were considered for regular maintenance as a part of the candidate list. In any event, the normal routine activities could not be applied or would not be justified for such roads. A reduced effort was considered for routes of this class, to be accomplished once each year to prepare the roads for dry-season use, or to be applied intermittently as justified by traffic.

Two general types of work were defined for this purpose, related to the natural soil conditions and other factors which might prevail. The work and cost for specific roads or trails would have to be estimated according to the conditions on their particular sections, taking all the circumstances into account. The two work classes were:

(1) Track shaping by motor grader. Where the road could be opened by a grader alone, the work would include reshaping the travelway and filling deep ruts, reworking the drainage crossings, cleaning ditches and water turnouts, and adding local borrow to reestablish and stabilize the roadway.

(2) Track opening with tractor-dozer. This would consist of the removal of small slides and other obstacles, the reshaping of drainage crossings and fords made impassable by rains, the addition of local borrow by dozer to re-form the travelway and stabilize sections of deep muds, and the filling of deep ruts left by traffic or erosion.

In both of the above cases one truck would accompany the dozer or grader for transporting personnel, fuels and other supplies, and for

the short haul of local borrow and stone, handloaded. The work group would also include laborers to assist in clearing obstacles and plant growth, for the repair and cleaning of drainage facilities, and the loading of materials.

j. Supplementary Maintenance Activities

Estimates of resource needs and cost were also prepared for the production of various maintenance materials. Among these were:

(1) Bank-run select material
(2) Processed select material
(3) Crushed stone base and surfacing
(4) Paving and seal coat aggregates
(5) Asphalt leveling course
(6) Premixed patching material.

D. Justified Levels of Maintenance

In different highway administrations, and their maintenance branches, there are sometimes noticeable variations in the emphasis placed on the various maintenance activities. In some cases very smooth paved surfaces are preserved at considerable cost to permit high-speed travel. Numerous agencies spend large amounts annually on pavement markings and regulatory and informational signs. Appearance is a prime objective on some sections of road, with great attention given to the care of planted slopes and landscaping. There are gravel roads carrying modest traffic volumes which are bladed so frequently that the marginal gain in smoothness is negligible.

Despite these differences, most maintenance organizations have adopted similar levels of attention to the basic tasks. The minimum requirements for these are fixed largely by nature and the demands of traffic, and few agencies have enough funds to go much beyond these minimums. Minimum effort sometimes results in overall costs that are ultimately higher than they would be with more intensive care, as when, for example, the maintenance of shoulder drainage and adjacent

ditches is not quite adequate to fully de-water the subgrades under pavements, and some additional surface failures occur. Nevertheless, the necessary level of work for most operations is fairly well established in general practice. Unfortunately, two other factors affect most maintenance programs, and they are often in direct conflict. . One is the availability of budgetary funds for the necessary work, and the other is public demand for improved road service. Resolution of these opposites would be greatly aided by studies of the effects of incremental changes in maintenance effort on user costs, but little information is available on the relationships between such things as quality of asphalt patching and vehicle operating cost, or the effects of weed growth on road capacity. In short, most of the activities involved are not subject to computations of benefit gained against cost incurred. The level of service provided to road users will usually depend, in a large measure, on the resources available and on the pressures from the public and, sometimes, from other branches of government.

It was a basic assumption of this study that the maintenance effort provided should be the minimum necessary for the preservation of the constructed highway, and the provision of no more than average standards of condition, safety, and comfort. Recommendations were formulated on those guidelines, and any higher standard of service adopted by the nation would imply an increase over the estimated program costs.

Concerning the maintenance of asphalt surfaces, it was assumed that all holes, breaks, cracks, and other observable failures which would permit the passage of surface water would be filled or sealed at least once each year, during the dry season and before the onset of a regular annual rainy season. Any effort less than this would permit the pavement to deteriorate to some degree for at least one annual cycle, multiplying the normal damage and requiring a greater cost to rehabilitate the surface at a later date.

It was assumed that all pavement types would receive a full-width seal coat at varying intervals of no more than 5 years, to seal the entire pavement, provide a new wearing surface, and reduce the effects of asphalt oxidation.

Maintenance to these standards would sometimes result in very high estimated annual costs, suggesting that the old pavement should be reconstructed or reinforced. In the opinionof the Consultants, general reconstruction with the same base thickness and surface type should not be considered since, under the same or increasing traffic, it would immediately begin to show the same distress as before. The reconstruction or reinforcement of extensive areas to a higher structural standard should not normally be a maintenance cost and should not be a maintenance decision. Any improvement expected to have a service life of 10 years or more, a practical minimum for such an undertaking, should be subjected to engineering and economic study to ensure that the proposed paving design, and the geometrics of the existing road, would remain adequate for traffic throughout the proposed service life, and that widening, relocation or some other alternative improvement would not be a better choice. In any case, the improvement cost should not be considered as maintenance.

The maintenance of gravel surfaces would consist of regular shaping to preserve reasonable smoothness and the drainage crown, plus replacing the lost surfacing at intervals. The latter should be done often enough to prevent the surface from becoming so thin that it would not bear the traffic loadings, or expose a subsurface layer of much rougher texture. The quantity of material added should be just enough to replace that lost to traffic and weather, except that it should be placed in minimum economical thicknesses and should, where the loss is rapid, provide some reserve thickness for anticipated wear so that resurfacing would only be necessary after several years. Original designs of gravel roads should include a similar reserve, and the replacement (to more than the absolute design requirement) should not be considered a betterment. The quality of the material used in resurfacing should be consistent with the standards and usage of the road.

As for the justified frequency of shaping, it was assumed that the limit of worst condition, the point at which the surface should be graded again, should be set at a roughness which would begin to cause a distinct rise in average vehicle operating costs for gravel roads. There are no

fixed numerical criteria for this, such as depth of corrugations or quantity of loose material per unit of surface area and, in fact, the general scales of vehicle operating costs on gravel have to encompass a wide range of surface qualities. The distinction which the Consultants wished to make was that maintenance forces should not attempt to maintain the best surface allowed by the nature of the material but should, for reasons of economy, allow a definite decline in surface quality before grading the road again.

The rapidity with which the decline took place would be a function of traffic, weather, material gradation, and other factors. The Consultants' specific estimates of required frequency for different road types are given in Section III-F, together with the quantity estimates for all other work functions.

The amounts of brush control set for various conditions was intended to clear the drainage facilities adequately, and to remove any growth from the shoulders which would obstruct drainage, prevent use of the shoulder as an emergency wheel path, or reduce the effective width of the travelway. No further clearing of the right of way was estimated except to maintain sight lines on the inside of horizontal curves.

The quantities of culvert and ditch maintenance estimated for all constructed roads were intended to keep those facilities clean, open and in good repair. Naturally, some impairment has to occur between repetitions of clearing, but no group of activities is more important to the protection of roads and the prevention of surface failures, and the annual effort for these items was estimated at levels which would assure those objectives. The shoulder maintenance on asphalt roads was assumed to be the minimum necessary to keep those well drained and to provide support for the pavement edge.

The annual total cost for bridge and channel maintenance was set somewhat higher than the current levels of expenditure, based on the observation that present efforts are not entirely sufficient to protect the existing structures. Other miscellaneous maintenance costs were established at about the current percentages.

Special maintenance costs were estimated in the amounts believed to be essential for the particular circumstances where these were required, whether as routine or emergency operations.

E. Labor-Intensive Methods

In nations where heavy road equipment is not manufactured, where the pool of skilled operators and mechanics is limited, and where there may be a seasonal or perennial excess of unskilled workers, there is an obvious economic need to limit machine methods in road construction and maintenance, and to favor labor-intensive procedures. The need is reinforced when fuels and lubricants also consume foreign exchange, and where distance from suppliers complicates the procurement of spare parts for equipment.

Off-setting these considerations in some degree, the increasing worldwide use of more numerous and more specialized machines has resulted from real cost-advantages, from the greater speed with which work can be completed, and from the fact that machines can often achieve a standard or quality of results which simply cannot be matched by hand methods.

It seemed apparent to the Consultants that some operations should clearly be performed by machine because it would be impossible or impractical to obtain satisfactory standards of work by hand. Just as obviously, some other functions would require labor methods by their very nature. Each of the activities identified for maintenance was considered individually before a work method was adopted as a basis for estimating.

To a certain extent, the choice was influenced by established IHA practice, because the change from handwork to machine or vice versa is not easily made for large programs. When hand methods are in use a major capital investment may be necessary for conversion, and permanent employees may have to be discharged. If an operation has previously been mechanized, it is the equipment which must be disposed of or put to other uses to increase the labor component.

Asphalt patching is now done almost entirely by hand; digging and squaring, the filling and tamping of base layers, priming, filling with

patching mix, brooming of raveled areas, spraying, covering with aggregates, all are done by hand. The asphalt heaters are of the simplest type, towed-trailer models with hand-operated pumps. Only the compacting is done by machines, usually by small steel-wheel rollers and there would seem to be no adequate labor-intensive substitute for the setting of cover aggregates (or the densification of large base repairs) by this means. Since both types of surface patching are done simultaneously by one crew (filled holes and bitumen-aggregate applications) there would be no advantage to hand-tamping the pre-mix patches alone. No change in patching methods was recommended.

In contrast to this, the periodic seal coating of asphalts clearly demands some mechanization. Uniform applications of bitumen are essential to satisfactory results, and cannot be obtained by hand spraying. Once the asphalt has been applied by a distributor truck, the rapid cooling requires that cover aggregates be placed and rolled within a short time, largely through the use of equipment. Nevertheless, the current IHA practice is to prepare the surfaces by hand brooming, and the devices used for spreading cover aggregates are the simple, push-type, rubber-tired spreader boxes, hooked to and moved by a dump truck operated in reverse. The handcasting of cover aggregates would be much slower, leading to more idle time for the asphalt distributor, and would be wasteful of material. The results would be less acceptable. No change to more labor-intensive procedures was considered for this work.

IHA practice for the shaping of gravel road surfaces is now to use motor graders. It might be possible to achieve an equal surface contour by hand, using straight edges and crown templates, but only with extreme difficulty and at much higher cost. Approximation shows a cost by grader about one-thirtieth of that for hand labor. The mixing and distributing effects as the gravel is moved across the road by a grader, and the appreciable compaction under the blade and tires, could not be duplicated by any practical means. The same considerations apply to the laying and shaping of new gravel during periodic resurfacing of such roads. In addition to the shaping of the surface, the watering and rolling assumed necessary to gravel resurfacing would not be practical as hand operations.

Maintenance cost estimates for both activities were based on the use of machines plus normal amounts of unskilled labor.

It is possible that total grader hours for gravel road maintenance could be reduced somewhat by the use of truck-towed drags, and the IHA has experimented with this. The cost of the drags is modest and the practice is applicable on some road sections when the surface is too dry or too wet for effective grading. The truck investment and operating cost is, of course, considerably less than that for a grader. Testing of different drags should certainly continue, but since no standard method has yet been adopted no estimate was made substituting some dragging frequency for part of the normal grader time.

Routine brush clearing on Ethiopian Roads is now done by labor crews. The IHA has no power mowers and no equipment for chemical spraying. Continuation of hand procedures was recommended, considering the relatively narrow shoulders and vegetation types prevailing.

The annual shoulder shaping along asphalt highways might possibly be considered for labor methods. It would certainly cost more to achieve equal uniformity by handwork, but since surface quality is not critical for shoulders an equal-cost operation might be satisfactory. However, the Consultants did not compute a comparison because the shoulder work is normally done in conjunction with regular ditch cleaning, recommended as a machine operation. It appeared that any small marginal advantage in doing shoulder shaping by hand would be lost in attempting to do the work separately from the ditch maintenance.

Regarding the ditch maintenance itself, a comparison of cost per lineal meter was made using assumed crews according to IHA practice and the production rates subsequently estimated for both hand and machine methods (rolling terrain). Both of these were later recommended for use, under different sets of conditions. The grader would normally work the full length of the ditch section to be cleaned, whether or not it was silted throughout, whereas labor crews would only clean those parts which had material to be removed. After adjusting for that difference of length covered per day, it was found that the cost by labor crews

would be approximately three times that for the machine operation. The computation can be derived from the data given in Sections III-F and III-G, for primary ditch cleaning by hand. It was felt that this direct-cost differential would outweigh any advantage to the national economy from labor utilization, and it was recommended that primary ditches be maintained by grader whenever technically feasible. All primary ditches in mountain terrain, and all others which were rocky and uneven, or which had paved channels or check dams to control erosion, would be cleaned by hand. It was assumed that all secondary ditches should be cleaned by labor, since these consisted of crown ditches on the tops of cut slopes, and outer longitudinal ditches beyond the cleared right of way, which would usually be difficult to reach and work by machine.

It was considered that all culvert maintenance should be done by hand methods. The cleaning of culverts is normally done in this manner, and the IHA has no special equipment, such as the "Gradall" for this work. Culvert repair and replacement in Ethiopia is predominantly mortar masonry construction.

Bridge upkeep is also primarily labor-intensive, but it was assumed that clearing channels under and near bridges, and necessary channel-changes, would usually have to be done by heavy equipment.

The transport of gravel and other materials by laborers or animal-drawn vehicles was rejected as impractical and inconsistent with the more rapid machine methods for placing. The present and anticipated investment in equipment could not be economically utilized unless enormous numbers of carriers were used.

Truck-loading by hand was considered as a substitute for the use of rubber-tired or crawler-mounted front-end loaders. These machines commonly have a bucket size of about one cubic meter, and loading loose material from a stockpile to a standing truck they will complete a cycle in 30 to 50 seconds. Using a cycle time of one minute to compensate for loss of power at altitude and for operators of ordinary skill, a six m^3 truck could be loaded in six minutes. With a total estimated cost per day of E$131 for loader and operator, the cost per 6 m^3 load would be E$1.87. In the hand excavation of ordinary earth or soils, as for ditches

and foundations, it was assumed throughout this study that the normal production for a laborer would be about one cubic meter per 7-hour day. It was estimated that this rate might be increased to 4 m^3 per 7 hours when loading loose material from a stockpile. This amounts to about 0.0095 m^3 per minute, or 0.057 m^3 per man in 6 minutes. The loading of a 6 m^3 truck in the same time as by machine would therefore require about 105 laborers. At a daily rate of E$1.10, the wage paid by IHA for temporary workers, the cost of 105 men for 6 minutes would be E$1.70, and the additional cost for a labor foreman about E$0.11. Ignoring overhead charges in both cases, the cost for hand-loading would then be about the same as that for the machine (E$1.81 versus E$1.87 per truck load).

However, a serious difficulty exists in that it is patently impossible to work 100 men around a truck. The greatest practical number would be about five on one side or around the back, and pit operations would be greatly complicated by trying to keep stock piles on both sides of a loading lane, at the right distance for shoveling, so that 10 men would have working space. Five men would need 2 hours and 6 minutes to load the 6 m^3 truck. The labor cost would be the same per truck load presuming that a foreman would still be needed for five laborers, but the truck rental for 2 hours of standing time, if charged at normal rates, would be about 16 times the cost of the labor for loading. There is a question of whether truck rental should properly be charged if the vehicle is not operating, but it is plain that to haul an equivalent volume of material, about 20 hand-loaded trucks would be needed to replace one machine-loaded vehicle. This equipment requirement alone seemed sufficient reason to discard handwork as a general means of loading materials in quantity. Naturally, some hand-loading of limited volumes will always be necessary, but truck loading was normally estimated as a machine operation for maintenance activities.

Considerations of other hypothetical procedures showed that extensive substitution of labor would not be economical or feasible in the production of aggregates. For emergency work such as slide removal, it was assumed that the need to restore traffic service quickly would dictate the use of equipment.

As a summary, the following list gives the recommended methods for the various maintenance functions:

A.	Routine Maintenance	
	o Surface patching, asphalt	Labor plus simple equipment
	o Surface grading, gravel	Machine
	o Brush control, all road types	Labor
	o Culvert cleaning, all types	Labor
	o Culvert repair, all types	Labor
	o Primary ditch cleaning	Machine (5% by labor in flat and rolling terrain; 100% by labor in mountain)
	o Secondary ditch cleaning	Labor
	o Shoulder grading, asphalt roads	Machine
	o Bridge maintenance, all types	Labor
	o Channel maintenance, all types	Machine
B.	Periodic Maintenance	
	o Seal coating, asphalt	Machine plus extensive labor
	o Shoulder reconstruction	Machine
	o Resurfacing gravel roads	Machine
C.	Special Maintenance	
	o Retaining wall repair	Labor
	o Excess brush growth	Labor
	o Slide removal	Machine and labor
	o Flood repair	Machine and labor
D.	Supplementary Operations	
	o Truck loading	Machine
	o Aggregate production	Machine plus extensive labor

F. Annual Maintenance Effort by Road Types

1. Asphalt Patching

The first work item quantified in terms of estimated annual effort was the surface patching of asphalt pavements (road types 1 and 2). This was first determined as square meters per kilometer which would have to be patched under different conditions. A standard crew for the work was then assumed, including necessary equipment. A production rate was estimated, and the quantities of materials needed. The annual effort per km could then be expressed in crew-days, and the labor, equipment and materials for this unit of measure would be known. These components were priced in subsequent steps.

Existing pavement widths were taken to be about seven meters, based on the 1971 condition surveys. An initial inspection of IHA reports indicated that patching rates as a percentage of total surface area were much in excess of ordinary pavement maintenance in other parts of the world. An extensive search was then made of the detailed monthly reports from the IHA Districts which have paved routes. Square meters of patching accomplished in recent years were totalled for specific road sections of known characteristics, looking for correlations with age, climate, traffic and construction standards. Road sections known to be seriously distressed or to be typical because of very poor subsoils or heavy traffic (in relation to design) were excluded, since normal averages were desired.

The first calculations of m^2/km/year of current and past work showed large variations and poor correlations with age and climate. The data was further studied to eliminate any exceptional efforts reported, such as patching in preparation for seal-coating, the catch-up of patching which had been deferred for two or more years, or anomalous sections mistakenly included. IHA patching procedure was inspected and district personnel consulted to determine how patching was measured for the reports. Good correlations were still not obtained, indicating that Ethiopian pavements are subject to a wider range of problems and variables than is normal. However, after the examination and adjustment

of all collected data it appeared reasonable to adopt the percentages and square meters per km given below. These represented necessary annual patching, assuming 7,000 m^2 of surface per km.

	Type 1 Roads	
Dry climates	1.25 percent	= 87.5 m^2/km/year
Moderate	1.75 percent	= 122.5
High rainfall	2.50 percent	= 175.0

	Type 2 Roads	
Dry climates	2.0 percent	= 140.0 m^2/km/year
Moderate	3.5 percent	= 245.0
High rainfall	5.0 percent	= 350.0

The total areas would be made up of two types of patches, determined to consist of about 30 percent by area of dug patches (for holes and breaks) and 70 percent skin patches of the bitumen-aggregate type.

The standard recommended labor and equipment force was established as shown on the estimate sheet for this work in the Engineering Appendix. Great difficulty was experienced in fixing a reasonable daily production rate for such a crew, even though it conformed generally to present practice. The work reported by section crews seemed consistently more than could be expected from the methods and resources used. Crew foremen were interviewed and inspections made of work in progress in an attempt to resolve this question. Estimates were made of theoretical production by different methods for comparison. From these investigations it was finally assumed that, under average conditions, the standard crew should do approximately 40 m^2 of dug patches plus 100 m^2 of skin patching per 7-hour shift. This rate was substantially less than that usually reported by the field crews, but the adopted annual rates of required patching were also less than the reported work on the roads, in about the same proportion. The adopted requirement figures of the table were divided by the assumed production rate to obtain the fractional numbers of crew-days per km per year needed to do the work. These are given in Exhibits III-B-1 and III-B-2 in the Engineering Appendix.

2. Brush Control

A search was made for data on brush-cutting reported by the Districts in recent annual periods, but these figures were in linear units (meters or kilometers) and were not useful as a guide, since it was obvious that the densities of growth would vary greatly. The total work programmed for recent annual periods over the whole road system was obtained in m^2 and used as a control, assuming that all necessary brushing was being scheduled and accomplished. That part identified as "sight distance improvement" was classified as betterment and excluded.

It was first assumed that brushing would vary more or less directly with rainfall. However, investigation showed that in some cases the densities and growth rates were more related to soil types and plant varieties. As a means of dealing with this irregular pattern, it was decided to estimate normal minimum brushing quantities by climatic zones, and to add a Special Maintenance cost where there was excess growth.

Using such information as was available, it was determined that normal brushing in all dry weather zones would be about 200 m^2 per km per year, with a density which would permit a daily production of approximately 500 m^2 per laborer. All roads in moderate rainfall zones were estimated to have double that area to be cleared, with an equivalent density. For high rainfall areas, the figures indicated there would be roughly 1,000 m^2 of clearing to be done annually on each km of road, and of a heavier growth so that production would drop to around 350 m^2 per man-day.

For those specific lengths of road with an unusual brush growth, it appeared that the above quantities should be increased by 2,000 m^2 per km in moderate climates and by 1,400 m^2 per km in wet areas. The vegetation would be the heavier density in both cases (350 m^2 per man-day of production). This was added as Special Maintenance where required.

In all instances, the annual effort in crew-day per km was derived by assuming a work force of 10 laborers, with necessary transportation,

as shown on the estimate sheet in the Engineering Appendix. The normal annual brush control for road types 1 through 6 are indicated on Exhibits III-B-1 through III-B-6.

3. Culvert Maintenance

The regular cleaning of culverts, and repairs to these small structures, were treated as separate activities to be done by different work groups. The annual effort would be reasonably uniform for all road types since, if fully constructed, they would all have about the same numbers of drainage crossings and culverts. The annual quantities would vary with topography, the frequency of natural channels being determined by the land-forms. In addition, the volumes of sedimentation to be removed would also increase with total annual rainfall, the transporting agent for sediments.

Particular road sections in the three topography classes will have considerable variations in the numbers and sizes of culverts in place, but the statistical averages for many sections taken together are normally quite regular. The IHA logs of culverts and bridges were examined to confirm the usual patterns of culvert occurrence, and the range was found to be from 0 to 12 per km for all terrain classes, with a normal frequency of from 2 to 5 or 6. This was about as expected, but the usual correlation with topography did not appear. No good explanation was discovered for this, but in part it seemed to be due to some road locations following ridges (drainage divides) and to the extensive use of fords on others. The distinction was considered to be necessary for part of the estimating process, and so it was arbitrarily assumed that the average numbers of culverts (of mixed sizes) would be three in flat terrain, four in rolling, and five in mountain.

Maintenance accounting does not normally report the volumes of silts removed from culverts, but the IHA "Condition Surveys" of 1971 seemed to offer a means of quantifying this work, and were examined. There were large differences between districts in the manner of reporting and, apparently, the bases of estimating sedimentation, and these discrepancies reduced the size of meaningful samples. The detailed

work reports of past years were checked, and all other information sources which would help to clarify the picture. From this analysis the best and most useful groups of samples were in rolling topography/wet climate (13 highway routes totalling 1,070 km), rolling topography/moderate (5 routes; 430 km), and mountain topography/wet climate (5 routes; 383 km). Based on these and supplemental data, a range of annual quantities was established, for three terrain classes within each of three climatic zones, in m^3 per kilometer. These were:

	Dry Climates	Moderate	Wet
Flat	0.50 m^3/km	0.55 m^3/km	1.00 m^3/km
Rolling	0.75	0.75	1.35
Mountain	1.00	1.15	2.10

A standard work crew consisting basically of 10 laborers was a adopted, as indicated in the Engineering Appendix. The sediments in culverts would normally be fairly loose and easily dug, but often difficult to reach inside the structures, so the basic production rate of one m^3 per man-day was used. The above volumes in m^3 per km were therefore divided by 10 to convert to annual crew-days per km.

The repair and replacement of culverts is not usually an important item of maintenance, but in Ethiopia there is presently a large annual expenditure for mortar masonry, and it was known that most of this was for culvert maintenance. Examination of the IHA culvert logs disclosed that, in all Districts, at least 85 percent of all culverts are basically of masonry construction. Originally these were built with arched masonry roofs and most still have these, although some have been replaced with reinforced concrete slab roofs or corrugated metal arch tops. Complicating the situation somewhat, there are major sections of road constructed in later years on which practically all minor culverts are round pipe, and on all roads there are significant numbers of CMP and concrete pipe culverts. In any event, the predominance of the masonry type and the age of most existing structures made it necessary to estimate their annual maintenance.

Using the same numbers of culverts per kilometer by topography classes, it was assumed that the maintenance effort would be proportional to those numbers and the average dimensions of the structures. Analysis of the IHA culvert logs gave an average span of 1.3 meters for arch culverts. Lengths were highly variable depending on type of headwall, depth of fills and the flow-line gradient, but appeared to range from 10 to 15 m in flat terrain and 10 to 50 m in mountain terrain. The averages were taken to be approximately 12 m in flat terrain, 14 m in rolling terrain and 19 m in mountain terrain. Reasonable figures for the cross-sectional area of the masonry mass for a 1.3 m span showed that the portions subject to repair would have a masonry volume of around 1 m^3 per linear meter of culvert length. It was estimated that the service life of such culverts would be 40 years, so that 2.5 percent of the mass might be renewed each year, or the entire structure after 40 years, on some combination of these.

This estimated rate was supported by taking the total mortar masonry requirement identified in the District "Condition Surveys," and attempting to adjust and distribute the quantity. Calculations were first made to subtract the amounts which might go into retaining wall and masonry bridge repairs. The remainder was further reduced by 50 percent to 60 percent assuming that the district surveys had listed an accumulation of needed work two or 2-1/2 times the annual requirement. This reduced total was then in fair agreement with the quantity which the 2.5 percent annual failure rate would give for the existing system with its lengths in different terrains.

The numbers of structures per km times their average lengths and the 2.5 percent rate gave the following estimates of m^3 of mortar masonry to be replaced each year:

Road Types 1 through 4, all Climates

Flat	3 x 12 x 0.025	= 0.90 m^3/km
Rolling	4 x 14 x 0.025	= 1.40
Mountain	5 x 19 x 0.025	= 2.40

It was assumed that Type 5 and 6 roads would require an equivalent effort and cost, whether applied to culverts, fords, or other drainage provisions.

A standard crew consisting of masons and laborers was adopted for this work, and information from both IHA and commercial sources indicated that such a crew (described in the Engineering Appendix) should accomplish about 3.2 m^3 per day of the type of masonry required. This was rounded to 3.0 for converting m^3 per km to annual crew-days per km, as given in Exhibits III-B-1 through III-B-6.

4. Ditch Maintenance

The regular cleaning of all ditches is an important activity which varies according to the length of ditch present, fixed largely by the landforms, and the annual incidence of rainfall as a transporting agent for sediments.

After discussions with District field personnel and some preliminary computations, primary ditch lengths were estimated as follows:

Flat Terrain--Normally with ditch on both sides for about three-fourths of the road length, or total ditch length 150 percent of road length (1,500 l.m of ditch for each km of road).

Rolling--Usually with ditch on both sides for about 60 percent of the length or 1,200 l.m of ditch per km of road.

Mountain--The average condition was assumed to be ditch on one side for the full length, or an equivalent arrangement, giving 1,000 l.m. of ditch per km of road.

Not all of the existing length would need cleaning each time the work was repeated because some parts would not be subject to silting. Substantial ditch length in Ethiopia has a natural turf which protects it from erosion, and this should not be disturbed more than necessary. From the investigation of field conditions the standards below were adopted.

Dry Climates--60 percent of existing ditch to be cleaned once every 2 years.

Moderate and Wet Climates--50 percent of existing ditch to be cleaned twice each year, before or after each of the two rainy periods.

Generally, in all flat and rolling terrain, 95 percent of the primary ditch length can be worked by motor grader, with the other five percent requiring hand cleaning. In mountainous areas practically all primary ditch is now cleaned by hand, and this practice will probably have to be continued indefinitely because the ditches are usually of small dimensions, and are often rocky and irregular, or paved.

The lengths of ditch in the different terrains multiplied by the percent to be cleaned each time and by the annual frequency according to climate gave the total lineal meters of primary ditch cleaning per km per year. One further multiplication (by 0.95 or 0.05) indicated the part to be done by machine or by labor outside of mountain topography. In addition, it was assumed that, in flat terrain only, an average of one culvert channel per km would have to be cleaned by motor grader for a distance of about 100 meters, on either the inlet or outlet side. This amount was added to machine ditch work for that topography class, and the total estimated lengths to be cleaned annually are shown below:

Road Types 1 through 5, l.m per km per Year

Flat Terrain	By Grader	By Labor
Wet climates	1,525	75
Moderate	1,525	75
Dry	528	22
Rolling Terrain		
Wet climates	1,140	60
Moderate	1,140	60
Dry	340	20

Mountain Terrain	By Grader	By Labor
Wet climates	-	1,000
Moderate	-	1,000
Dry	-	300

The crew for primary ditch cleaning by machine would consist only of a motor grader with an operator and one assistant, as indicated in the Engineering Appendix. There was general agreement that the length which could be cleaned in one day would vary according to topography (because of the effect of curves and grades) but the production rates reported by field personnel seemed to be quite low in comparison with machine capabilities and normal yields in general road maintenance. The following compromise rates in lineal meters per day were adopted:

Flat terrain	4,000
Rolling terrain	2,500

The Appendix includes an estimate sheet for hand-cleaning primary ditches, and this shows the standard crew assumed for the work. The whole ditch length to be cleaned was estimated to have an average of 0.07 m^3 of sediments per lineal meter, and it was felt that one laborer could remove two m^3 per day of this material. The daily production rate for a 10-laborer crew was therefore 286 l.m. per 7-hour day.

Dividing the appropriate quantities by the applicable production rates gave the annual requirements for primary ditch cleaning by machine and by hand, in crew-days per km, for road Types 1 through 5, Exhibits III-B-1 through III-B-5. Type 6 roads were arbitrarily assumed to have only 75 percent of these requirements.

Secondary ditches, consisting of intercept channels above cut slopes and in other locations, would be cleaned by hand only. The same crew would be used as for hand-work on primary ditches, and with the same production in m^3 per day.

The total length of secondary ditch per km for major roads was assumed to be 100 lineal meters in flat terrain, 250 in rolling, and 300 in mountain terrain. Of these lengths, 50 percent would have to be

cleaned once annually in high rainfall zones, and 25 percent in moderate or dry climates. Crew-days per km per year, as shown in the exhibits of maintenance effort and cost for the four principal road types, were derived by multiplying assumed length by percent to be cleaned, and dividing the resulting lineal meters by the daily production rate. This requirement was reduced by 50 percent for Feeder roads (Type 5), and eliminated entirely for Service-to-Traffic roads.

5. Shoulder Grading, Asphalt Roads

This work item was estimated only for road Types 1 and 2, since the shoulder areas of gravel roads would be maintained as necessary in the course of surface grading. Much of the shoulder alongside asphalt surfaces would be shaped at the time of primary ditch cleaning, twice yearly for most routes, and the Consultants felt that this should satisfy much of the requirement. However, it was assumed that every other year some new material (select) would have to be added and the shoulders graded over all their length, as a separate operation from ditch work. The requirement would be roughly the same in all climates and terrain classes, with the higher rainfall of wet areas balanced by plant cover, and the more rapid erosion on grades offset by the generally narrower shoulders in rolling and mountain topography.

Survey data from the IHA District offices shows the shoulder widths to be quite irregular, and usually less than the minimum desirable. A general average width of one meter was adopted. A loss-rate of 2.5 cm of depth per year was estimated, from the effects of weather and use by pedestrians, animals and vehicles. This was equivalent to 50 m^3 per km per year for 2,000 m^2 of area.

A standard work force of men and equipment was assumed, and is described on an estimate sheet in the Engineering Appendix. The lineal meters of shoulder worked by such a crew in one day would be somewhat different in the three terrain classes, since curves and grades would slow both the hauling speeds and placing of the material. Despite this, a single average production rate of 12,000 l.m. per day was assumed to avoid having variable numbers of trucks for the haul requirements

of one shift of grader time. Since 12,000 l.m. of shoulder would be 6 km of road length, one-sixth of a crew-day would be needed per km for each repetition. Doing the work every second year, the annual effort would be 0.084 crew-days per km. See Exhibits III-B-1 and III-B-2.

6. Surface Grading, Gravel Roads

Grading is the most expensive routine activity on gravel roads, and a careful balance must be found between the needs and desires of road users and the budget limitations of the maintenance agency. At the same time, there is no precise method of determining how often the work should be done, since the changes which take place after shaping are of several kinds, and occur slowly or rapidly depending on conditions. Some changes contributing to the decline of surface quality will stabilize after a short period, while others become more severe at a steady rate. The conditions which cause the changes vary by routes and areas, and even from one kilometer to the next on the same routes. The frequency of blading is usually left to the judgment of maintenance supervisors, and must be to a large extent, but it is desirable to have reasonably uniform standards and results in all districts and throughout the system.

Because of variations in climate, materials, and traffic, the IHA has not established schedules for this activity, and the programming and reporting of surface grading (in hours) does not present any definite picture of effort in relation to specific factors affecting the surfaces. In general, during the dry seasons when blading is not very effective and the surface quickly goes back to a rough condition, the District Engineers have found it necessary to reshape the roads every seven to ten days whenever the traffic volume is appreciably more than 100 ADT. This order of frequency is not unusual in normal maintenance practice, though it often results more from public pressures than from demonstrable results in comparison with costs. Clearly defined wheel-paths are normal to gravel surfaces, along with some corrugations and loose material, and these characteristics, in combination with higher rolling resistance and reduced tire life, account for the normal differences in vehicle operating costs between paved and gravel roads.

The established IHA practice is to do only "light" blading when the surfaces are very dry, redistributing loose gravel to fill irregularities without attempting to cut into the corrugations or reshape the compacted surface. This is a minimum-cost operation which improves the travelway substantially, and while the results are not long-lasting, there is little else that can be done at such times. When adequate moisture is present "heavy" blading is done at longer intervals, the surface being reworked to a greater depth and the cross-section restored as necessary.

In fixing the recommended frequencies for surface blading in Ethiopia, the Consultants examined and considered the IHA methods, the types of material available, traffic volumes, climate, vehicle speeds and other factors. It was apparent that frequency of blading should vary depending on conditions, but for an initial index it was considered that Type 4 gravel roads (average ADT 40 to 100) on flat terrain in moderate rainfall zones should be graded about every 21 days during the dry seasons, and at intervals about twice that long, or every six weeks, in the rainy periods. The total annual time when moisture would be sufficient to allow "heavy" blading was taken to be four months. This gave an average of 11 repetitions in eight dry months and another three in the wetter period, or 14 per year. Based on a range of 40 to 100 ADT, or an average of 70, the 21-day cycle in dry seasons would provide for reshaping after approximately 1,500 vehicles had traveled over the road.

The same frequencies were applied to Type 4 roads in high rainfall zones, but it was assumed that heavy blading could be done during five months of the year, or four different times, and in the seven drier months light blading would be repeated 10 times.

In areas of dry climate these same assumptions would give about 17 repetitions per year, but this was considered excessive, especially since most Ethiopian gravel roads in dry regions have less traffic than elsewhere in the nation. Twelve repetitions were assumed for these sections, with one considered to be heavy blading after rains. At a volume of 50 vehicles per day, this 1-month cycle would again provide reshaping after every 1,500 vehicles.

Increasing traffic volumes multiply the problems of maintaining good running surfaces on gravel, but the index of 1,500 vehicles cannot be economically applied on heavily-traveled roads because it would quickly lead to almost constant blading. The results are not commensurate with the cost, and repeated blading of dry surfaces causes excessive loss of fines and loose gravel. Between 100 and 300 ADT (Type 3) it was considered that surfaces should be light-graded every two weeks, or more thoroughly worked once a month when the moisture content would permit. In moderate rainfall zones this would result in 16 light and four heavy bladings annually. With high rainfall, this would become 14 light and five heavy bladings. The grading of high-volume gravel roads in dry-climate areas was again set arbitrarily, at 26 repetitions per year, or one every two weeks. One of the 26 repetitions was assumed to be heavy grading after rains.

The crew for reshaping gravel surfaces would consist only of a grader operator and an assistant, with a motor grader, as set forth in the Engineering Appendix estimate sheet. To fix a daily production rate, the activity was discussed with IHA administrators and field personnel, and work on the road was observed in progress. Naturally, the daily accomplishment was found to vary with the surface width and number of passes required (three to five), with the quality and distribution of the surfacing and, to a lesser extent, with topography. Taking all major factors into consideration, the average production per 7-hour day for all gravel surfaces (widths six to seven meters) was estimated to be 11 km of light blading or six km of heavy. It is obvious that these rates would be achieved only with sufficient material on the road to permit normal operation.

The annual requirements in crew-days per km for Type 3 and 4 roads were computed by dividing the numbers of repetitions of light and heavy blading for each climate zone by the corresponding production rates and summing the results, as shown below.

Type 3 Roads (ADT 100 or more)

Dry Climate Zones

Light: 25 ÷ 11 km/day = 2.273
Heavy: 1 ÷ 6 = 0.167

2.440 crew-days/km/year

Moderate Rainfall Zones

Light: 25 ÷ 11 = 1.454
Heavy: 4 ÷ 6 = 0.667

2.121 crew-days/km/year

High Rainfall Zones

Light: 14 ÷ 11 = 1.273
Heavy: 5 ÷ 6 = 0.833

2.106 crew-days/km/year

Type 4 Roads (ADT under 100)

Dry Climate Zones

Light: 11 ÷ 11 km/day = 1.000
Heavy: 1 ÷ 6 = 0.167

1.167 crew-days/km/year

Moderate Rainfall Zones

Light: 11 ÷ 11 km/day = 1.000
Heavy: 3 ÷ 6 = 0.500

1.500 crew-days/km/year

High Rainfall Zones

Light: 10 ÷ 11 km/day = 0.909
Heavy: 4 ÷ 6 = 0.667

1.576 crew-days/km/year

At the time of the study, very few roads of Types 5 and 6 were under IHA responsibility and receiving normal maintenance. Thus, it was difficult to establish the comparative grading requirements for these types. Based on the narrower surface width (six meters) and the generally lower traffic volumes, the numbers of crew-days per km were arbitrarily reduced, and computed as percentages of the requirements for Type 4 roads; 75 percent for Type 5 and 50 percent for Type 6. The total annual crew-days per km used were:

	Type 5	Type 6
Dry climate zones	0.875	0.584
Moderate rainfall zones	1.125	0.750
High rainfall zones	1.182	0.788

7. Spot Regraveling

On all gravel roads, there is a constant need to add small quantities of surfacing material to correct localized erosions, to fill depressions, and to cover short sections which are slick, unstable or excessively rough. In addition to this normal requirement, the rate at which surfacing is lost in Ethiopia due to weather, traffic, and other factors suggests that a good part of this longer-term loss should be replaced each year. Annual replacement would be less economical than well-planned gravel resurfacing at intervals of several years, but the condition of many roads now maintained is such that replacement of annual losses cannot be deferred until a regular cycle is established. Present circumstances do not permit all the gravel roads to be brought to normal standards of surface thickness and given some reserve to allow for wear until the next scheduled resurfacing. This situation can only be improved gradually and, for the present, it appears necessary to divide the available resources and give some annual attention to the worst sections of all gravel routes. By this is meant a more intensive spot regraveling than is usual for such roads, with larger quantities of material placed.

Although the total volume of gravel per km would be significant and would be concentrated on the sections of most rapid wear or greatest distress, the average thickness placed would be quite small. Watering and rolling would not be justified, and it was assumed that spreading would be combined with regular surface grading of the roads. The work, therefore, would consist only of the production and transport of material. Naturally, whenever possible placing should be done when natural moisture conditions would allow proper mixing of the new gravel with the old surface and reasonable compaction under the grader and traffic.

The annual loss-rates of gravel surfacing were considered in detail, and are estimated later for the different road types under the periodic maintenance item "gravel resurfacing." It was concluded that about one-third of the yearly loss should be made up in the routine maintenance. The assumption was made that this quantity would also take care of localized base failures, small erosions and other problems normally handled by spot regraveling.

Annual loss-rates of surfacing were estimated in centimeters per year of thickness lost across the full travelway width, taken to be an average of seven meters for all Type 3 and 4 roads. One centimeter of loss would therefore represent 70 m^3 per km. The total estimated yearly loss-rates are shown in a table below. These were multiplied by 33 percent to get the amount to be replaced in this work item, and by 70 to obtain the annual quantity in cubic meters for spot regraveling.

No conversion from loose to compacted volume was assumed, since the material would be only semi-compacted during placement. However, the estimated quantities lost were increased by 15 percent because the original surfacing was assumed to be of higher density.

A typical crew was assumed for loading, hauling, and tailgating the material, as shown on the Estimate Sheet in the Engineering Appendix. A production rate for the crew was calculated to be about 200 m^3 per day, based on loader capacity, standard assumed haul distances, and a reasonable number of available trucks.

The conversion from loss-rate in centimeters of depth to crew-days for the work consisted of computing the quantity required in m^3/km/year and dividing this by the daily production rate. For Type 3 and 4 roads, the quantities in place were calculated by multiplying the total annual loss-rate by 33 percent and by 70 m^3/km to get total m^3/km/year for the different climate and topography classes. This was then converted to work requirements in crew-days for the loose volume by applying the factor 0.00575 (which was 1.15 ÷ 200). The resulting quantities are shown below:

Type 3 Roads (ADT 100 or more)

	Total Loss-rate (cm/yr)	Spot Regraveling (m^3/km/yr)	Crew-days per km (per year)
		Dry and Moderate Climates	
Flat	3.25	75	0.431
Rolling	2.75	64	0.368
Mountain	2.50	58	0.334
		High Rainfall Zones	
Flat	3.90	90	0.518
Rolling	3.30	76	0.437
Mountain	3.00	69	0.397

Type 4 Roads (ADT under 100)

		Dry and Moderate Climates	
Flat	1.95	45	0.259
Rolling	1.65	38	0.218
Mountain	1.50	35	0.201
		High Rainfall Zones	
Flat	2.60	60	0.345
Rolling	2.20	51	0.293
Mountain	2.00	46	0.264

The annual days of effort for spot regraveling on Type 5 and 6 roads were reduced because of their narrower surface widths and lower traffic. For the equivalent climate and topography classes, those on Type 5 were set at 75 percent of the requirement for Type 4 roads, and those on Type 6 at 50 percent of the estimate for Type 4 roads. All crew-day quantities are indicated on Exhibits III-B-3 through III-B-6 in the Engineering Appendix.

Although the quantity required, and therefore the annual effort, is not affected by the type of material used for regraveling, the cost obviously will depend on the source and how the material is produced. The later cost estimates of this report section are based on the use of processed select material for spot regraveling on Type 3 and 4 roads (oversize crushed and excess fines removed) and of bank-run granular materials for Types 5 and 6. The crew-days of work include only the loading of the material from a stockpile, plus transport to where it is placed. Production of the stockpiled material is estimated separately.

8. Miscellaneous Routine Maintenance

As stated previously under Section III-C, provision was made for including some effort and cost to cover the maintenance of bridges and channels plus, when necessary, other miscellaneous activities such as work on signs, markers, guard railings, fences, and so on.

Both of these work-groups are highly variable from one route or section to another, and have no obvious relationship with the different road type classifications. It was recognized that work and cost for bridge maintenance would be concentrated where the structures occur, and that most segments of road would not have these expenditures. However, the methodology required a distributed average effort for all segments. This was quantified by attempting to obtain from the records the current total annual cost of bridge and channel maintenance, and expressing this as a percentage of the estimated total annual cost for culvert maintenance as derived in Section III-F-3 above. This percentage was then increased by a modest amount to provide for improved care

and protection of the structures and their waterways. The figure finally adopted for road Types 1 through 6 was 22 percent of the cost of Routine Maintenance Items 3-a and 3-b, culvert cleaning and culvert repair (see Section III-G, "Maintenance Costs"). Labor, equipment, and materials needs, as opposed to monetary cost, were obtained by using an assumed crew for such work.

The budgetary cost of "other routine miscellaneous maintenance" for road Types 1 through 4 was taken to be 2.5 percent of all routine maintenance activities 1 through 4 (comprised of surface, brush, culvert, and ditch maintenance). The 2.5 percent approximated the current IHA expenditures for signs, markers, and so on. Labor, equipment, and materials were again quantified through the use of an assumed crew. No costs or resource needs for "other routine miscellaneous maintenance" were included for Feeder standard or Service-to-Traffic roads. With this exception, the appropriate percentages for the two items are indicated in Exhibits III-B-1 through III-B-6 in the Engineering Appendix.

9. Periodic Maintenance, Asphalt Seal Coating

Established maintenance practice dictates that asphalt surfaces be sealed at intervals of several years, to prevent the passage of water, rejuvenate the oxidized bitumen, and restore the wearing surface. Although this need is clearly recognized by the IHA, it was the observation of the Consultants that the need has not been met in recent years. Because of the lack of resources, long sections of pavements have been left unsealed for many years, and the resulting deterioration is evident in cracking, raveling, and surface failures due to the penetration of rainwater. It was presumed that the worst of this distress would be corrected in rehabilitation projects, but there was an obvious necessity to make provision for this work in the list of maintenance activities for road Types 1 and 2.

The past programs of the IHA did not furnish a guide to the required frequency for this item under Ethiopian conditions, but the general experience of maintenance practice was felt to be applicable with

respect to interval. It was concluded that all asphalt pavements in dry weather zones should receive a simple seal coat once every 5 years, and that those in moderate and high rainfall areas should be sealed every 4 years. In both cases the surface seal would consist of a full-width uniform application of bitumen followed by crushed stone cover aggregate. In addition to this, the past performance and existing condition of Ethiopian pavements in moderate and high rainfall zones appeared to indicate a general need for a preparatory leveling course preceding the seal coat on all such pavements, regardless of age.

The leveling course is not an ordinary requirement for periodic asphalt maintenance, particularly on surfaces less than 10 years of age. It is not a universal necessity in humid areas of Ethiopia, but the need seems to be so widespread on the pavements in these zones as to justify adopting it as a standard. It appeared from the information available that the use of light-duty pavements (double surface treatments) in moderate and high rainfall areas has persistently resulted in localized surface and base failures, excess patching needs and small relative distortions of the longitudinal and transverse profiles. This pavement type is fundamentally susceptible to damage from moisture, and unless the roadway designs and construction control are completely adequate these difficulties must be expected in regions with extended rainy seasons.

The leveling course specified in the Estimate Sheets of the Engineering Appendix is not intended to reinforce the pavement structure, being limited, as an average, to a depth of 2.0 cm over only 25 percent of the total pavement surface. The material called for is a fine-graded road mix (or pre-mix from a convenient mixing site nearby), to be distributed over the pavement surface with a motor grader prior to rolling. This method of leveling small deformations and improving surface quality prior to seal coating has been used by the IHA with good success.

Estimate Sheets showing labor, equipment, and materials were prepared for the leveling course and seal coat operations, separately. It was assumed that regular annual patching of the pavements would be done as routine maintenance in the years when seal coating was scheduled, and immediately preceding that work, in preparation for seal coating.

The daily production rate for the leveling course crew was estimated to be 1.8 km of total roadway length (normal seven-meter width). Each repetition would therefore require 0.556 crew-days per km. On a 4-year cycle, the prorated annual requirement would be 0.139 crew-days per km.

The sealing-crew production rate was taken to be 1.0 km per day, whether the work was done independently or following placement of a leveling course. Consequently, the prorated annual requirement would be 0.250 crew-days for a 4-year cycle (moderate and high rainfall zones), and 0.200 for the 5-year frequency in dry climates. The prorated annual effort is shown in the appropriate spaces of Exhibits III-B-1 and III-B-2 in the Engineering Appendix.

It is apparent that seal coating, like other periodic operations, will have to be programmed on long-term schedules, beginning with the sections now in greatest need and with an energetic effort during the next 2 to 3 years to treat all routes which are now showing some distress.

10. Shoulder Reconstruction

A review of IHA experience indicated a need to periodically reconstruct the shoulders and fill slopes along paved roads in dry climate zones, but only in flat and rolling terrain. This is due to an absence of plant growth in the drier areas, which leaves the slopes vulnerable to erosion from wind and from occasional high-intensity rains. The requirement was found to be unimportant in more humid climates, and in mountainous terrain of dry climates.

From estimates of erosion rates and average fill heights, it appeared that something like 300 m^3 to 500 m^3 of material would have to be replaced on each kilometer of road in flat terrain, about every 5 years. In rolling terrain, the fill heights would be greater, but less of the total road length would be in embankment section and this length would be less subject to erosion, consisting of relatively coarser material taken from cuts.

It was assumed that the 300 to 500 m^3 per km would be about 1 days production for a 100 H. P. crawler tractor with operator, and that the work would not involve any other cost. One day per km each 5 years prorated to an annual requirement gave 0.200 crew-days per km per year for flat terrain, and the effort in rolling terrain was set at one-half that amount. No estimate sheet was prepared, but crew-days are shown for item B-2 on Exhibits III-B-1 and III-B-2 in the Engineering Appendix. The cost can be derived from data presented later in Section III-G, "Maintenance Costs."

11. Periodic Gravel Road Resurfacing

The surface material on gravel roads is lost at a fairly constant rate through the action of traffic, rain, and wind. The fine particles are lost most rapidly, and faster than they are created by the wear and decomposition of the coarser sizes. Gravel has to be added to the surface periodically to preserve the bearing strength, and to maintain a reasonably fine-grained texture.

The rate at which surfacing is lost depends on traffic volume, vehicle speeds, the nature of the material, moisture content during the year, runoff velocities, and winds. The principal variables for which the effects can be estimated are ADT and general climate. Less important factors are difficult to isolate or tend to balance out, as when the higher erosion rates from rainfall on mountain grades and curve superelevations are offset by lower travel speeds.

Considering the probable annual loss-rates of gravel, an examination was made of resurfacing quantities placed on various roads of the present system in past years. It appeared that this record would not give a satisfactory guide, since the data was sometimes unclear and in other cases it was apparent that the material added over a period of time was less than that being lost.

Previous studies by the IHA and others have suggested a direct relationship between traffic volume and surface wear, of 2.5 cm per year of loss for each 100 vehicles per day. This appeared to be fairly realistic at modest traffic volumes, but would give unreasonable wear-rates with appreciable traffic (400 ADT would mean 10 cm lost each year).

In the experience of the Consultants, a better approximation would result from assuming a more dominant and more uniform effect from natural factors, with a significant influence by traffic, including vehicle speed.

For both Type 3 and Type 4 roads, it was assumed that the losses would be about the same in dry climates and in moderate rainfall zones for equal volumes of use. That is, that the loss on the drier and looser surface would be about the same as for the greater rainfall erosion of the slightly wetter climate. Considering all elements, the following basic annual loss-rates were estimated.

Type 3 Roads (ADT 100 or more)

Dry and moderate climates	- 2.5 cm/year
High rainfall zones	- 3.0 cm/year

Type 4 Roads (ADT under 100)

Dry and moderate climates	- 1.5 cm/year
High rainfall zones	- 2.0 cm/year

The above basic rates were modified for the pronounced effect of higher vehicle speeds by assuming that in flat terrain all rates would be increased by 30 percent, and in rolling terrain by 10 percent. This gave the series of annual loss rates shown below:

Type 3 Roads (ADT 100 or more)

Dry and Moderate Climates		
Flat	2.5 x 1.3	= 3.25 cm/yr
Rolling	2.5 x 1.1	= 2.75 cm/yr
Mountain	-	= 2.50 cm/yr
High Rainfall Zones		
Flat	3.0 x 1.3	= 3.90 cm/yr
Rolling	3.0 x 1.1	= 3.30 cm/yr
Mountain	-	= 3.00 cm/yr

Type 4 Roads (ADT under 100)

Dry and Moderate Climates		
Flat	1.5 x 1.3	= 1.95 cm/yr
Rolling	1.5 x 1.1	= 1.65 cm/yr
Mountain	-	= 1.50 cm/yr
High Rainfall Zones		
Flat	2.0 x 1.3	= 2.60 cm/yr
Rolling	2.0 x 1.1	= 2.20 cm/yr
Mountain	-	= 2.00 cm/yr

The IHA design practice for gravel roads (primary and feeder) is to provide part of the bearing strength with "base" layers and the remainder with final surfacing. The latter is usually 10 to 15 cm in thickness. No excess depth is provided for anticipated wear.

Obviously, those routes with the higher traffic volumes should have the thicker bases and surfaces but, even so, at the most rapid loss-rates given above all of a 15 cm surfacing would disappear within a very short time, less than 4 years in the extreme case. It is apparent that resurfacing should not be delayed until the surface is so thin that the structural capacity of the road is jeopardized. It was assumed by the Consultants that the minimum thickness reached should be about two-thirds of the design requirement.

There is of course, a great variation in the depths of gravel which have been placed on different Ethiopian roads, as original or replacement surfacing. There is also a wide range in the thicknesses of remaining gravel but, generally, it is now substantially less than two-thirds of what the design requirement would be. In some cases even part of the base material has been worn away, so that there is an urgent need for doing what might be termed "deferred" maintenance, to restore the bearing strength and running surface of the road. In order to derive normal annual maintenance costs for economic analysis, such rehabilitation costs must be estimated separately (discussed elsewhere in this report) and the assumption must be made that all other gravel surfaces now

have at least the minimum thickness required for stability and normal blading.

One of the routine IHA maintenance activities is "spot regraveling" of unpaved roads, in which surface material is added to different short sections during each year, to correct base failures, cover bare stretches and reinforce thin sections. These surface additions are usually very limited in thickness and total area covered, but nevertheless have a substantial total cost. In part, this cost is due to the wide dispersion of the effort and material, applied to the scattered sections of most urgent need.

The cost per unit volume of gravel resurfacing in place on the road would be less if laid at intervals of several years, in larger quantities with a uniform thickness, and by organized work groups. However, in the present circumstances it clearly will not be possible to place immediately all the surfacing which is needed on the 4,900 km of gravel road under IHA maintenance. In view of this, the Consultants concluded that the "spot regraveling," a normal maintenance activity, should be continued indefinitely by the IHA as a regular annual means of replacing a certain part of the surface material lost each year. This would slow the decline in surface thickness which has been taking place, and would space out the scheduling of uniform-lift resurfacing. It was assumed that about one-third of the annual loss-rates for the different road types should be provided for in annual maintenance, (described in paragraph F-7 above) and the other two-thirds in quantity resurfacing at intervals of several years. Accordingly, 33 percent of the derived loss-rates were converted to m^3/km/yr to be placed as annual spot regraveling. The remaining 67 percent of surface wear should be replaced as a scheduled periodic maintenance activity, at intervals of several years. The average periods for different road types would be determined by the rates of loss and the minimum thickness which could be placed in an economical operation. The placement would have to include watering and rolling to achieve good results and to minimize the subsequent wear rates, and the total cost of producing, hauling, and laying suitable

material could not be justified for a thickness of less than 10 cm, especially for gradation-controlled gravel.

Dividing two-thirds of the various loss rates into the figure 10 indicated that the different classes of road should be resurfaced at intervals of from four to 10 years, at which time the 10 cm lift would replace two-thirds of the estimated surfacing lost in the intervening years. The approximate interval is shown for each type in the table below, in parentheses, but since it is prorated yearly cost which is desired for the effort and cost estimates, the annual loss rates derived previously were used directly (less the 33 percent placed in spot regraveling) to obtain m^3 per kilometer per year required. The conversion was made by multiplying by 70, the volume in m^3 for each centimeter of depth--loss for a travelway seven meters wide. The quantities were then rounded.

Type 3 Roads (ADT 100 or more)

		Resurface Cycle (years)
Dry and Moderate Climates		
Flat	3.25 cm/yr x 67% x 70 = 150m^3/km/yr	5
Rolling	2.75 cm/yr x 67% x 70 = 130m^3/km/yr	5
Mountain	2.50 cm/yr x 67% x 70 = 115m^3/km/yr	6
High Rainfall Zones		
Flat	3.90 cm/yr x 67% x 70 = 180m^3/km/yr	4
Rolling	3.30 cm/yr x 67% x 70 = 155m^3/km/yr	5
Mountain	3.00 cm/yr x 67% x 70 = 140m^3/km/yr	5

Type 4 Roads (ADT under 100)

Dry and Moderate Climates		
Flat	1.95 cm/yr x 67% x 70 = 90m^3/km/yr	8
Rolling	1.65 cm/yr x 67% x 70 = 75m^3/km/yr	9
Mountain	1.50 cm/yr x 67% x 70 = 70m^3/km/yr	10
High Rainfall Zones		
Flat	2.60 cm/yr x 67% x 70 = 120m^3/km/yr	6
Rolling	2.20 cm/yr x 67% x 70 = 105m^3/km/yr	7
Mountain	2.00 cm/yr x 67% x 70 = 95m^3/km/yr	7

A standard crew for resurfacing projects was established, and can be found in the Engineering Appendix. The daily production for a crew was estimated to be about 385 m^3 of gravel (loose volume) transported and placed, and this was converted and rounded to 325 m^3/day compacted in place. This rate, divided into the annual m^3 per km, gave the numbers of crew-days per km as the prorated annual effort required, although the work would actually be done in cycles of several years. The conversions for Types 3 and 4 roads were:

Type 3 Roads (ADT 100 or more)

Dry and Moderate Climates

Flat	$150m^3$km ÷ 325 m^3/day	= 0.462 crew-days/km/yr
Rolling	$130m^3$km ÷ 325 m^3/day	= 0.400 crew-days/km/yr
Mountain	$115m^3$km ÷ 325 m^3/day	= 0.354 crew-days/km/yr

High Rainfall Zones

Flat	$180m^3$km ÷ 325 m^3/day	= 0.554 crew-days/km/yr
Rolling	$155m^3$km ÷ 325 m^3/day	= 0.477 crew-days/km/yr
Mountain	$140m^3$km ÷ 325 m^3/day	= 0.431 crew-days/km/yr

Type 4 Roads (ADT under 100)

Dry and Moderate Climates

Flat	$90m^3$/km ÷ 325 m^3/day	= 0.277 crew-days/km/yr
Rolling	$75m^3$/km ÷ 325 m^3/day	= 0.231 crew-days/km/yr
Mountain	$70m^3$/km ÷ 325 m^3/day	= 0.215 crew-days/km/yr

High Rainfall Zones

Flat	$120m^3$/km ÷ 325 m^3/day	= 0.369 crew-days/km/yr
Rolling	$105m^3$/km ÷ 325 m^3/day	= 0.323 crew-days/km/yr
Mountain	$95m^3$/km ÷ 325 m^3/day	= 0.292 crew-days/km/yr

As in the case of routine spot regraveling, the annual crew-days per km for periodic resurfacing were reduced for Type 5 and 6 roads, to make the effort consistent with the six-meter width and the generally lower traffic volumes of these roads. For the equivalent climate and terrain groups, yearly crew-days for Types 5 and 6 were again

set at 75 percent and 50 percent, respectively, of those for Type 4 as given in the table. In addition, bank-run select material would be used for resurfacing (and spot regraveling) on these lower-standard routes, as opposed to the processed select material for Types 3 and 4.

The estimated production rate of the placement crews contemplated only the loading of the material from stockpiles, plus transport and placement on the road. The number of crew-days necessary for the work was, therefore, independent of the type of surfacing to be utilized. The cost of material, however, would be significantly different for pit-run gravel and processed select material. These differences are discussed later and are reflected in the appropriate Estimate Sheets and in Exhibits III-B-3 through III-B-6 of the Engineering Appendix.

12. Special Maintenance

In the process of estimating annual maintenance effort for the various road types, it became obvious that certain road sections had conditions or characteristics requiring attention and cost beyond the normal range for the classification. In these cases, an adjustment was made in the total annual cost for the section, by estimating the additional effort and cost required. Units of work were established for the anticipated items, as shown below, and were applied as necessary.

(a) Retaining Wall Repair: Crew-days/year (including labor, equipment, materials, and overhead) as for "culvert repair and replacement." This was added for segments of road with extensive lengths of retaining wall known to require substantial yearly repairs.

(b) Excess Brush Growth: Crew-days/year as for "brush control." On those road sections with abnormal brush growth in relation to climate, additional crew-days were assumed.

(c) Slide Removal: Where recurring slide problems were known to exist, added work and cost were estimated for specific segments of road. In some cases labor

crews were considered to be sufficient, while in others one or more units of equipment were added. All effort was expressed in crew-days so that resource requirements and cost could be quantified.

(d) Flood Repair: This recurring special work was estimated for known locations in the same manner as for slide removal. Combined machine-and-labor or machine-only crews were assumed in the various cases.

(e) Miscellaneous: Other minor items of special maintenance were estimated as necessary. Sometimes this was basically an approximation of extra annual cost but, as in all the above cases, provision was made to determine also the labor and equipment hours and the materials needed to do the work.

13. Regular Maintenance Activities Not Covered

Some general cost elements of highway maintenance are not included in the foregoing estimates of annual effort by road type. Administrative overheads, naturally, are not reflected but, in addition, some personnel time not usually classed as overhead has been excluded. No attempt was made to assign the time of employees working with the field forces to measure quantities or perform other such functions. The duties of Section Foremen take them to various locations and activities during the day, and since these vary with the conditions and seasons there was no means of subdividing this time by individual work programs. These costs and the added expenses for guards, clerks, and so on at the highway section level were added to District-level overheads.

The general costs for producing common maintenance materials (gravel surfacing, seal coat aggregates, patching mix, etc.) were excluded from the crew-day effort and cost, which usually included only loading from a stockpile, transport to the work site, and utilization. Instead, separate Estimate Sheets were made up for the production and

stockpiling of these materials. The estimates appear in the Engineering Appendix, and the estimating method is discussed later in Section III-G.

Some specific functions of maintenance are also not covered by the methodology, the most important being the transport of equipment and some materials within the Districts and, to a lesser extent, between Districts. For example, the time and cost for truck-tractors and low-boy trailers does not appear in the estimates. It was believed that part of this omission could be made up in the program totals by arbitrary additions, and part by adjusting the costs of purchased materials, such as bitumens, to cover transport. The remaining understatement of needs and costs was not considered to be significant.

14. Intermittent Maintenance of Nonsystem Roads

Typical crews of two different kinds were established for the possible maintenance of tracks, trails, and penetration roads, even though no routes of such standards were analyzed for maintenance ranking. These crews were described generally in Section III-C previously, and estimate sheets are provided in the Engineering Appendix. The appropriate uses of such maintenance effort are discussed later in Section XV-A, with recommendations on a policy.

G. Maintenance Costs

In the preceding material of this report section the highway maintenance requirements were first described, and then quantified in terms of crew-days of annual effort for one kilometer of road of a defined type under different conditions of climate and topography. The estimate sheets referred to for each activity show the men, equipment units, and materials necessary for one crew-day of the work named. The same sheets (found in the Engineering Appendix) also indicate the estimated cost for a crew-day, with four components; labor, equipment, materials, and District-level overhead. The rates applied to each component to obtain total crew-day cost were derived using the sources and methods described below.

1. Labor

The basic monthly pay rates for permanent employees were taken from the IHA "Revised Personnel Manual" of January, 1972, and the associated "Schedule II, Approved Assignments of Pay Ranges to Classes." Step "C" of the basic monthly rates was used throughout as being a reasonable average of present IHA maintenance forces with respect to years of service and promotions from initial step. In consultation with the Accounting Branch, it was concluded that the basic pay rates should be increased by 20.47 percent to cover fringe benefits, consisting of paid holidays and average days of annual, sick, and injury leave. No other social benefits were identified for the normal case, but a second set of adjusted pay rates had to be developed for personnel working in "desert areas." These areas are defined in the Revised Personnel Manual, Appendix B, and the present IHA practice is to increase basic pay by 30 percent for employees in such zones.

The specified work week for IHA personnel is 39 hours. However, some maintenance activities are carried on for the half-day on Saturdays, while others are discontinued to provide time for equipment servicing and other tasks. After some calculation it was concluded that the overall average of effective working time would be about 159.5 hours per month. The monthly pay rates with fringe benefits were divided by this figure to derive the total hourly labor costs for the appropriate classifications as shown in the table below.

Basic Monthly and Adjusted Hourly Pay Scales for Maintenance Field Personnel

Class Title	Monthly Pay Rate	Adjusted Total Hourly Cost	
		Normal	Desert Areas
Laborer I	E$ 55	E$0.415	E$0.519
Laborer II	81	0.611	0.764
Labor Foreman	144	1.087	1.357
Construction Foreman I	350	2.642	3.300
Construction Foreman II	480	3.623	4.526

Class Title	Monthly Pay Rate	Adjusted Total Hourly Cost	
		Normal	Desert Areas
Construction Superintendent	640	4.830	6.034
Powderman	144	1.087	1.357
Maintenance Man	320	2.416	3.017
Quarry Foreman	320	2.416	3.017
Quarry Supervisor	640	4.830	6.034
Maintenance Superintendent	640	4.830	6.034
Driver	144	1.087	1.357
Equipment Operator I	210	1.586	1.980
Equipment Operator II	250	1.887	2.357
Equipment Operator III	295	2.226	2.781
Stationary Equipment Operator I	144	1.087	1.357
Stationary Equipment Operator II	250	1.887	2.357
Helper I	67	0.506	0.631
Helper II	119	0.899	1.103
Equipment Foreman I	685	5.170	6.459
Equipment Foreman II	730	5.510	6.882
Equipment Foreman III	870	6.571	8.201
Mason I	210	1.586	1.980
Mason II	295	2.226	2.781
Mason Foreman	440	3.321	4.149
Laborer (Contracted)	0	0.163	0.163
Driller I	380	2.869	3.584
Driller II	560	4.227	5.286

2. Equipment

The estimating procedure utilized hourly equipment rental rates which were intended to reflect all costs of using the equipment except for operator's wages. The rates were applied for the assumed

hours of actual equipment operation, and not for any nonworking time. The components of cost in the rates consisted of depreciation, fuels and lubricants, tires, and other consumed items (i. e., cutting edges), and servicing and repairs.

Normally, rental rates of this type, which are in common use, are developed from consolidated accounting data covering several years, which establish the average working lives for units and permit the prorating of all other costs by hours of operation, including those for spare parts and shop labor. Information suitable for this purpose was not available from IHA records or other sources in Ethiopia. Equipment charges on a different basis had previously been worked out by the IHA, but a review of these indicated that they could not be used directly nor adapted to the needs of the study.

This was a critical impasse, since the equipment rates were obviously a fundamental element of cost, and no solution was found which could be accepted with real confidence. However, in discussions with the Supply and Equipment Division Manager and the Project Manager, Highway Equipment Repair Facilities Project (HERF Project), it was agreed that the most realistic approach would be to use basic rates from U.S. experience, and attempt to adjust these to reflect Ethiopian costs and conditions. This process resulted in the schedule of rates shown below.

Estimated Composite Rental Rates per Hour of Operation

IHA Maintenance Equipment

Dump truck, six m^3	E$14.90
Asphalt heater, trailer mounted	3.90
Roller, Tandem, 8-10 ton	21.80
Roller, Tandem, 3-5 ton	13.90
Loader, rubber tired, 1-1/2 yard	16.80
Loader, crawler, 1-1/2 yard	16.50
Tractor, crawler, D-4 size	13.50
Tractor, crawler, D-7 size	30.70
Asphalt distributor, 1,500 gallon	25.60

Asphalt relay truck, 1,500 gallon	23.90
Aggregate spreader, tow type	8.10
Broom, pull type	8.10
Truck, water, 1,500 gallon	23.90
Crushing and screening plant, 75 ton/hour	210.00
Crushing and screening plant, 100 ton/hour	240.00
Conveyor belt, 30 meter	18.80
Compressor, 600 cfm	38.30
Wagon drill, 1.125"	33.80
Truck, 2-1/2 ton	13.80
Grader, 12 F size	19.00

The accuracy of these estimated rental rates could not be verified with available information. The development of realistic Ethiopian maintenance cost figures, by the process used in this report, by maintenance formula, or by any other method, will not be possible until adequate data has been assembled to adjust the above rates or to derive, in some alternate manner, the actual costs of owning and operating the necessary equipment.

It was recognized that, within the different equipment classifications, there were a variety of types and sizes of machines, with distinct capacities and acquisition costs, which implied that they should have different rental rates. However, it would obviously have been impractical to try to identify and assign specific units of the present IHA fleet to particular areas, with their individual hourly rates. Further, this would have resulted in non-uniform maintenance cost estimates which would not have been suitable for comparative economic analyses of routes. The rates shown in the table were selected as representing the predominant equipment types now owned, or a reasonable average of those in service, or of the types which will probably become most common with future acqusitions.

Regarding the crushing and screening plants specifically, the cost estimates for production of materials used in ordinary maintenance were based on the use of 75 ton per hour units. This size was chosen as a compromise between the present IHA equipment (50 ton/hour and smaller) and the much larger plants being considered for recommendation by advisors to the IHA. In the Consultants' view, average cost derived for the 75 ton/hour units would give a reasonable estimating base in a rather unsettled picture as to what the future mix of machines might be.

3. Materials

Various common materials are called for in the estimate sheets of the different maintenance activities, in quantities required per crew-day. The unit costs of these materials were obtained from the records of the IHA, or were calculated by the Consultants in a manner similar to that used for the estimate sheets of maintenance activities on the roads. The labor and equipment forces necessary to produce and stockpile the materials were identified, and the unit costs of the materials obtained by estimating the average daily production and dividing this into the total cost per day of the production force. The prices of all important materials are given in the table which follows, with the data source indicated as IHA or Con. (Consultants).

Unit Costs of Maintenance Materials

Description	Unit of Measure	Unit Cost	Data Source
Crushed aggregate, 2-1/2" minus	M^3	E$10.00	IHA
Crushed aggregate, 1-1/2" minus	M^3	12.10	IHA
Crushed aggregate, 3/4"	M^3	15.00	Con.
Crushed aggregate, 1/2"	M^3	15.00	Con.
Crushed aggregate, 3/8"	M^3	18.00	Con.
Crusher-run sand	M^3	5.70	IHA
Processed select material (1-1/2" minus)	M^3	9.67	Con.
Pit-run select material	M^3	2.26	Con.
Pit-run borrow material	M^3	2.00	IHA

Description	Unit of Measure	Unit Cost	Data Source
Cut stone for masonry	M^3	5.65	IHA
Liquid asphalt (all grades, delivered)	Ton	187.38	IHA
Grader-mixed asphalt leveling course material or patching mix	M^3	32.00	IHA
Portland cement (50 kg bag)	Bag	4.25	IHA

It must be understood that the actual costs of the first 10 items on the foregoing list can vary through a very wide range in the various Maintenance Districts and sections of Ethiopia. Prices at a specific production site will depend on the types and ages of equipment used, the characteristics of the natural materials in place, and other conditions. In particular, the costs of single-size (scalped) and other crushed-stone aggregates are highly dependent on hardness of stone, blasting procedure, the setting of jaws and rolls, selection of screens, and the experience of operating personnel. Records and estimates available to the Consultants often showed lower prices for these materials. It appeared that these were usually based on higher than average production estimates, different equipment rental rates, and the calculation of crew-costs without adjusted labor rates and overheads.

4. Overheads

In order to reflect the total costs of the different maintenance activities, it was considered necessary to establish the direct costs of the various crew-days, as in the above paragraphs, and then to add an overhead percentage which would include the remaining undistributed costs of maintenance operations, plus that part of District-level administration attributable to maintenance. Accordingly, data was obtained from the Accounting Branch on past-year expenditures for the following:

a. Maintenance Section Foremen; salaries and vehicle expense.

b. Maintenance Office Personnel and Guards

c. Maintenance Office Supplies

d. Section Warehouse Operation

e. District Office Personnel, travel and per diem

f. District Vehicle Expense

g. District Office Supplies, utilities, and building maintenance.

Those costs chargeable directly to maintenance were accumulated, and to them were added a proportion of general District administrative expenses. The proportion for each District was based on the relative expenditures in 1971/72 between maintenance and construction, with an overall average of about 65 percent. The sum of the two components was expressed as a percentage of other (direct) maintenance expenditures in 1971/72, and was found to be 21.1 percent.

General IHA administrative costs (Addis Ababa headquarters) were calculated by a similar procedure, and represented an additional 14.8 percent of direct costs, or 12.22 percent of the combined direct costs and District overhead costs. This general administrative overhead was not added to the maintenance cost estimates for analysis. It was calculated only to permit comparisons with prior reported IHA expenditures, and for discussion of total maintenance program costs in later sections.

5. Derivation of Crew-Day and Annual Costs

The estimate sheets of the appendix give the numbers and hours per day of personnel classes and equipment units for each type of work. Quantities of purchased and IHA-produced materials are shown separately. Applying the unitary costs for these three elements provided a subtotal of direct costs, and the 21.1 percent District-level overhead was added to all subtotals, (with one exception) to derive the estimated total cost per crew-day for each activity, as shown on the estimate sheets. The exception was that where IHA-produced materials were subsequently shown as utilized on the estimate sheet for an activity, the 21.1 percent overhead was not applied a second time, which would cause a duplication.

The annual numbers of crew-days for each maintenance activity on each road type are indicated in Exhibits III-B-1 through III-B-6 in the Appendix. These numbers (or decimal parts) of crew-days were multiplied by the cost per crew-day to obtain the annual cost per kilometer for each activity on each road type. The annual costs are given by work items on the same Exhibits III-B-1 through III-B-6. In addition, the summarized annual basic cost per kilometer for each road type is shown on Exhibit III-C below.

6. Base Year and Financial-Economic Costs

All cost figures estimated and developed in the foregoing sections of this report are in current 1972 Ethiopian dollars. All such information represents financial cost. The conversion of these values to economic costs (shadow pricing) for economic analysis is presented later in Section V, Maintenance Priority Ranking.

It must also be emphasized that the estimated annual maintenance costs per kilometer are intended to be the total financial costs of doing the work, including depreciations. These depreciations are not an item of direct annual expenditure by the IHA Operations Branch, and may or may not appear in annual budgets at different levels of current administrative practice.

H. Road Material Types and Sources

1. General

The foregoing section on maintenance costs indicated that various materials used on the roads must be produced by IHA forces, consisting mostly of crushed aggregates and granular materials from quarries, pits, and other deposits. The quality requirements of those products for asphalt maintenance are fixed within narrow limits; only durable stone of specific sizes will give satisfactory results for base repairs, patching mix, and seal coating. Alternatively, the materials for gravel maintenance can be more variable in standards.

EXHIBIT III-C

SUMMARY OF ESTIMATED BASIC ANNUAL MAINTENANCE COST PER KM BY MAINTENANCE TYPE

FINANCIAL COSTS IN 1972 ETHIOPIAN DOLLARS

Road Type	Dry Weather Zones			Moderate Rainfall Zones			High Rainfall Zones			Dry Weather Zones With Desert Allowance			Moderate Rainfall Zones With Desert Allowance		
	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M
1	1-DF $1,745	1-DR $1,785	1-DM $1,885	1-MF $2,960	1-MR $3,040	1-MM $3,250	1-HF $3,320	1-HR $3,430	1-HM $3,660	1-DFd $1,785	1-DRd $1,830	1-DMd $1,940	1-MFd $3,020	1-MRd $3,105	1-MMd $3,335
2	2-DF $2,060	2-DR $2,105	2-DM $2,200	2-MF $3,705	2-MR $3,780	2-MM $3,995	2-HF $4,380	2-HR $4,490	2-HM $4,720	2-DFd $2,130	2-DRd $2,170	2-DMd $2,275	2-MFd $3,800	2-MRd $3,890	2-MMd $4,120
3	3-DF $4,745	3-DR $4,240	3-DM $3,975	3-MF $4,745	3-MR $4,255	3-MM $4,080	3-HF $5,615	3-HR $5,010	3-HM $4,830	3-DFd $4,815	3-DRd $4,310	3-DMd $4,050	3-MFd $4,820	3-MRd $4,325	3-MMd $4,165
4	4-DF $2,840	4-DR $2,500	4-DM $2,475	4-MF $2,965	4-MR $2,635	4-MM $2,700	4-HF $3,850	4-HR $3,520	4-HM $3,470	4-DFd $2,885	4-DRd $2,545	4-DMd $2,530	4-MFd $3,015	4-MRd $2,685	4-MMd $2,765
5	5-DF $1,250	5-DR $1,145	5-DM $1,200	5-MF $1,360	5-MR $1,260	5-MM $1,405	5-HF $1,725	5-HR $1,630	5-HM $1,735	5-DFd $1,270	5-DRd $1,165	5-DMd $1,235	5-MFd $1,385	5-MRd $1,290	5-MMd $1,450
6	6-DF $ 855	6-DR $ 790	6-DM $ 850	6-MF $ 925	6-MR $ 865	6-MM $1,000	6-HF $1,175	6-HR $1,110	6-HM $1,210	6-DFd $ 870	6-DRd $ 805	6-DMd $ 830	6-MFd $ 950	6-MRd $ 895	6-MMd $1,035

F = Flat, R = Rolling, M = Mountain

At present, the materials needed for pavement maintenance are obtained by crushing and classifying blasted rock, and quarrying appears to be the best general solution in Ethiopia, and the only acceptable method in many areas. However, approximate calculations early in the study showed that the total quantity needs for these aggregates would be modest, and could be met without difficulty. This referred to maintenance needs only, and not to asphalt rehabilitation, in which base and surface reconstruction could require much larger volumes.

In contrast to the asphalt maintenance, the resurfacing of gravel roads would call for great quantities of granular materials each year. The IHA preference has been to use crushed stone for this purpose also, because of its controlled maximum size and greater resistance to wear. Budget and equipment resources during past years have not been sufficient to permit this, however, and the necessary alternative on most existing gravel roads has been to resurface with pit-run materials of much poorer characteristics. The results obviously cannot have been equal, but just as obviously the costs have been lower. The Consultants were presented with the question of what course should be recommended for this work in the future.

2. General Review of Maintenance Costs

An evaluation of the annual costs per kilometer given in Exhibit III-C reveals that while those for asphalt surfaces (Types 1 and 2) and for low standard gravel roads (Types 5 and 6) are generally within normal or reasonable limits, the costs for primary gravel roads are exceptionally high. If the tables of effort and cost for these roads (Exhibits III-B-3 and III-B-4) are examined, it can be seen that travelway maintenance alone (surface grading, spot regraveling, and periodic resurfacing) ranges, for Type 3, from 85 percent to an astonishing 97 percent of the total prorate annual cost, and for Type 4 from 81 percent to 95 percent. This proportion for travelway conservation is certainly abnormal. Further examination of the tables shows that the surface grading by itself it not an excessive fraction of the cost, usually 7 to 12 percent of the total. It is the replacement of lost surfacing which

represents the major share of total prorated annual cost on these roads, with a variation of from 70 percent to 89 percent.

This exceptional cost for routine and periodic graveling has an obvious explanation; the estimated total quantity required is large, and the unit cost for the material is high. These two factors were reexamined separately in the study.

3. Loss-Rates of Surfacing

The recorded data on the annual wear of gravel surfaces in Ethiopia was not really sufficient to support firm estimates of this factor. An IHA report of May, 1967, entitled "Highway Maintenance Costs in Ethiopia" examined and accepted the figure of 2.5 cm per year for each 100 vehicles of ADT. The same report cited a paper by Dr. R.S. Millard on "Roads, Road Transport and Traffic in Developing Countries," in which the same loss-rate had apparently been derived from tests and measurements.

As stated in Section III-F-11 of this report, the Consultants assumed a less direct relationship with traffic alone, but the rates adopted in the study were similar at about the 100 ADT level. Type 4 roads were found to have traffic volumes ranging usually from 40 to 100 ADT or an average of about 70, which would indicate 1.75 cm per year. The loss-rates assumed, after adjustment for higher speeds in flat and rolling terrain, averaged 1.70 cm/year in dry and moderate climates, and 2.27 cm/year in high rainfall zones. A sampling of present traffic volumes on existing Type 3 roads shows a mean of around 180 ADT. The quantity 1.8 times 2.5 would suggest a loss-rate of 4.5 cm/year, which was considered to be unrealistic. The adjusted average rates used for cost estimating by the Consultants were 2.83 cm/year in dry and moderate climates and 3.40 in the wetter zones. The highest rate used was 3.90 cm/year.

It appears then from the best data available, that the annual needs for resurfacing material have not been over-estimated in the tables of maintenance cost. Obviously, it will be important for the IHA to verify these estimated rates by means of controlled tests.

4. Sources of Select Material

Although there are certain areas of Ethiopia where good quarry sites have not been located, there is general agreement that along the great majority of present highway routes there are ample sources of durable stone for crushing. Consequently, if a decision were made to accept the cost of crushed material for gravel road surfacing, it could almost always be found within economical haul distances. The other alternatives considered for surfacing were the continued use of pit-run select material as at present, or the processing of such material to improve its characteristics (with some increase in its cost), or to search for other natural materials.

In order to arrive at a choice among these alternatives it was necessary to assemble data on the nature, location, and quantities of select materials now being utilized. To this end, a large number of pits were examined by study personnel in the course of travel for inventory verification, equipment inspection, and other purposes. In addition, a letter was sent to all District Engineers requesting data on the known sources of granular surfacing. The letter asked for locations and a description of the material, including the origin or basic formation, an observation as to its hardness and performance under traffic, and estimated gradation percentages in the following sizes:

Large stones over 5" in greatest dimension
Medium size stone, 5" to 1"
Smaller stone, 1" to 3/8"
Small aggregate, 3/8" to No. 40 screen
Fine material passing the No. 40

The District Engineers were further asked to state whether the material had been tested by the IHA Materials and Research Laboratory, and to give an opinion as to whether it would provide a good surfacing if processed to remove or crush the oversize, or to remove excess fines.

Eight Districts sent replies to the letter, providing most of the needed information, but with considerable variations in presentation

and content. To the extent possible the data was put into a uniform format, and is shown as Exhibit III-F in the Engineering Appendix. A prior report from the IHA files was used to enter partial information for the one district which did not reply.

The most important conclusions which were drawn from a review of the data were these:

a. Along the existing routes there are large numbers of known sources for granular materials, which have been or can be used for surfacing gravel roads. Some 192 locations were listed, or one for about every 25 km of the present gravel road system. Naturally, this "average" distance is a distortion of the real availability picture, since pits are often closely spaced in areas of favorable geology, and there are long sections of road in other regions where the search for suitable materials has not been successful. Nevertheless, as a generalization, sources have been located along most routes at economical spacings for hauling.

b. Almost none of the material has been tested for gradation and hardness (only five locations) so there is really no reliable basis for judging quality. According to the District Engineers' descriptions (as interpreted by the Consultants) 76 pits were rated as good, 86 as fair, and nine as poor (one site is used for base material only). Most of the materials were classed as "durable" or "fairly durable."

c. A persistent characteristic of the pits was the existence of oversize stone as a substantial percentage of total volume. Some 91 pits, or 53 percent of the total, were said to consist of sizes grading down from five inches or larger. Another four sites had a maximum normal size of 4", 20 had 3" stone, and four pits had 2" maximum size. Some of the remaining locations had gradations which could be used directly on the road, but 14 were described as having excess fines, plasticity, or other undesirable qualities. Six sites were quarries requiring crushing (with or without blasting) located on gravel roads and used only to produce granular surfacing.

d. The estimates of quantity in the replies were very different in form and magnitude, suggesting individual approaches to estimating procedure, but the general impression was one of substantial reserves.

Considering the above conclusions and statistics, it appeared that no more than 30 percent of the known pits offered material which could be used directly on the roads with satisfactory results and normal vehicle operating costs for the public. It was concluded that the continued use of this material "as is" should not be recommended as a general solution for gravel surfacing.

5. Comparisons of Material Costs and Advantages

The unsuitability of natural select material indicated that surfacing for the roads would have to be produced by crushing quarry stone, by processing pit-run materials, or by finding new sources.

In processing naturally-formed granular materials, it would sometimes be sufficient to simply put the pit-run over a nonmechanical grizzly to remove the oversize. This is an economical solution if the percentage of oversize is not too great and the gradation of the remainder is satisfactory. This procedure could certainly be adopted by the IHA for some locations. However, if the volume of oversize is large it quickly presents problems of rehandling and disposal.

Generally, it would be necessary to put existing select material through a crushing and screening plant. This would be a relatively low-cost operation, in which the bulk of the material would pass through the plant without being affected, offering a high production rate per day. In the most common case, the excessive oversize would be crushed and utilized, instead of being hauled to the road where it either makes an unsatisfactory surface or must be windrowed on the shoulder or disposed of with considerable difficulty. The increased fracture from the crushing of oversize would raise the internal friction and stability of the surfacing. In addition, the jaws and rolls could be set to supply, in part, some of the deficient sizes and improve the general gradation. Where excess fines were present, a part of this fraction could be screened out, or its

proportion of the total reduced by addition of the crushed oversize or by crushing some stone from adjacent sources.

What would be the cost of processing the existing select material, in comparison with that for crushing stone? The three pertinent prices developed for use in the study were these:

a. Pit-run select, dozed from the bank or deposit and stockpiled for loading, including site preparation--E$2.26 per m^3.

b. Processed select (1-1/2 minus) dozed from the bank (without blasting), passed through the plant to get controlled gradation, and stockpiled--E$9.67 per m^3.

c. Crushed aggregate, 1-1/2" minus. Drilled and blasted, crushed and screened to controlled gradation, and stockpiled--E$12.10 per m^3.

The unit prices above are based on a careful consideration of all factors involved, including the adjusted real costs of equipment and labor. They are intended to be prices resulting from a hypothetical "average" set of conditions. In reality, to speak of average unit costs in Ethiopia, or any other large region with variable geology, is almost meaningless. Nevertheless, the prices given above are believed to be reasonable for system-wide application.

The continued use of pit-run surfacing at E$2.26 per m^3 instead of the processed select called for in the tables would permit a reduction of the crew-day cost of spot regraveling from E$2,671 to E$1,189, or 55 percent. The same substitution for periodic resurfacing would reduce that crew-day cost from E$6,446 to E$3,593. Taking the Type 3 HR as being typical of important rural gravel roads in the system, its total annual maintenance costs per kilometer would drop from E$5,010 to E$3,002, a dramatic savings. At first glance it would seem that such a reduction would be worth while in a developing country, regardless of the increased roughness of the road. However, as discussed later in this report, it was estimated that ordinary gravel roads of the system with pit-run surfacing would have vehicle operating costs about 22 percent above those with gradation-controlled surfacing (in rolling

terrain) if all other factors were equal. The exact percentage would depend on the vehicle type. With an ADT of 180 and a normal mix of vehicles, such as that on route 1 north of Dessie, the annual savings of E$2,008 for one kilometer would be overcome by increased costs to the public in just over 100 days. On this basis, the use of pit-run material would not be, and is not, an economical alternative for these roads. It should be noted that either the differential material cost or vehicle operating cost would have to be in error by a factor of three to equate the costs and savings. Furthermore, if the values are correct but the traffic were to be reduced by two-thirds, to below the average for Type 4 roads, the cost of the better surfacing would still be offset by savings to the road users. Again, it was concluded that pit-run select material should not be recommended for continued use on Type 3 and 4 roads. (Throughout the study, this material was specified for road Types 5 and 6.)

The use of crushed stone surfacing in place of processed select material would usually produce a somewhat longer-wearing surface because of the generally harder stone. The Consultants found no means of assessing this in terms of comparative cost, but concluded that greater hardness in the crushed stone could only compensate for a part of the higher cost, probably less than 30 percent. This because durability would only reduce abrasion losses, not water or wind erosion. Furthermore it is difficult to get a good surfacing gradation by crushing blasted rock. If the material is produced at minimum cost it is usually found to be deficient in fines and is a problem to compact unless finer material from some other source is added. If the fines are not provided the surfacing forms windrows quickly and is susceptible to being thrown off by traffic.

The one thing which is certain is that the crushed aggregate has to cost more than processed select. Drilling and blasting are added expenses, and almost 100 percent of the blasted rock has to be reduced in the plant, usually in both the jaws and the rolls. There is no advantage in vehicle operating cost to offset the higher unit price. If it is

assumed that a satisfactory gradation resulting in normal VOC can be achieved by processing the select material, a reasonable assumption at the cost quoted, then no further reduction in VOC would result from using crushed stone.

6. Possible Use of Larger Plants

Another question was whether the unit price of crushed quarry stone could be substantially reduced by the acquisition of large crushing and screening assemblies with much higher production rates. Although this economy would apply equally well to the processing of select material, the matter of optimum-size equipment had to be examined in any case.

An estimate was prepared of the cost per day for a plant with a jaw-type primary crusher, a gyratory secondary, and the necessary classifier and conveyor belts. A correspondingly larger force of workers and support equipment was assumed. The combination selected was estimated to have a rated capacity of 200 to 225 tons per hour, and a daily production of 1-1/2" minus material around 945 m^3. The unit cost derived was about E$5.50 per m^3. Processed select material from the same plant would probably cost about E$4.40 per m^3.

It was plain that these lower costs for surfacing would have a profound effect on the annual maintenance costs of gravel roads, but the feasibility of using such equipment would depend on the total quantity requirements and the dispersion of needed amounts.

As developed later in this report, the total needs of crushed aggregates for asphalt maintenance (patching of two types, and seal coats including leveling course) will only be about 73,000 m^3 per year for the present paved roads system (2,488 km). This amounts to only about 30 m^3 per km, or 3,000 m^3 for each 100 km. Plainly, it would not be economical to acquire large plants solely for this scattered need.

On the other hand, surfacing for the Type 3 and 4 roads of the same system amounts to about 1,000,000 m^3 each year, loose volume. This is distributed over some 3,795 km, for an average of 270 m^3 per

km per year. Most of the haul calculations in the maintenance cost estimated were based on a 60-km spacing of pits or stockpiles, and the average requirement for this is not sufficient to justify large plants, since the quantity would require only a 15 working-day run at a production rate of 945 m^3/day. However, it is not prorated annual quantity which is pertinent, but the total needed in the year in which resurfacing is scheduled, at intervals of 4 to 10 years for the different road classifications. The average of all these is about 6.5, but in actual practice this would probably be reduced to meet the needs of flat sections where the loss is more rapid. For an assumed cycle of 5.5 years, the total requirement would be about 89,000 m^3. This would be a run of 90 to 95 working days, an economical amount for a large plant. Two-thirds of the material would be used in the resurfacing, and one-third stockpiled for annual spot regraveling.

Nevertheless, this computation was not taken as a definitive answer to the question of optimum crusher size and material cost. It was apparent that the introduction of large plants could cut the annual maintenance cost of Type 3 and 4 roads by a substantial margin, whether they were used to crush quarry stone or, at even lower unit cost, to process select material. What was also evident was that the maintenance costs would still be unusually high in comparison with those for equivalent roads in other countries. Such roads are not usually surfaced with crushed or partially crushed material (unless future paving is scheduled) just as they are not usually surfaced with gravels containing 5" stones. Instead, it has normally been possible for other highway agencies to locate usable, naturally-occurring materials within acceptable haul distances, which can be stockpiled at the pit site with unit prices approaching those for common excavation. Whether they consist of river gravels, alluvial deposits, volcanic cinders, weathered stone, calcareous soils, or whatever, they have usually been found to exist, and with natural gradations which permit them to be used directly on the roads or made usable by simple treatments to remove oversize stone. These common granular surfaces provide normal vehicle operating costs because, in fact, they have formed the basis for the tables of VOC on gravel roads.

It is the opinion of the Consultants that such acceptable natural surfacing materials must exist in Ethiopia as well. This view is not known to be supported by geological reports or exploration data, but neither is there any firm evidence that Ethiopia is uniquely devoid of such materials. The Consultants felt that a comprehensive exploration program should be organized with expert technical assistance to search for sources of these materials and that, until this was done, it would be unwise for the IHA to make any huge additional investment in crushing and screening plants, large or small, which would represent a de facto long-term commitment to surfacing with crushed or processed material. Some additional crushing capacity should, however, be provided.

Many of the pits and quarries now being exploited by maintenance forces are adjacent to the roadway or at distances of only a few hundred meters. This suggests that they were uncovered in the course of construction, or by limited searches close to the roads. Naturally, such locations have the advantages of short haul distances and minimum cost for access roads, but the pattern implies little exploration of promising formations off the highways. The potential benefits from discoveries of other sites and better natural gravels are enormous. In some areas visited by study personnel the roads were surfaced with very poor pit-run materials, while vast deposits of river gravels were visible in nearby riverine plains at distances of one to five km from the road. These gravels were not tested, and their qualities cannot be determined without standard exploration and testing, but it is obviously possible that they could offer a much better surfacing than the pit-run select at a modest increase in cost.

This matter was discussed with the Materials and Research Branch of the IHA, which has located materials sources for present and planned projects to be constructed by contract. The dominant need in most of these projects was for quarries to supply crushed stone base and paving aggregates. No organized search has been ordered or made along the existing gravel highways for alternate sources of surfacing.

7. Conclusions

It seemed reasonable to the Consultants to assume that a well-conceived and thorough materials search could provide suitable sources of natural surfacing for 60 to 70 percent of the length of Type 3 and 4 roads, and that this material could be produced at unit costs of E$2.50 to E$3.00. Using the higher figure, to cover additional costs for access roads and lengthened haul, and assuming a continuing cost of E$9.67 for the other 35 percent of the total annual requirement, the system-wide average cost would be E$5.33 per m^3 for surfacing to be used on these roads.

As an interim procedure, until the results of materials exploration could be known it was concluded that some additional crushing capacity should be provided for maintaining the most important Type 3 and 4 roads with processed select material. It was the opinion of the Consultants that the plants to be acquired solely for maintenance should be limited in number on the assumption that the quantity requirements for crushed or processed material would be greatly reduced by the exploration program.

Section IV

EFFECTS OF NOT MAINTAINING ROADS

A. Road Condition and Transport Costs

The various maintenance activities described in Section III have different purposes. Some, such as asphalt patching and the grading of gravel roads, are necessary to preserve the condition of the travelway. Ditch cleaning and culvert maintenance have the distinctly different function of protecting the whole roadway against damage and closure. Emergency operations like slide removal and the repair of flood damage are required when traffic has been interrupted or restricted, or when there is a danger that this will occur. Such longer-term activities as asphalt seal coating and gravel resurfacing are needed to restore the surfaces.

The scope of work of this study poses the question of what economic benefits might result from the postponement of maintenance and rehabilitation. This implies that the savings from deferment of all or part of the work might have, in economic terms and at a relatively high opportunity cost of capital, net values greater than the cost to the public of using the deteriorating roads. The analysis of this question required an evaluation of the effects on transport costs of insufficient or zero maintenance.

B. Vehicle Operating Costs, General

These road user costs are related almost entirely to the type and condition of the running surfaces. An array of costs per kilometer for different vehicle types on paved, gravel, and earth roads is usually intended to give averages for normal ranges of condition on the three kinds of surfaces. Only when these become abnormally rough or unstable, due to deficient maintenance or other factors, will the operating costs be significantly affected. The normal costs per kilometer assume that the entire facility will be kept in continuous service by adequate attention to the drainage and other elements which are not a part of the travelway.

Obviously, user costs can also be affected somewhat by the standards of ditch, culvert and shoulder maintenance, without complete closure occurring. For example, if water is forced on to the road by a blocked ditch it may cover or erode a part of the travelway, or cut shallow channels across it. The increased roughness will add some small increment to tire and vehicle wear, affecting all road users, and the condition will also impose slower travel speeds, further raising the real costs, at least for commercial haulers. More serious erosions resulting in temporary closure and the use of detours or fords will raise vehicle operating costs in the same manner. So will small slides, which might be attributed in part to failure to clean the crown ditches above cut slopes, or partial fill failures on sidehill roads where the slip-planes have been lubricated by water left standing in the ditches. Even leaving the brush and weeds untended will reduce sight distances and, in consequence, passing opportunity, and will reduce the effective width of the roadway. Both of these factors will cause fractional additions to the cost of transport.

The quantification of all these effects is exceedingly difficult. Even for the very obvious and sometimes immediate consequences of neglecting the running surface, there is no established scale of probable increases in operating costs for specified changes in condition. A few of the published studies in highway engineering have some cost increase factors for "rough" surfaces (e.g., "Running Costs of Motor Vehicles as affected by Road Design and Traffic," U.S. Highway Research Board, National Cooperative Highway Research Program Report No. 111, 1971). However, such reports usually cover only part of the elements of cost (the cited report has no factors besides those for fuel consumption), and give no definitions of the surface condition for which the factors were developed.

There is a persistent need for better empirical data on this subject, to furnish a basis for evaluating the benefits of pavement reconstruction and reinforcement and for definitive analyses of the economical levels of surface maintenance. But, to the knowledge of the Consultants,

this need has not been met. The scope of the present study does not include such fundamental research, which would entail very careful measurements of fuel use, tire life, vehicle repairs, and depreciation for several vehicle types on a wide range of surface conditions. These might vary from smooth and stable travelways to badly broken, heavily patched, irregular, severely rutted or otherwise deformed pavements, and to gravel surfaces with extreme corrugations, potholes, projecting stone, base failures, deep wheel paths or excessive loose material.

A common practice in maintenance studies, and studies of the feasibility of repaving or surface improvement, has been to assume that when surfaces are in a condition worse than "normal," the vehicle operating costs will lie somewhere between those that are normal for the type and those normal for the next lower type of surface. That is, as pavement deteriorates the VOC will increase from the established value for paved roads toward that for gravel roads, and as gravel condition worsens the VOC will approach that for earth surfaces. However common, this assumption is open to some question, especially if the change in VOC is taken to be linear. Driving on asphalts that are severely broken or potholed often gives an impression of greater discomfort and vehicle damage than driving on ordinary gravel, suggesting that the VOC first rises above that for gravel, then declines again as the pavement disappears entirely. When gravel roads are neglected, the VOC rises rapidly as potholes or corrugations are formed, then much more slowly because the dimensions of these features do not change much. Typically, there is a firm secondary surface, the top of a more compacted mass, or a layer built of coarser aggregates. This forms a floor for the wheel paths, which have windrows of loose gravel between them and on the shoulders. The material in the windrows becomes coarser and less bound as fines are blown or washed away, and is gradually thrown off by traffic. The secondary floor loses smaller particles as well, becoming rougher and more rocky. This process is gradual in comparison with the first stage. While the VOC may eventually reach that for an earth surface, it will

probably result from a different mixture of cost elements, since a constructed gravel road will rarely revert to a normal earth surface. The latter is typified by deep ruts, mud ridges, rolling depressions, or loose, fine material of considerable depth. Naturally, some non-gravel surfaces classified as "earth" may actually be very rocky in sections and a seriously deteriorated gravel road might resemble these.

C. VOC Related to Maintenance

In order to estimate the benefits which would result from improved highway maintenance and from the rehabilitation of distressed sections it was necessary to adopt a probable scale of VOC values for each surface type, ranging from low to high as the condition varied from excellent to very poor. In addition, the rationale developed for the comparative ranking of routes for maintenance priority utilized the same scale of VOC values, related to condition. This was applied as hypothetical stages of cost increase which would be avoided by doing the required maintenance, and could therefore be taken as benefits to be compared with the costs of doing the necessary maintenance.

It was recognized in the study, and it is important to emphasize, that ordinary highway maintenance cannot produce any true benefits in the sense of reducing user costs below those that are normal for the surface type originally constructed. Further reduction, and real economic benefits, would require more capital investment, to construct a higher surface type, realign the road, or otherwise improve its standards. If maintenance can achieve a lowering of direct user costs it is only because the surfaces have been allowed to deteriorate to a condition which imposes an abnormally high VOC. Presumably, some past savings in annual maintenance costs will have been realized in such cases, but a corresponding stream of disbenefits will also have taken place as the costs of transport increased. The feasibility analysis made to justify the original construction of the road, (or implied in the decision to build it) would necessarily have assumed a normal level of vehicle operating costs for the surface designed, plus a continuing maintenance effort

sufficient to ensure that the transport costs would not go up. Failure to provide the maintenance would bring the feasibility into question by decreasing the benefits assumed for the investment.

As an initial step, the basic vehicle operating costs developed in the 1969 General Road Study were evaluated in detail. The conclusions reached, and the modifications made in these costs, are described in a later section of the report. Next, the GRS discussion of the effects of road standards on VOC was studied, to assess its applicability to variations in maintenance effort. The objective of the earlier consultants was to develop incremental VOC values which could be used in screening the entire road system for possible highway improvements over a longer term. The increments of VOC for a particular surface type were therefore related not only to condition, but also to physical standards, especially profile and alignment. Since it is not within the realm of maintenance to change these characteristics it was necessary to consider how the differential VOC values would be related to condition alone. This is quite a different problem, but appropriate points in declining condition, taken alone, would correspond to the incremental points in the VOC scales established for the combined factors. Determination of the proper relationships would permit the use of the GRS scales, already reviewed and updated.

Three separate questions were recognized: (1) Where were the existing roads, with present levels of maintenance, located within the ranges of VOC for their particular surface types; (2) What were the positions of the distressed sections in the same scales, and; (3) Assuming the postponement of all or part of normal maintenance, how would the VOC rates change, and in what period of time would the VOC rise from normal to the highest value for the surface type. For all three of the above questions, the answers would obviously be different for paved and gravel roads.

1. Asphalt Surfaces

The tables of VOC for these roads included values for each of the representative vehicle types at average speeds in flat, rolling,

and mountain terrain, on surfaces in normal condition. A similar set of tables was developed for gravel roads in ordinary condition. The differences between these two sets of costs (expressed in E$ per vehicle-kilometer) were divided uniformly into three increments. In effect, this said that as any paved surface deteriorated, the VOC on the road (for any vehicle type in any of the three terrain classes) would rise from normal to a cost equivalent to that for operating on a gravel road, and that this increase could logically be divided into three increments. This did not imply that the actual VOC would go up by one-third at each stage, but rather would increase by approximately 6 to 10 percent, since the total change in VOC from paved to gravel surface, for any vehicle or terrain, would only be from 19 to 29 percent of the base VOC for pavement in normal condition (see Section V.).

The base VOC plus the three increments of increase established four cost-points corresponding to worsening condition of the pavement. These four points were equated with generalized physical characteristics of the pavements, and defined as follows:

Condition 1 - Reasonably smooth and uniform surface; normal VOC for paved roads.

Condition 2 - Significantly deteriorated surface; extensive patching and irregularity, VOC about 6 to 10 percent higher than Condition 1.

Condition 3 - Seriously deteriorated; repeated patching, observable failures, and widespread deformations of the surface, VOC about 12 to 20 percent higher than Condition 1.

Condition 4 - Pavement breaks and roughness sufficient to impose VOC levels equal to those for a good gravel surface.

It was felt that separation into smaller increments, or a larger number of deterioration stages, would not be useful because all distinctions could only be qualitative and the cost differences for the four conditions were, in any case, relatively small.

a. Existing Paved Roads

All paved surfaces covered by the study were classified, by segments, as being in Condition 1, 2, 3, or 4. For those in the first group, and for all segments which appeared to be in a stable state at Condition 2, it was assumed that normal maintenance, as recommended in this study, would be adequate. Any sections in Condition 2 and deteriorating rapidly, or long neglected, were evaluated for rehabilitation. All sections (of significant length) classified in Condition 3 or 4 were considered as distressed and were evaluated for rehabilitation.

For the purposes of economic analysis, it was assumed that normal (recommended) maintenance, or rehabilitation followed by such maintenance, would return the above roads to Condition 1, or preserve them in that state. That is, thereafter the VOC and maintenance costs would be normal for the road type.

b. New Paved Roads

It was assumed that all new paved roads taken over for IHA maintenance during the period of the study would be, and would remain, in Condition 1.

c. Maintenance Priority Rationale

To establish a model for the comparative ranking of paved routes for maintenance, it was assumed that all paved surfaces, present and future, would start at Condition 1. The hypothesis was posed that beginning with that condition, and deferring all maintenance, pavements would deteriorate from Condition 1 to Condition 4 in a certain period of time, variable according to the age of the pavement (Type 1 or 2) and the climate zone. If this were permitted to happen, the expenses of maintenance would not occur, but the total vehicle operating cost for the route would rise as its condition worsened. Because the deferment of maintenance was hypothetical and would never actually take place on an important route, the avoidance of the annual rise in VOC could be taken as a benefit. The annual cost of obtaining the benefit would be that of adequate maintenance (that necessary to preserve

Condition 1). With both the annual costs and the benefits converted to present worth at an appropriate interest rate over the estimated deterioration time (from Condition 1 to Condition 4), the net present value of maintaining the route could be obtained.

This process would give only a relative ranking of routes and not a measure of their intrinsic values to the nation. The latter would require a much deeper analysis of factors beyond the responsibility of this study. It is apparent that the benefits quantified would be a function of the volume and composition of the traffic, and of the traffic growth rate. These benefits would be set against the required maintenance cost, which would vary according to pavement age, climate and topography. Routes of highest traffic for equal maintenance costs and change in VOC would have the higher indices (net benefits).

The assumption that all pavements would start at Condition 1 was clearly not in accord with the actual condition of the roads, but it was a logical and necessary assumption for economic analysis. What was desired was a relative ranking of benefits from maintenance on separate routes, and this would obviously be distorted if sections were started at their actual condition ratings (when greater than 1). Extraordinary distortion would occur for distressed sections, initially rated at Condition 2, 3, or 4, and some of these sections are located on routes of obvious importance. The time period for hypothetical deterioration to Condition 4 would be significantly shorter in these cases (sometimes zero), the related accumulation of benefits (change in total VOC) much less, and the maintenance cost dominant.

The time periods for deterioration from Condition 1 to Condition 4 in the total absence of maintenance had necessarily to be estimated. The Consultants were not aware of any data on the performance of roads given zero maintenance but remaining in normal service. It was apparent that the hypothesis should be considered only as a ranking exercise, because normal traffic growth was assumed whereas, in reality, diversion would occur as condition declined whenever an alternative route existed, and rising VOC would tend to diminish traffic in all other cases. It was further apparent that some minimum maintenance of drainage facilities would be essential to prevent the total closure of

most road sections within a year or less. Consideration was given to separating and using in the model only those maintenance costs related to the travelway. However, since these travelway costs, routine and periodic combined, make up a large percentage of total costs, and since the use of partial or total costs would affect all sections almost equally in the ranking exercise, it was decided that this additional step would not be necessary.

In the calculation of maintenance priority, the increase in VOC with time (deterioration) was taken to be linear. It was considered more likely that the curve would actually be concave (accelerating), but in the absence of empirical data to fix the rate of change this supposition was not applied. Present worth would be affected by the shape of the curve, but about equally for all sections ranked.

It was further assumed that the rise in VOC for deteriorating pavements would stop at the level of VOC for normal gravel surfaces. This implied that the distressed pavement would be bladed off at that point, avoiding any possible further increase. The estimated periods from Condition 1 to Condition 4 were predicated on this assumption, whereas the actual time to total disappearance of the pavement without being bladed off would be much longer.

One set of deterioration lives was estimated for Type 1 pavements (less than 10 years old) and another for Type 2 (10 years or more). This assumed that the residual lives of the older pavements would be generally shorter, and that this should be reflected in more rapid deterioration rates.

Beyond the pavement type, it appeared that the lives for ranking would vary with climate, as do the rates of annual patching and the intervals for periodic seal coating. After consideration of these factors, and the history and present condition for existing roads, the following periods in years were estimated for deterioration from Condition 1 to Condition 4 in the maintenance ranking model:

Type 1 Pavements

Dry Climates	8 years
Moderate Rainfall Zones	6 years
High Rainfall Zones	4 years

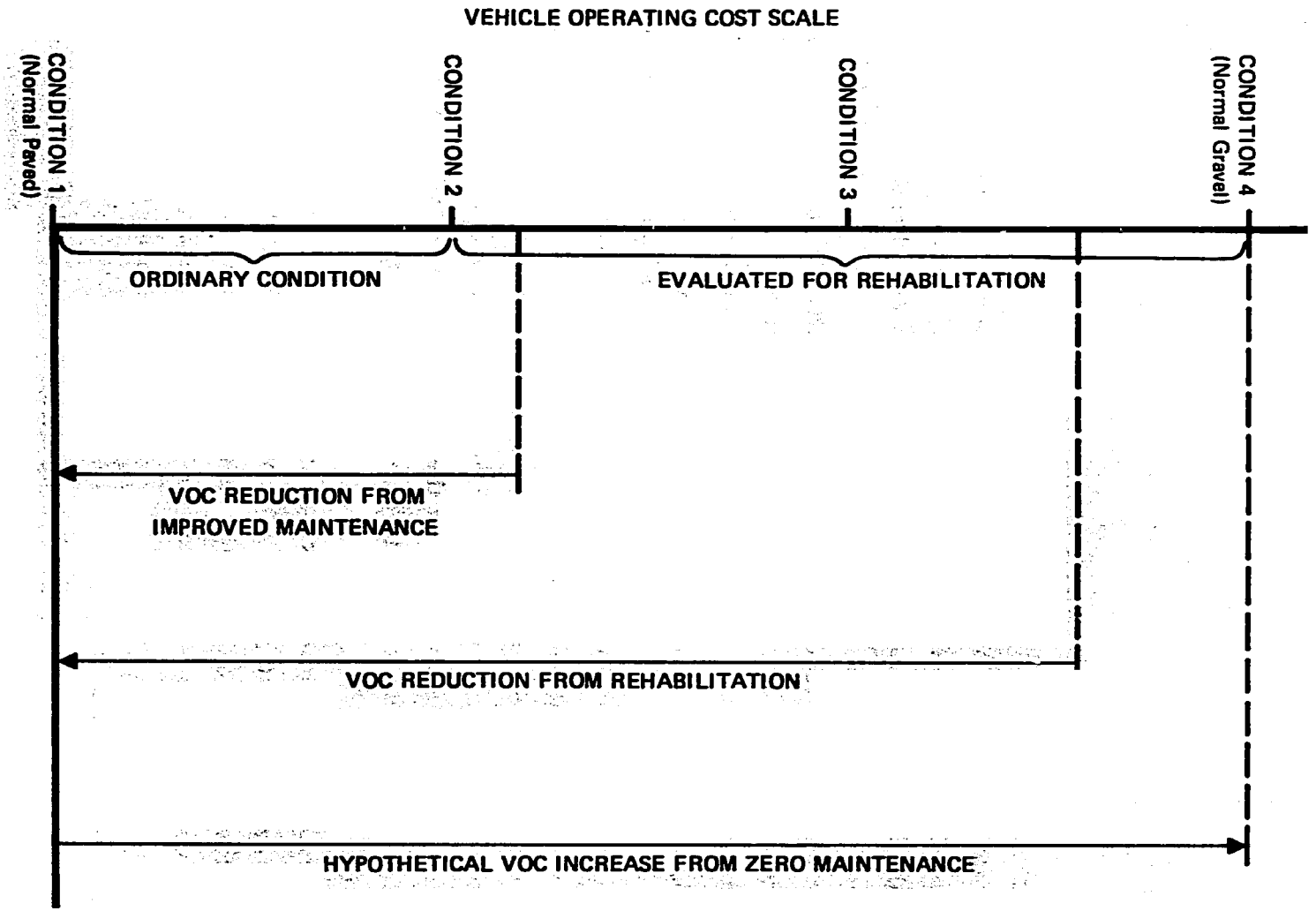

EXHIBIT IV-A CONDITION RATING AND INCREMENTAL VOC DIAGRAM, PAVED SURFACES (Road Types 1 and 2)

Type 2 Pavements

Dry Climates	7 years
Moderate Rainfall Zones	5 years
High Rainfall Zones	3 years

2. Gravel Surfaces

The initial tables of VOC for gravel roads were similar to those for pavements, with values for different vehicle types operating at average speeds in three classes of topography. A third set of basic costs were developed for earth surfaces. The total differences between normal gravel and normal earth, expressed as a percentage of the standard values for gravel, were substantially larger than the increase from paved to gravel, being from 56 to 71 percent. The VOC increases from normal gravel to normal earth were uniformly divided into six increments, giving step changes of 9 to 12 percent.

The base VOC for normal gravel plus the six increments gave seven cost-points corresponding to worsening condition of gravel surfaces. Again, qualitative descriptions were written for these intermediate points, and are given below. In addition, two basic conclusions were reached. First, that a section could not be classified as Condition 1, at the lowest VOC (normal), unless the surfacing material itself was of good gradation (in the particle sizes) and had a maximum aggregate size of 1-1/2 inches. In short, roads surfaced with bank-run select material could not be so classified in normal circumstances. Second, it was assumed that gravel roads with both base and surface courses (including Telford base) would not reach Condition 7, with VOC values equal to those for earth roads, because the base would always give significant stability, however rough it might be.

Definitions of Gravel Condition Rating

Condition 1 - Normal vehicle operating cost. Good gradation and sufficient thickness of material, so that adequate maintenance would preserve normal gravel VOC.

Condition 2 - Best Ethiopian roads under present circumstances. Potential for Condition 1 with more equipment and budget. Equivalent to best Feeder road condition.

Condition 3 - Standard existing gravel road with pit-run select material including oversize, but with surfacing thickness apparently adequate. Equivalent to best condition on roads of Service-to-Traffic standard.

Condition 4 - Marginal condition between normal and distressed. Either normal pit-run select so thin that base begins to show, or abnormal oversize and plastic material in surface.

Condition 5 - All surfacing gone but base still stable and not excessively rough.

Condition 6 - All surfacing gone and base still stable for most of length, but extremely rough base or with plastic material pumping through.

Condition 7 - Earth surface, unstable when wet, or extremely rocky and uneven, or deep sand, or similar.

a. Existing Gravel Roads

Rating the condition of gravel surfaces is distinctly different from rating pavements, in that their smoothness and transverse profile change rapidly after grading. The apparent condition varies depending on when the road is observed in relation to last blading. The rate and severity of change vary with the seasons, traffic, quality of surfacing and how it was placed. It was considered logical to rate gravel surfaces on their potential condition with good maintenance, and this would depend primarily on the quality of the surfacing material, the amount remaining on the road, average moisture content, and traffic volume. However, due to the shortage of IHA motor graders, it was considered that none of the gravel routes was being maintained to Condition 1 in 1972, regardless of its potential.

With these guides, all existing gravel road sections were classified as being in Condition 2 to Condition 7. Those in Conditions 2, 3, or 4 were considered to fall within the range for normal maintenance, unless there was some special factor to be taken into account at the fourth stage. All sections which were doubtful at Condition 4, and any classified as Condition 5 to Condition 7, were considered as possibly distressed and were evaluated for rehabilitation.

For economic analysis, it was assumed that the recommended levels of maintenance of this study, including the use of crushed stone, processed select or other good-gradation material for resurfacing, would permit bringing all primary gravel sections to Condition 1, after any required rehabilitation. Thereafter, the VOC and maintenance costs would be normal for the road type. Feeder roads could be brought to Condition 2 by normal maintenance with bank run select material, and Service-to-Traffic roads to Condition 3.

b. New Gravel Roads

It was assumed that all new gravel sections to be taken over for maintenance during the time span of the study would have the potential for Condition 1 if the recommended surfacing was of controlled gradation, and for Condition 2 or Condition 3 if it was bank-run select material. In the latter case this was consistent with the earlier assumption (for maintenance effort) that inital construction would be to adequate standards.

c. Maintenance Priority Rationale

The model for the comparative ranking of gravel roads for maintenance was very similar to that for paved routes. Again, the hypothesis was posed that if all maintenance were deferred, the road would deteriorate from some initial to some final condition, in a period of time which would be variable according to physical circumstances. The rise in VOC associated with the hypothetical deterioration could be avoided by a certain maintenance expenditure, and comparing the present worth of the two quantities over the estimated life would indicate the net benefits of maintaining.

One departure from the paved model was that gravel surfaces on primary and feeder roads were assumed to start at Condition 2 instead of Condition 1, and to decline to Condition 6, one increment short of the VOC for the next lower surface type (earth). Condition 2 was chosen for the initial state because even starting with the best possible surface on a good gravel section, if maintenance were interrupted the

condition would decline sharply during a first brief period, of one or two months. Afterward, the rate of increase in VOC would be much slower, and was assumed to be nearly linear. Service-to-Traffic sections were presumed to start at Condition 3 and decline to Condition 7.

Again, there was no data base for fixing the actual configuration of these curves, but it was the opinion of the Consultants that a straight-line increase starting from Condition 2 (or 3) would give a better approximation of the actual increase in operating costs. For the primary and feeder types, Condition 6 was selected as a final state instead of equivalence with an earth surface (Condition 7), and the deterioration lives were estimated in accordance with this magnitude of change.

The periods for the hypothetical decline from Condition 2 to 6 were assumed to be related basically to the annual loss-rates of surfacing developed in the estimates of maintenance effort. These periods would then vary according to traffic (as generalized for Road Types 3, 4, 5, and 6), climate, and topography. It seemed plausible to assume that, for the purposes of economic ranking, all roads in these classes would have, initially, some normal minimum thickness of surfacing plus enough to provide half the loss figured for spot regraveling and periodic resurfacing. This would put them near the mid-point of the resurfacing cycle. However, loss rates 50 percent greater than those for normal maintenance were used, based on the assumption that lack of maintenance would cause more rapid losses from both weather erosion and traffic. Service-to-Traffic roads were taken to have not more than 10 cm of surfacing.

The foregoing rationale, converted to simple formulas, gave approximations of the years of life from Condition 2 to 6 and from Conditions 3 to 7. Rounded to the nearest whole year for computation, these estimated lives were:

<u>Type 3 Roads (ADT 100 or more)</u>

Dry Climates:	Flat	- 3 years
	Rolling	- 4 years
	Mountain	- 4 years

Moderate:	Flat	- 3 years
	Rolling	- 4 years
	Mountain	- 4 years
High Rainfall:	Flat	- 3 years
	Rolling	- 3 years
	Mountain	- 3 years

Type 4 Roads (ADT less than 100)

Dry Climates:	Flat	- 5 years
	Rolling	- 6 years
	Mountain	- 7 years
Moderate:	Flat	- 5 years
	Rolling	- 6 years
	Mountain	- 7 years
High Rainfall:	Flat	- 4 years
	Rolling	- 5 years
	Mountain	- 5 years

Types 5 and 6 roads were taken to have the same deterioration lives as those for Type 4 because, while they would start with less surface thickness, they would also have lower traffic volumes generally, and slower losses of material from this factor. Approximate calculations were made to verify this assumption.

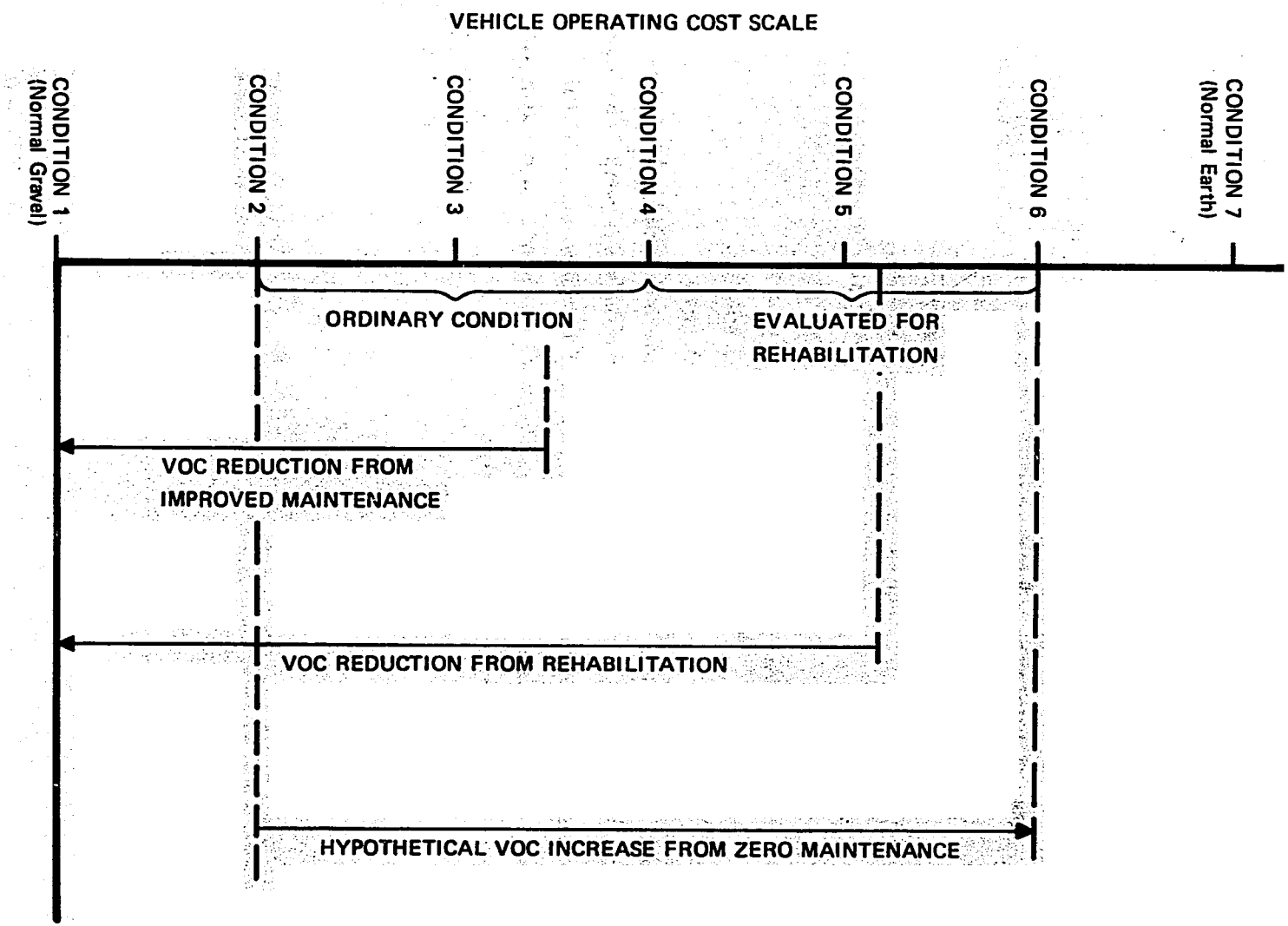

EXHIBIT IV-B CONDITION RATING AND INCREMENTAL VOC DIAGRAM, HIGH-TYPE GRAVEL SURFACE (Road Types 3 and 4)

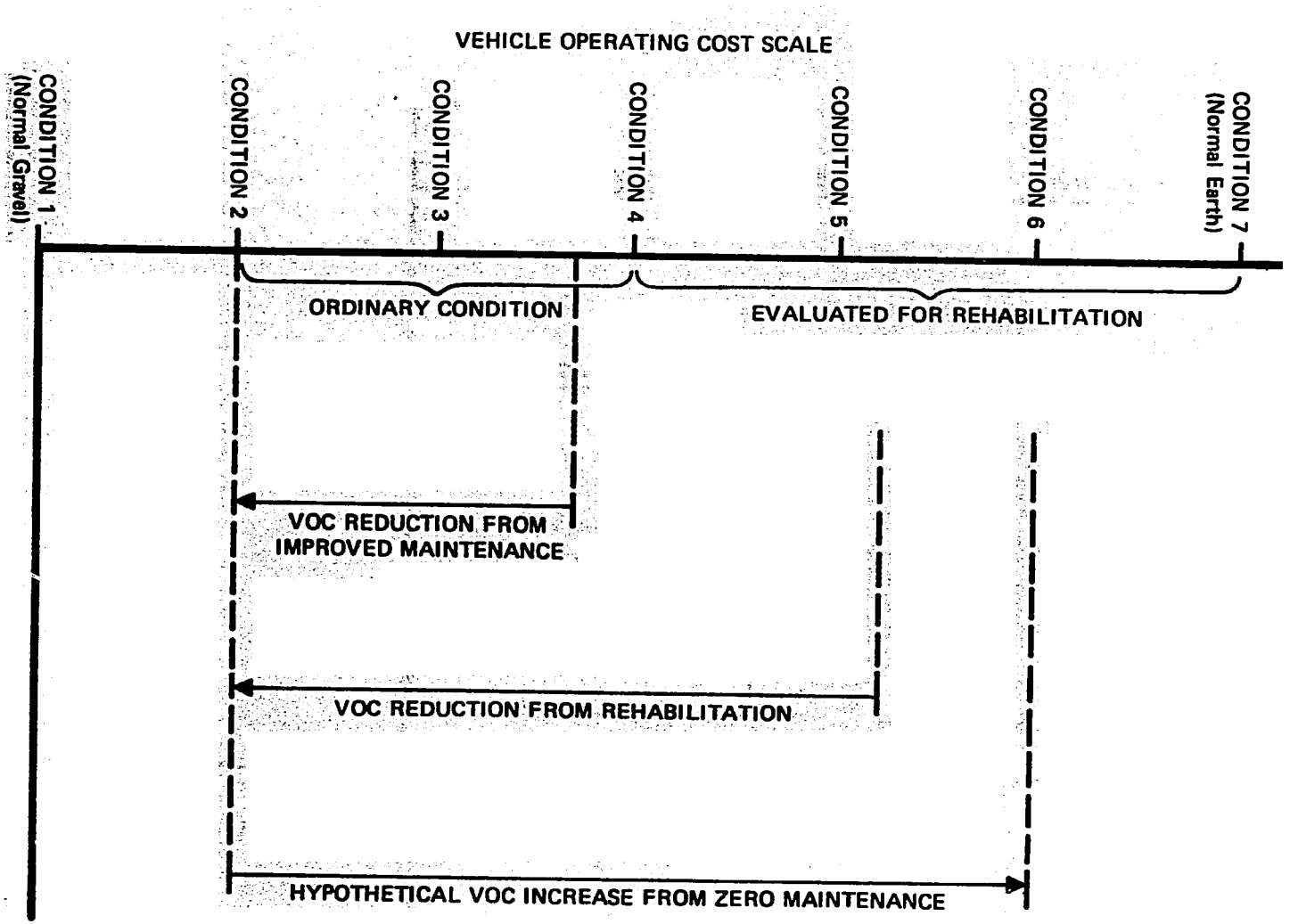

EXHIBIT IV-C CONDITION RATING AND INCREMENTAL VOC DIAGRAM, INTERMEDIATE GRAVEL SURFACE (Feeder Standard - Type 5)

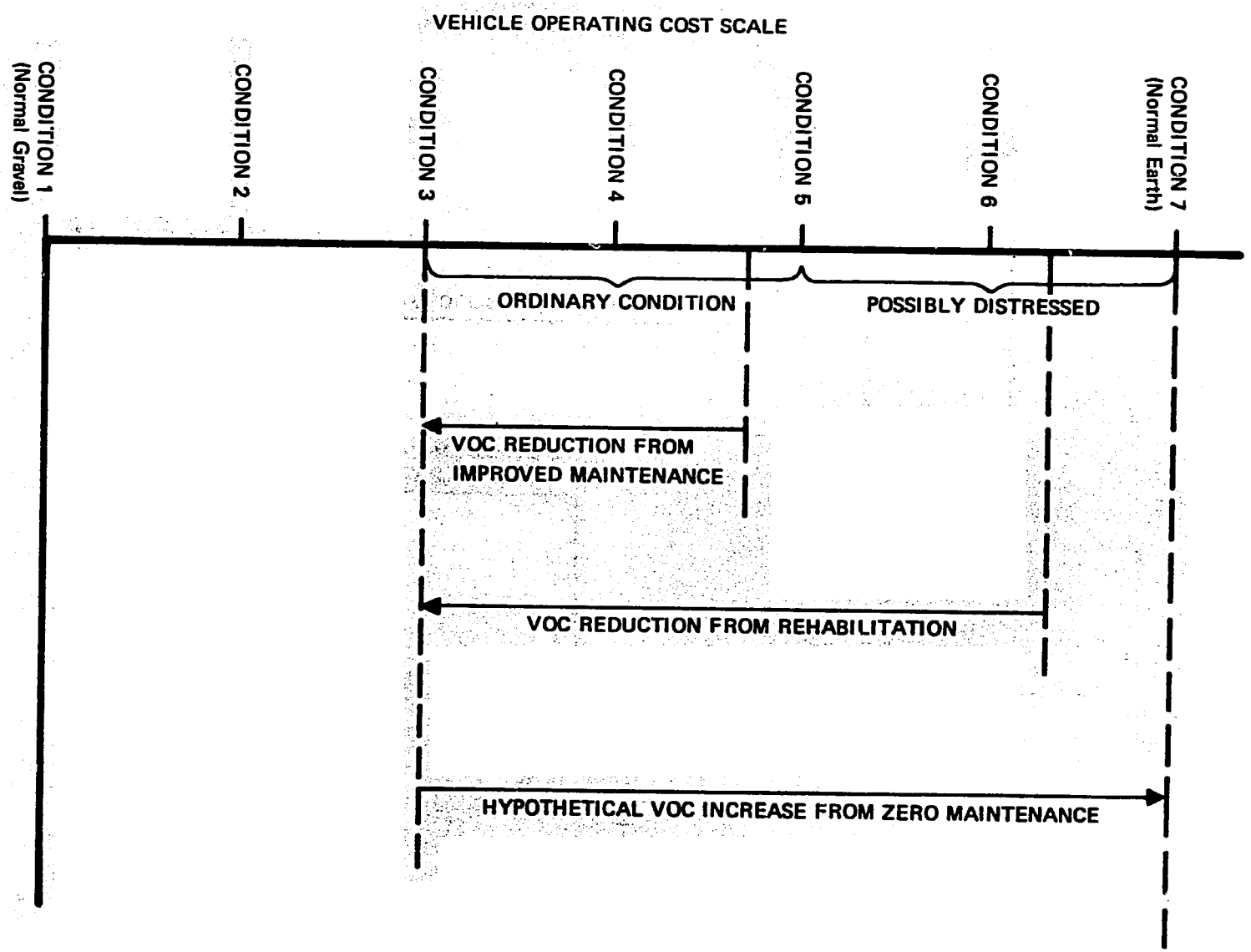

EXHIBIT IV-D CONDITION RATING AND INCREMENTAL VOC DIAGRAM, SERVICE TO TRAFFIC ROADS (Gravel Surface - Type 6)

Section V

MAINTENANCE PRIORITY RANKING

A. General

One of the primary objectives of the study was the determination of maintenance priorities within the Ethiopian highway system. The ranking of highway sections in terms of net benefits to highway users was a fundamental stipulation in the scope of work. Initial efforts were directed toward assessing the broad economic worth to the IEG of various highway sections, but such criteria as national unity, foreign exchange generated, facilitation of trade, and regional access were too broad and general to apply to the numerous small segments of highway which had to be considered in the development of a comprehensive maintenance program. There was one common variable that applied equally to long or short sections of road; the differential costs incurred by the users of the system. The methodology developed during the study was based on the fact that maintenance prevents the gradual increase of vehicle operating costs. The prevention, or avoidance, of this increase was viewed as the benefit of maintenance. The costs were those that would have to be borne to protect the original highway investment. The derivation of maintenance costs is described in Section III; subsequent paragraphs of this section discuss the ranking technique in detail.

1. Ranking Methodology

In order to rank all highway segments equally, it was necessary to assume that all sections were in a condition where vehicle operating costs were "normal." This did not reflect the true status of the highway system, but was a necessary assumption to make the ranking process fair. Sections or segments of highway that had deteriorated could not be disadvantaged because of previous budgetary, equipment or manpower problems. For the ranking exercise, all sections of road were assumed to be in condition which met the normal standards for the road type.

A second assumption in the ranking procedure was that the required maintenance expenditure was the minimum necessary to keep the road at an accepted standard, and prevent its loss. This assumption was also necessary to achieve equality in the ranking process. To estimate lower maintenance costs on some sections would, in part, predetermine the importance of those sections. Using the outputs of the ranking process, planners can draw judgments as to the worth of, or need to preserve, a road section, but the maintenance expenditure and incremental VOC are but two of the many variables which should enter into such a decision. There might be persuasive reasons for considering a lower level of maintenance in some circumstances, but at any lower level some deterioration of the road would take place, according to the assumption.

The methodology developed consisted of classifying the current and projected systems by road segments. The classification was made on the basis of surface type, topography, climate zone and traffic. This procedure resulted in the identification of about 500 segments of road. Maintenance practices were analyzed and minimum maintenance packages were costed out for 54 basic road types (six surface standards times three climate types times three terrain classes). Due to special physical conditions, such as unstable slopes, some of the basic maintenance costs had to be increased for individual road segments. The derivation of the maintenance costs and the identification of segments are described in Section III.

It was necessary to estimate the lives of all road types under the condition of zero maintenance. These lives were defined as the time it would take for the surface to degenerate to the next lower surface type; that is, the time for an asphalt surface to become gravel and for gravel to become earth. Section IV describes the rationale for these estimates. It should be noted that for asphalt pavement the life is a function of climate and the age of the surface. For gravel, it is a function of the topography, climate and generalized traffic volume.

If a road were permitted to deteriorate through the estimated lives, the highway users would experience increasing operating costs

above those normal for the surface at its basic standard. As stated, the avoidance of these increased costs was taken as a benefit realized from maintenance. In reality, such benefits would never be enjoyed, as the original justification of the road expenditure should have considered that the necessary maintenance would be provided. To say that maintenance has benefits above those that were included in the initial feasibility study would be to double count those benefits. Therefore, net benefits due to maintenance are meaningful only for ranking purposes. In the later estimation of the real benefits which could be obtained by adopting the maintenance program proposed by the Consultants, no benefits were assumed for the new or improved highways of future years (except for a postulated one-increment deterioration in gravel surfaces if present maintenance levels were continued).

The ranking consisted of determining the increasing VOC to users as maintenance was (theoretically) no longer provided. Exhibit V-1 is a flow chart describing the process. The ranking program required as inputs the segment identification, the length of the segment, the average daily traffic that was forecast to exist in 1972 by vehicle type, the incremental cost of operating the vehicles on the next lower surface type, the expected growth rate in traffic per year per road segment, the maintenance cost per kilometer per segment, the opportunity cost of capital, and the expected life of the present surface, given no maintenance. Vehicle operating costs were assumed to increase linearly as the surface deteriorated. It was realized that this assumption might not be true, but for the purpose of ranking it was considered valid.

The annual expected traffic was multiplied by the incremental economic VOC per vehicle per segment per year, for each year of the life of the surface. This generated the total incremental VOC per year for each segment of road.

The estimated minimum maintenance cost per segment was multiplied by an economic factor reflecting the shadow maintenance cost. This generated the annual minimum maintenance cost. This cost included the routine, periodic and special maintenance costs needed to

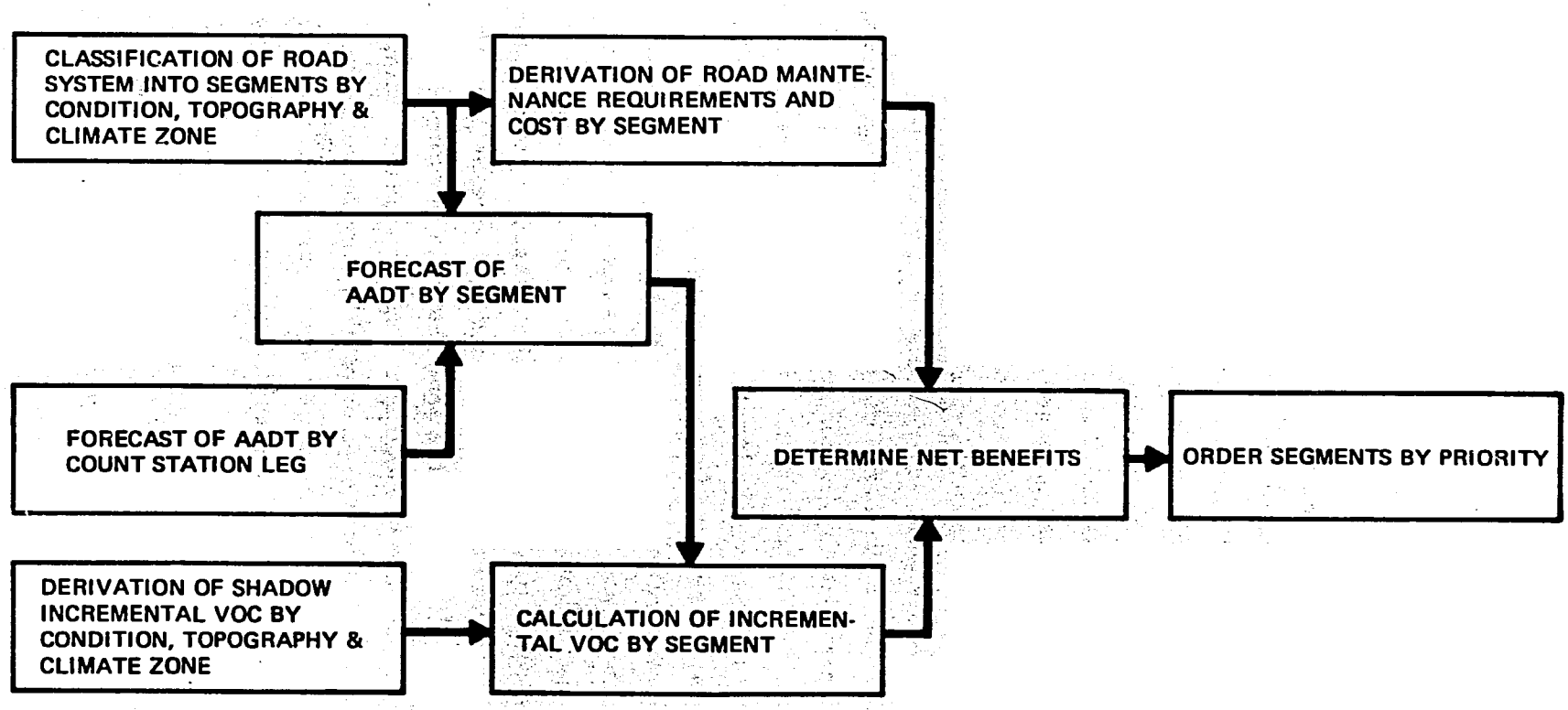

EXHIBIT V-1 FLOW CHART - PRIORITY RANKING OF ROAD SYSTEM

preserve each specific segment. The program generated a time stream of incremental increases in VOC and total maintenance costs over the life of the segment. The annual difference between the maintenance cost and the incremental VOC was calculated, which represented the annual net benefit. The present value of this benefit was computed at the opportunity cost of capital, producing an estimate of the present value net benefit due to maintenance. The road segments were then ordered in a descending scale, with the highest present value net benefit segments ranked first. This ranking served as an indicator of the importance of each segment.

It must be emphasized that the ranking procedure adopted did not quantify the benefits that would occur due to the implementation of the maintenance program recommended by this study. Those benefits, which are quantified by another technique described in Section XIII, are the reduction of VOC's that could be realized on the road system selected for maintenance. The costs of obtaining those benefits would be the incremental maintenance cost difference for the recommended program, compared with present level expenditures.

The ranking process simply places priorities on maintenance. It does not measure national benefits associated with a specific road segment, or with the entire system. Since vehicle operating cost is only one element in the justification for preserving a road, no decision to reduce or discontinue maintenance on a specific segment should be taken without considering other criteria. The ranking methodology presented here gives only a partial indication of the segment's importance.

B. Vehicle Operating Cost Derivation

1. Synopsis

The vehicle operating cost analysis, as it pertains to the road maintenance study, was based primarily on data from the General Road Study (GRS) performed by Rendel, Palmer, and Tritton. Early in this present study the Consultants investigated the availability of VOC information which might have been developed since the draft GRS report was published. Except for studies by the Road Transport Administration,

which were concerned with the overall cost of operating a truck-tanker between Addis Ababa and the Asseb Refinery, and an analysis of vehicle insurance costs, no additional work was encountered. The Consultants then proceeded to investigate whether there was any new material regarding VOC by major class of vehicle on different conditions of surface, especially in developing countries. Except for a few scattered references to investigations in the United States, no relevant work was located. Therefore, it was decided to use the GRS data with some modifications. This decision was reached in consultation with the IHA and USAID.

It is important to understand the function of determining the VOC's. As described in Section V-G, which details the ranking process, the benefit (avoidance of increasing VOC), is set against the expenditure required to preserve the road. As the maintenance cost has been carefully determined, it is important for the ranking process that the VOC's for the major vehicle types be correct in relation to each other. Based on this consideration and the lack of data concerning actual VOC's on various surface types and conditions, the modification of the GRS work was the most cost-effective way to proceed.

In the detailed material concerning vehicle operating costs, which is a part of the Economics Appendix, the derivations from the GRS are discussed. The techniques and major assumptions employed in the GRS have been validated through the Consultants' experience in other countries. Changes were made whenever updated data showed that the 1968 GRS figures would distort the present VOC. The GRS recommended that Ethiopian operating costs be more thoroughly examined in a special analysis, and the Consultants agree that a more accurate determination is needed. A task of the IHA Planning and Programming Division should be the study and tabulation of these costs. This data is essential to feasibility studies both for road upgrading and for new roads.

The detailed analysis of the VOC resulted in the economic costs shown in Exhibits V-2 and V-3. Exhibit V-4 shows the percentage increase in VOC from 1968 to 1972.

EXHIBIT V-2

ECONOMIC VEHICLE OPERATING COSTS (E¢/KM) ON PAVED SURFACES

Terrain	Highway Standard	Vehicle Type: Truck-Trailer	10-Ton Truck	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
Flat	1	81.2	45.7	28.8	57.3	20.5	13.5	7.1
	2	86.4	49.2	30.7	62.1	22.5	14.9	7.8
	3	91.6	52.8	32.5	67.0	24.5	16.1	8.4
	4	96.8	56.4	34.4	71.9	26.5	17.4	9.1
Rolling	1	116.2	54.4	34.2	66.1	24.6	14.1	7.4
	2	123.9	58.6	36.5	71.6	26.9	15.4	8.1
	3	131.5	62.7	38.7	77.0	29.1	16.8	8.8
	4	139.2	67.0	40.9	82.5	31.4	18.1	9.5
Mountainous	1	167.2	74.0	42.9	85.9	31.2	15.5	8.1
	2	178.1	79.7	45.8	92.7	33.9	16.9	8.9
	3	188.9	85.2	48.7	99.6	36.7	18.4	9.6
	4	200.1	90.9	51.6	106.5	39.4	19.8	10.3

EXHIBIT V-3

ECONOMIC VEHICLE OPERATING COSTS (E¢/KM) ON GRAVEL SURFACES

Terrain	Highway Standard	Vehicle Type: Truck Trailer	10-Ton Truck	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
Flat	1	96.3	56.2	33.9	71.0	26.3	14.6	8.9
	2	107.6	61.4	37.8	78.9	29.1	16.0	9.8
	3	119.3	67.7	41.7	86.9	31.9	17.6	10.8
	4	130.6	72.0	45.7	96.2	34.7	19.1	11.7
	5	141.9	73.1	49.6	103.1	37.6	20.6	12.6
	6	153.2	82.6	53.6	111.1	40.3	22.1	13.6
	7	164.5	87.9	57.4	119.7	43.2	23.7	14.6
Rolling	1	138.4	66.7	40.4	81.6	31.2	15.2	9.3
	2	154.2	73.0	45.0	90.8	34.6	16.7	10.2
	3	170.7	79.3	49.6	100.2	37.9	18.2	11.2
	4	186.9	85.6	54.2	109.5	41.2	19.8	12.2
	5	203.1	91.8	58.8	118.9	44.5	21.4	13.2
	6	219.3	98.1	63.3	128.1	47.8	22.9	14.2
	7	235.5	105.7	68.0	137.5	51.1	24.5	15.1
Mountainous	1	199.0	90.5	50.9	105.3	39.2	16.6	10.1
	2	222.0	99.7	56.6	117.3	43.3	18.2	11.1
	3	244.7	108.9	62.3	129.4	47.4	19.9	12.2
	4	268.1	118.0	68.0	141.4	51.5	21.6	13.2
	5	291.2	127.2	73.7	153.4	55.7	23.3	14.3
	6	314.3	136.4	79.4	165.4	59.8	24.9	15.3
	7	338.7	145.8	85.2	177.4	64.0	26.6	16.4

EXHIBIT V-4

PERCENTAGE INCREASE IN ECONOMIC VOC
1968-1972

Surface-Terrain	Truck-Trailer	10-Ton Truck	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
Paved - Flat	23.0	23.0	30.9	12.3	7.8	6.2	7.0
Paved - Rolling	18.5	20.8	26.6	13.9	11.8	6.3	7.0
Paved - Mountainous	16.9	19.0	26.1	14.5	11.4	6.3	6.0
Gravel - Flat	18.8	22.1	25.5	12.6	14.3	3.9	7.0
Gravel - Rolling	17.2	21.2	22.4	13.3	15.2	9.3	8.0
Gravel - Mountainous	17.0	19.0	21.0	13.2	16.6	10.1	7.0

C. Shadow Cost Factors for Vehicle Operating Cost

The financial vehicle operating costs had to be adjusted to true economic costs for the purposes of determining the real economic benefits associated with improved highway maintenance. The use of shadow costs did not affect the ranking methodology since constant factors were applied to both maintenance costs and VOC. The use of shadow prices would affect alternative methods of maintenance, but such alternatives were not considered in the ranking process.

Basically, shadow costs are determined by excluding taxes, registration fees and insurance, and adjusting the labor costs by the shadow wage rate. This requires that the depreciation cost be modified to reflect the CIF price of the vehicle, and the interest rate must be adjusted to the opportunity cost of capital. Taxes and profit have to be subtracted from the fuel and tire costs, wages must be adjusted to reflect the shadow wage rate, and the labor and parts cost of vehicle maintenance must be estimated.

1. Derivation of Shadow Cost Factors

Exhibit V-5 provides the CIF price and the selling price of the major vehicle types. The shadow price factor is then taken to be the ratio of the CIF price to the selling price. This factor is subsequently applied to the depreciation cost per kilometer for each vehicle type.

Similarly, Exhibit V-6 illustrates the derivation of the shadow price factor for tires. In reviewing these figures it must be remembered that the selling price varies for different buyers depending on the size of purchase, manufacture of tire, place of purchase, etc. However, the shadow price factor for tires is fairly consistent, ranging from 0.68 to 0.795. The GRS range was from 0.74 to 0.825. The difference is due to the fact that the selling price has increased more rapidly than the CIF price.

The determination of the shadow price of fuel is shown in Exhibit V-7. In this case the shadow price has risen faster than the

EXHIBIT V-5

SHADOW PRICE FACTORS FOR VEHICLES

	10-Ton Truck	Trailer	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
CIF Price (E$)*	32,240	12,070	18,571	69,700	19,400	4,690	3,015
Selling Price (E$)**	48,680	20,280	23,800	95,800	32,600	12,140	7,300
Shadow Factor	.7854	.60	.78	.73	.60	.38	.30

*Source: IEG Ministry of Customs, and dealer interviews.
**Source: Local dealer interviews.

EXHIBIT V-6

SHADOW PRICE FACTOR FOR TIRES

	Large Truck/Bus	Medium Truck	Small Bus	Large Car	Small Car
CIF Price (E$)	370	184	100	52	30
+ Transport (E$)	10	4	3	2	2
+ Margin (E$)	45	27	14	7	4
Shadow Price	425	215	117	61	36
Selling Price (E$)	540	270	160	80	53
Shadow Price Factors	.79	.795	.73	.765	.68

EXHIBIT V-7

SHADOW PRICE OF FUEL

	Gasoline	Diesel
Ex-refinery Price (E¢/liter)	14.00	8.75
Transport Cost	5.70	5.70
Lessee Margin	1.10	1.10
Oil Company Margin	4.25	4.25
Shadow Price (E¢/liter)	25.05	19.80
Selling Price (E¢/liter)	50.0	42.5
Shadow Factor	.5	.465

selling price because the refinery price and the transport cost have risen, while the selling price has been held stable. The price at Addis Ababa was taken as representative, since the majority of the vehicle fleet operates out of that center.

The shadow price factor for the drivers' and assistants' wages was taken as 0.78. The "Guide to Planning in Ethiopia" states that the shadow price for skilled labor should be 1.0 and for unskilled labor 0.75. As the GRS determination of the shadow wage was a specific analysis directed towards mechanics and drivers, it was felt that the use of their shadow price factor was more accurate. However, the difference between 0.78 and 1.0 has little effect on the vehicle operating costs and, as stated earlier, none on the ranking.

The maintenance shadow price factor is determined by assuming some proportion of labor costs and parts costs for maintenance. Unfortunately, no good data could be found on the mix of labor and material used in maintenance. Individual owners perform most of the maintenance themselves, and often with used or built parts. Large fleet owners hire mechanics on a permanent basis and use both new and old parts. No records were available as to the work on any specific types of vehicles. Therefore, it was necessary to determine whether the mix of labor and materials was important in fixing the shadow cost factor. If an 80/20 mix of labor to material is used, then a shadow factor of .63 results. This is using a labor shadow cost factor of 0.78 and a parts shadow cost factor of 0.5. The latter is assumed since there is a 50 percent duty on new parts. In reality, the factor may be different due to use of rebuilt and used parts but this is difficult to determine. If a mix of 30/70 labor and material is used, then the shadow cost factor is 0.7. Obviously the difference is not significant. The 0.7 factor is used in this analysis. Exhibit V-8 shows the shadow cost factors for each item.

2. Calculation of Economic Vehicle Operating Costs

The shadow price factors are applied to the financial vehicle operating costs for each vehicle type. The ratio of the economic VOC

EXHIBIT V-8

SHADOW COST FACTORS

Item	Truck Trailer	10-Ton Truck	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
Depreciation	.78	.60	.78	.73	.60	.38	.30
Fuel	.465	.465	.465	.465	.465	.5	.5
Tires	.79	.79	.79	.79	.73	.76	.68
Wages	.78	.78	.78	.78	.78	.78	.78
Maintenance	.7	.7	.7	.7	.7	.7	.7

to the financial VOC for each vehicle type is the shadow VOC factor for that type. The economic VOC and the ratio for each vehicle type are shown in Exhibits V-9 through V-15. These factors are next applied to the vehicle operating costs on the various surface types, terrains and surface standards. The resulting economic costs are shown in Exhibits V-16, V-17, and V-18.

It was necessary to group the VOC's into the four vehicle categories that have been used by the IHA for count station purposes. In 1971 the traffic count was more detailed than formerly, but it is difficult to draw inferences from one year's data. The truck-trailer VOC was not modified since it is a specific vehicle type in the station counts. Exhibit V-19 shows the detailed vehicle mix that existed on the Ethiopian roads in 1971. Examination of the exhibit shows that the mix of traffic throughout the country is not uniform. For costing purposes, the 10-ton heavy truck and the 7-ton medium truck VOC's are averaged. The VOC's for large and small buses and those for large and small cars are also averaged. Exhibit V-20 illustrates the average VOC by vehicle type, surface and terrain for these averaged costs.

3. Economic Vehicle Operating Cost Range

The ranking process requires that the hypothetical annual increases in VOC be determined as the surface deteriorates from one surface type to the next. This is under the assumption that the maintenance required to preserve the road is not performed. Exhibit V-21 illustrates the incremental VOC as the surface condition deteriorates from one condition to the next. The determination of the range of conditions that paved and gravel surfaces go through, and the lives of various surfaces, are described in Section IV. The costs shown in Exhibit V-21 are those that are used in the ranking program. These costs are divided by the life of the specific segment of road that is being ranked. This generates an annual incremental vehicle operating cost for each segment.

EXHIBIT V-9

22-TON TRUCK ECONOMIC OPERATING COST
(E¢/KM)

Cost Element	Paved Surface		Gravel Surface		Earth Surface	
	E¢	%	E¢	%	E¢	%
Depreciation	8.4	13.6	12.1	16.6	21.0	16.7
Interest	5.6	9.1	5.8	7.9	9.8	7.8
Fuel	7.9	12.8	9.0	12.3	13.2	10.5
Oil	.8	1.1	1.0	1.4	1.7	1.3
Tires and Tubes	18.1	29.4	20.1	27.5	36.2	28.8
Wages	10.3	16.7	10.3	14.1	18.0	14.3
Maintenance and Repair	10.5	17.0	14.7	20.1	25.9	20.6
Total Costs	61.6		73.0		125.8	
Shadow Cost Factor	.69		.69		.69	

EXHIBIT V-10

10-TON TRUCK ECONOMIC OPERATING COST
(E¢/KM)

Cost Element	Paved Surface		Gravel Surface		Earth Surface	
	E¢	%	E¢	%	E¢	%
Depreciation	5.5	13.3	7.8	15.3	13.6	17.2
Interest	4.9	11.7	5.8	11.4	7.1	9.0
Fuel	5.1	12.3	5.8	11.4	8.6	10.9
Oil	.6	1.4	.7	1.4	1.1	1.4
Tires and Tubes	8.5	20.1	9.4	18.5	17.0	21.5
Wages	9.7	23.5	11.6	22.8	14.2	17.9
Maintenance and Repair	7.0	16.9	9.8	19.2	17.5	22.1
Total Costs	41.3		50.9		79.1	
Shadow Cost Factor	.66		.66		.66	

EXHIBIT V-11

7-TON TRUCK ECONOMIC OPERATING COST
(E¢/KM)

Cost Element	Paved Surface		Gravel Surface		Earth Surface	
	E¢	%	E¢	%	E¢	%
Depreciation	4.6	16.7	6.6	20.4	11.6	20.9
Interest	2.7	9.8	2.7	8.3	4.7	8.5
Fuel	3.9	14.2	4.6	14.2	6.6	11.9
Oil	.4	1.4	.5	1.5	.8	1.4
Tires and Tubes	4.3	15.6	4.7	14.6	8.5	15.3
Wages	7.8	28.4	7.8	24.2	13.6	24.5
Maintenance and Repair	3.8	13.9	5.4	16.8	9.6	17.3
Total Costs	27.5		32.3		55.4	
Shadow Cost Factor	.666		.656		.663	

EXHIBIT V-12

LARGE BUS ECONOMIC OPERATING COST
(E¢/KM)

Cost Element	Paved Surface		Gravel Surface		Earth Surface	
	E¢	%	E¢	%	E¢	%
Depreciation	10.7	20.2	15.3	23.2	26.9	24.3
Interest	9.6	18.1	11.3	17.7	19.3	16.5
Fuel	5.1	9.6	5.8	8.8	7.9	7.1
Oil	.7	1.3	.9	1.4	1.6	1.4
Tires and Tubes	8.5	16.0	9.5	14.4	17.1	15.5
Wages	12.5	22.9	14.3	21.7	23.2	20.9
Maintenance and Repair	6.2	11.7	8.7	13.2	15.5	14.0
Total Costs	52.9		65.8		110.6	
Shadow Cost Factor	.695		.677		.676	

EXHIBIT V-13

SMALL BUS ECONOMIC OPERATING COST
(E¢/KM)

Cost Element	Paved Surface		Gravel Surface		Earth Surface	
	E¢	%	E¢	%	E¢	%
Depreciation	3.5	17.4	5.1	20.3	8.9	21.5
Interest	2.9	14.4	3.4	13.5	5.4	13.0
Fuel	3.9	19.4	4.6	18.3	6.6	15.9
Oil	.3	1.5	.4	1.6	.6	1.4
Tires and Tubes	2.3	11.4	2.6	10.4	4.7	11.4
Wages	4.1	20.4	4.7	18.7	7.5	18.1
Maintenance and Repair	3.1	15.4	4.3	17.1	7.7	18.6
Total Costs	20.1		25.1		41.4	
Shadow Cost Factor	.605		.601		.604	

EXHIBIT V-14

LARGE CAR ECONOMIC OPERATING COST
(E¢/KM)

Cost Element	Paved Surface		Gravel Surface		Earth Surface	
	E¢	%	E¢	%	E¢	%
Depreciation	2.9	26.5	4.1	29.7	7.2	32.9
Interest	2.7	24.7	3.4	24.6	5.1	23.3
Fuel	2.6	23.8	2.9	21.0	4.0	18.3
Oil	.2	1.8	.3	2.2	.4	1.8
Tires and Tubes	.8	7.7	.9	6.6	1.7	7.8
Wages	-	-	-		-	
Maintenance and Repair	1.7	15.5	2.2	15.9	3.5	16.0
Total Costs	10.9		13.8		21.9	
Shadow Cost Factor	.514		.50		.49	

EXHIBIT V-15

SMALL CAR ECONOMIC OPERATING COST
(E¢/KM)

Cost Element	Paved Surface		Gravel Surface		Earth Surface	
	E¢	%	E¢	%	E¢	%
Depreciation	1.8	25.3	2.6	29.2	4.5	30.6
Interest	1.6	22.5	1.9	21.3	3.1	21.1
Fuel	2.0	28.1	2.3	25.8	3.1	21.1
Oil	.1	1.4	.2	2.2	.3	2.0
Tires and Tubes	.54	7.0	.61	6.7	1.6	10.9
Wages	-		-		-	
Maintenance and Repair	1.1	15.5	1.3	14.6	2.1	14.3
Total Costs	7.1		8.9		14.7	
Shadow Cost Factor	.458		.447		.449	

EXHIBIT V-16

ECONOMIC VEHICLE OPERATING COSTS ON PAVED SURFACES
(E¢/KM)

Terrain	Highway Condition	Vehicle Type: Truck Trailer	10-Ton Truck	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
Flat	1	81.2	45.7	28.8	57.3	20.5	13.5	7.1
	2	86.4	49.2	30.7	62.1	22.5	14.9	7.8
	3	91.6	52.8	32.5	67.0	24.5	16.1	8.4
	4	96.8	56.4	34.4	71.9	26.5	17.4	9.1
Rolling	1	116.2	54.4	34.2	66.1	24.6	14.1	7.4
	2	123.9	58.6	36.5	71.6	26.9	15.4	8.1
	3	131.5	62.7	38.7	77.0	29.1	16.8	8.8
	4	139.2	67.0	40.9	82.5	31.4	18.1	9.5
Mountainous	1	167.2	74.0	42.9	85.9	31.2	15.5	8.1
	2	178.1	79.7	45.8	92.7	33.9	16.9	8.9
	3	188.9	85.2	48.7	99.6	36.7	18.4	9.6
	4	200.1	90.9	51.6	106.5	39.4	19.8	10.3

EXHIBIT V-17

ECONOMIC VEHICLE OPERATING COSTS ON GRAVEL SURFACES
(E¢/KM)

Terrain	Highway Condition	Vehicle Type: Truck Trailer	10-Ton Truck	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
Flat	1	96.3	56.2	33.9	71.0	26.3	14.6	8.9
	2	107.6	61.4	37.8	78.9	29.1	16.0	9.8
	3	119.3	67.7	41.7	86.9	31.9	17.[illegible]	10.8
	4	130.6	72.0	45.7	96.2	34.7	19.1	11.7
	5	141.9	73.1	49.6	103.1	37.6	20.6	12.6
	6	153.2	82.6	53.6	111.1	40.3	22.1	13.6
	7	164.5	87.9	57.4	119.7	43.2	23.7	14.6
Rolling	1	138.4	66.7	40.4	81.6	31.2	15.2	9.3
	2	154.2	73.0	45.0	90.8	34.6	16.7	10.2
	3	170.7	79.3	49.6	100.2	37.9	18.2	11.2
	4	186.9	85.6	54.2	109.5	41.2	19.8	12.2
	5	203.1	91.8	58.8	118.9	44.5	21.4	13.2
	6	219.3	98.1	63.3	128.1	47.8	22.9	14.2
	7	235.5	105.7	68.0	137.5	51.1	24.5	15.1
Mountainous	1	199.0	90.5	50.9	105.3	39.2	16.6	10.1
	2	222.0	99.7	56.6	117.3	43.3	18.2	11.1
	3	244.7	108.9	62.3	129.4	47.4	19.9	12.2
	4	268.1	118.0	68.0	141.4	51.5	21.6	13.2
	5	291.2	127.2	73.7	153.4	55.7	23.3	14.3
	6	314.3	136.4	79.4	165.4	59.8	24.9	15.3
	7	338.7	145.8	85.2	177.4	64.0	26.6	16.4

EXHIBIT V-18

ECONOMIC VEHICLE OPERATING COSTS ON EARTH SURFACES
(E¢/KM)

Terrain	Vehicle Type						
	Truck Trailer	10-Ton Truck	7-Ton Truck	Large Bus	Small Bus	Large Car	Small Car
Bench Mark (Flat, straight)		79.1	55.4	110.6	41.4	21.9	14.7
Flat	165.6	88.0	58.0	119.4	43.4	21.9	14.7
Rolling	237.3	105.8	68.7	137.2	51.5	22.7	15.2
Mountainous	340.8	145.9	86.1	177.0	64.2	24.7	16.5

EXHIBIT V-19

VEHICLE MIX - PERCENTAGES

Route No.	Count Station No.	Station Location	Cars	Large Rover	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck Trailer
6	16	Nazreth								
		a. West to Modjo	43.6	9.1	25.8	1.5	5.3	4.8	7.7	2.2
		b. East to Wlenchiti	27.5	15.1	10.7	3.0	8.3	11.4	18.2	5.8
		c. South to Assela	53.4	10.8	13.4	1.7	6.6	5.2	7.9	1.0
	8	Dengego								
		a. Dire Dawa Leg	46.9	12.8	15.6	5.0	6.0	4.2	9.4	0.1
		b. Southeast to Harer	44.6	12.8	21.2	2.2	5.2	3.9	9.9	0.2
		c. West to Kulubi	18.9	20.4	12.7	8.9	12.0	7.2	19.4	0.5
4	9	East of Harer, Jigiga Road	22.2	14.6	10.2	11.8	13.0	9.4	17.4	1.4
20	5	Menagesha, 30 km West of Addis Ababa	28.6	8.4	21.5	6.8	6.9	7.5	18.2	2.1
	20	Guder Northwest to Lekempty	9.8	10.4	10.2	21.5	3.2	4.7	38.9	1.3
	15	Shashamane, Junction to Sodo								
		a. Shashamane town	27.9	12.3	23.3	3.9	8.1	10.1	12.7	1.7
		b. South to Wondo	32.3	12.6	19.8	3.9	8.3	10.1	11.6	1.4
		c. Sodo Road	26.2	12.9	21.7	5.0	8.9	10.8	13.7	0.8
6	14	Junction on Road to Yergalem								
		a. North to Shashamane	23.6	16.2	21.0	7.8	6.3	6.8	15.8	2.5
		b. South to Wondo	42.6	12.1	16.3	5.6	4.4	6.1	10.8	2.1
		c. East to Yergalem	45.1	9.2	23.8	7.8	4.2	5.2	4.5	0.2
6	13	Wondo								
		a. Southwest to Dilla	16.5	14.9	24.3	8.3	5.9	12.6	15.7	1.8
		b. Kebremengist Road	12.5	19.6	13.2	5.1	8.8	10.6	22.1	8.1
7	6	Alemgena, 19 km Southwest of Addis Ababa								
		a. Northwest to Addis Ababa	36.9	8.6	21.0	5.7	9.0	6.5	10.5	1.8
		b. Southwest to Ghion	35.8	8.5	21.0	6.0	9.6	6.9	10.1	2.1
		c. South to Butajira	26.6	10.0	21.6	6.6	11.4	8.9	13.5	1.4
7	11	North of Gion (to Alemgena)	21.0	10.1	24.4	11.5	8.0	8.5	13.3	3.2
	22	North of Welkite (to Ghion)	14.1	13.2	24.7	13.6	7.8	8.3	15.5	2.7
	19	North of (to Jimma)	20.3	13.5	10.9	10.2	9.8	11.6	20.2	3.6
11	106	Junction to Merara Road Northwest of Asmara								
		a. Southeast to Asmara	26.2	4.1	12.7	11.4	6.5	13.3	15.2	10.6
		b. Northwest to Keren	14.5	3.4	-	13.5	9.2	35.3	24.1	-
		c. North to Merara	21.7	3.3	16.1	6.7	6.7	38.8	6.7	-
	103	Edaga Junction to Massawa Rd.								
		a. Northwest to Asmara	58.9	2.2	15.6	2.2	8.7	5.9	3.6	2.9
		b. East to Massawa	57.0	3.1	17.5	2.7	10.4	5.3	2.7	1.3
		c. South to Arkibo	49.8	4.7	14.1	2.7	12.9	7.5	5.7	2.6
		d. North to Grar	55.0	2.3	10.4	4.6	10.8	7.1	6.8	3.0
2	17	East of Bati	4.2	5.1	2.5	4.6	2.6	3.8	6.9	70.3
3	4	Chancho 35 km North of Addis Ababa	29.2	7.9	24.5	11.6	6.4	6.8	13.3	0.3
	10	Junction on Road to Fitche								
		a. South to Chancho	19.1	8.8	20.2	12.1	6.6	6.7	26.0	0.5
		b. North to Dejen	16.6	11.0	18.4	11.9	7.4	6.0	28.2	0.5
		c. North to Fitche	19.4	13.6	39.6	10.4	4.9	4.6	7.4	0.1
3	113-A	Junction Near Addis Zemen								
		a. South to Bahir Dar	7.3	10.8	16.5	42.3	6.3	4.2	12.1	0.5
		b. North to Gonder	18.3	11.0	10.6	11.0	7.3	4.9	33.7	3.2
		c. North to Addis Zemen	13.7	18.1	13.2	45.2	17.6	4.0	7.2	1.0

EXHIBIT V-19
(Continued)

Route No.	Count Station No.	Station Location	Cars	Large Rover	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck Trailer
	113	Azezo Junction 13 km from Gonder								
		a. North to Goner	36.3	12.2	13.0	8.5	9.4	5.1	14.4	1.1
		b. Southeast to Addis Zemen	47.4	13.1	9.4	10.9	6.5	3.2	9.1	0.4
		c. North to Gorgora	10.4	12.6	31.2	12.4	14.7	9.3	8.7	0.7
	112	Debarek, 10 km North of Gonder	6.4	8.3	10.1	18.3	1.8	8.7	36.3	10.1
	110-A	Junction North of Enda Selassie to Axum	5.8	6.0	7.1	15.4	5.4	13.8	38.9	7.6
	110	Adi Abun								
		a. North to Asmara	14.8	4.9	6.6	4.4	4.0	14.0	43.0	8.3
		b. West to Axum	10.6	7.3	8.2	26.3	4.3	17.5	22.9	2.9
		c. South to Adwa	19.2	4.4	16.4	25.0	3.5	21.0	9.3	0.3
		d. East to Adigrat	2.8	1.2	12.0	30.0	6.4	36.4	10.0	1.2
	105	Junction 7 km Southwest of Asmara								
		a. North to Asmara	33.4	3.7	21.5	9.7	8.5	9.3	11.3	2.6
		b. South to Adi Ugri	38.9	3.6	16.5	6.9	8.4	12.1	11.3	2.3
		c. West to Himberti	43.4	7.4	7.5	2.0	14.0	15.6	9.1	1.0
	1	North of Akaki 17 km Southeast	52.3	5.7	14.7	1.9	6.0	5.8	8.7	4.9
	2	Modjo Junction 70 km South of Addis Ababa								
		a. Northwest to Debre Zeit	42.1	8.1	16.6	3.1	6.1	6.2	10.8	7.0
		b. East to Nazreth	41.2	7.4	16.7	2.9	5.9	6.7	12.1	7.1
		c. South to Shashamane	39.0	9.1	12.3	5.6	9.5	7.7	9.5	7.3
	3	Sendafa 38 km Northeast of Addis Ababa	14.1	6.9	15.5	13.0	6.0	7.4	7.1	30.0
	21	Southwest of Debre Berhan	9.4	6.9	14.3	15.7	6.6	8.2	6.5	32.4
	12	Combolcia								
		a. South to Debre Berhan	9.1	6.0	10.5	12.3	3.4	5.7	6.6	46.4
		b. North to Dessie	14.9	8.1	20.3	17.4	4.8	7.5	6.4	20.6
		c. East to Bati	7.9	5.3	9.0	6.0	3.8	5.1	8.5	54.4
	18	North to Dessie (Dessie-Quiha)	21.9	11.1	20.0	9.4	10.1	9.9	7.5	10.1
	114	Quiha								
		a. North to Adigrat	27.5	6.1	0.2	2.4	3.3	4.9	34.5	21.1
		b. South to Machew	11.0	6.0	3.0	2.0	3.0	6.0	47.5	11.5
		c. West to Mekele	35.7	16.9	1.4	9.8	6.7	12.7	13.3	3.5
	111	Adigrate								
		a. North to Senafe	10.0	3.0	8.3	6.3	4.6	7.2	34.4	26.2
		b. South to Quiha	20.5	4.6	11.2	7.3	7.3	11.2	36.6	1.3
		c. West to Adwa	16.8	6.2	1.8	38.0	5.3	13.3	17.7	0.9
	104	Decamere								
		a. Northwest to Asmara	26.2	4.0	14.0	7.4	8.4	13.6	17.4	9.0
		b. South to Senafe	36.2	3.0	6.9	8.8	7.6	24.5	12.4	0.6
		c. Northeast to Nefasit	42.6	4.0	4.7	5.5	9.5	19.5	13.5	0.7
	109	2 km North of Decamere								
		a. West to Asmara	39.3	2.8	10.4	6.6	5.0	16.5	14.6	4.8
		b. South to Decamere	8.2	1.4	2.8	0.8	3.4	56.9	26.2	0.3
		c. Terramini	22.9	2.8	16.2	21.2	3.4	24.6	6.7	2.2
	101	Nefasit								
		a. West to Asmara	35.2	3.6	0.7	4.4	13.5	6.6	20.3	15.7
		b. East to Massawa	35.7	4.6	0.4	4.8	14.3	9.0	18.7	12.5
		c. South to Decamere	12.4	9.1	-	6.9	16.4	41.4	12.7	1.1

EXHIBIT V-19
(Concluded)

Route No.	Count Station No.	Station Location	Cars	Large Rover	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck Trailer
	102	Maaday Junction 9 km from Asmara								
		a. West to Asmara	36.9	1.9	12.0	2.6	10.9	14.0	13.9	7.8
		b. East to Massawa	51.0	1.4	15.6	1.9	1.9	9.4	6.3	3.5
		c. North Gurgusm	49.7	1.8	11.6	1.8	11.2	8.2	12.0	3.7
	107	Junction 1 km South of Akordat								
		a. Northeast to Keren	0.7	2.8	-	19.2	2.4	8.6	35.7	30.6
		b. Southwest to Barentu	3.4	2.7	0.4	27.9	2.7	16.0	28.8	18.1
		c. North to Akordat	6.7	7.3	0.4	22.1	4.0	12.4	26.2	20.9
	108	Junction 6 km Northeast of Tesseney								
		a. Southeast to Barentu	-	-	-	-	-	-	-	-
		b. Southwest Tesseney	-	-	-	-	-	-	-	-
		c. North to Sebderat	-	-	-	-	-	-	-	-
20	7	West of I. D. (Gota Road)	29.1	11.5	1.7	9.8	10.5	13.1	24.2	0.1
	23	Debre Markos to Dejen Road	13.3	11.1	16.5	10.7	9.2	9.4	29.3	0.5
	24	Dangla to Debre Markso Road	11.2	11.7	20.2	12.5	7.8	14.1	21.5	1.0
	25	Bahir Dar to Dangla	18.0	12.7	19.9	9.7	9.1	10.0	18.9	1.7
	26	Kobo								
		a. North to Kulubi	19.6	17.1	16.2	8.5	6.4	8.8	22.9	0.5
		b. South to Asbe Teferi	19.9	15.2	14.8	10.4	5.1	8.7	25.2	0.7
		c. To Deber	35.8	32.7	15.4	2.0	7.9	2.1	4.1	-
	28	Junction Jimma								
		a. Northwest to Welkite	24.7	10.9	20.0	6.2	7.1	9.6	19.3	2.2
		b. Northeast to Agaro	28.3	15.2	26.6	2.4	6.9	7.9	12.0	0.7
		c. Southeast to Bonga	23.0	15.8	24.9	4.3	11.4	10.9	9.4	0.3
	30	East of Lekempty	31.5	20.3	6.0	7.1	7.9	6.8	19.9	0.5
	29	West of Lekempty to Ghimibi Road	23.1	16.3	3.4	6.7	5.5	7.9	36.6	0.5
	27	Toba Agaro	42.1	13.9	13.6	1.9	4.7	3.4	17.6	2.8
		Toba Bedele	37.9	13.7	12.1	3.0	9.5	5.2	15.9	2.7
	31	Melkasa South to Assela	22.8	17.7	23.8	4.3	7.2	5.9	17.1	1.2
	15-A	Kofole Junction								
		a. Meki	33.0	11.4	16.8	6.8	7.6	7.0	15.1	2.3
		b. Shashamane	27.9	12.8	18.2	6.3	7.7	8.2	16.6	2.3
		c. Kofole	23.4	18.6	16.2	4.5	10.1	10.6	14.8	1.8
	32	Mieso								
		a. Awash	17.5	16.6	12.0	4.8	8.5	13.8	26.1	0.7
		b. Asbe Teferi	24.7	16.0	12.6	4.1	6.8	11.8	23.3	0.7

EXHIBIT V-20

ECONOMIC VEHICLE OPERATING COSTS (E¢/KM)

Surface - Terrain	Truck Trailer	Single-Unit Truck	Bus	Passenger Car
Paved - Flat	81.2	37.2	38.9	10.3
Paved - Rolling	116.2	44.3	45.3	10.7
Paved - Mountainous	167.2	58.4	58.5	10.8
Gravel - Flat	96.3	45.0	48.6	11.7
Gravel - Rolling	138.4	53.5	56.4	12.2
Gravel - Mountainous	199.0	70.7	72.2	13.3
Earth - Flat	165.6	73.0	81.4	18.3
Earth - Rolling	237.3	87.2	94.2	18.9
Earth - Mountainous	340.8	116.0	120.6	20.6

EXHIBIT V-21

VOC RANGE FOR SURFACE TYPES AND TERRAIN BY CONDITION INCREMENTS (E¢/KM)

Surface - Condition Range	Truck Trailer	Single-Unit Truck	Bus	Passenger Car
Paved - Flat, 1-4	.16	.08	.10	.03
Paved - Rolling, 1-4	.23	.10	.11	.03
Paved - Mountainous, 1-4	.33	.13	.14	.03
Gravel - Flat, 2-6/3-7	.46	.19	.22	.05
Gravel - Rolling, 2-6/3-7	.65	.22	.25	.05
Gravel - Mountainous, 2-6/3-7	.92	.30	.32	.06

D. Analysis of the Shadow Price of Maintenance

The shadow price of maintenance was developed on the basis of the Little-Mirrlees method. The following breakdown shows the present elements of maintenance cost within the IHA:

Maintenance Cost at Market Prices	Percentage
Labor, skilled	12.1
Labor, unskilled	8.4
Materials	10.7
Plant and Equipment	39.6
Overheads	29.2
	100.0

(Source: IHA Cost Accounting Branch)

Each of the listed items had to be adjusted by a shadow price factor to convert the market price of maintenance to the economic price. Subsequent paragraphs provide the detailed breakdown of each of the items. All figures used were taken from IHA records. The Cost Accounting Branch had provided the identical information for the GRS and, except for slight changes in the percentage makeup of the detailed components under each item, there were no modifications. The new shadow price factors for labor as provided by the Planning Council were used. The resulting shadow price factor for maintenance is equal to 1.1.

1. Labor

Skilled labor accounts for 12.1 percent of the maintenance cost, while unskilled labor contributes 8.4 percent, for a total of 20.5 percent of the market value. Shadow wage factors of 1.0 and 0.7 are applied to these percentages, respectively. After adjusting for these factors, labor represented 17.4 percent of the economic cost of maintenance.

2. Materials

The materials content of the maintenance cost is 10.7 percent of the total. This is further broken down into IHA-provided and

contract-provided materials. The respective percentages are 98.7 and 1.3. This is a considerable change from the breakdown in 1968, when the percentages were 77.5 and 22.5. The unskilled labor portion of the materials cost is 38.3 percent while depreciation, materials, fuel and lubricants, and repairs account for the remaining 61.7 percent. After adjustment, this cost accounted for 16.2 percent of the economic cost of maintenance.

3. Plant and Equipment

Plant and equipment costs account for 39.6 percent of the maintenance cost at market prices. Of the 39.6 percent, 25 percent is for depreciation, 23 percent for materials and spares, 33 percent for repair labor, and 19 percent for operational fuels and lubricants. The adjusted plant and equipment cost is 47.6 percent of the economic cost of maintenance.

4. Overheads

This item accounts for 29.2 percent of the market price of maintenance. It is composed of 54.7 percent skilled labor allowance, 42.5 percent materials and equipment allowances, and 3.8 percent allowance for building depreciation. The adjusted overhead cost is 29.3 percent of the economic cost of maintenance.

E. Opportunity Cost of Capital

The opportunity cost of capital as used for this study is 10 percent. This is the rate recommended by the Planning Commission Office. The use of a common rate is an obvious necessity if multisectoral projects are to be evaluated by the Commission. This rate was also verified with the National Bank of Ethiopia. It is the rate that applies to the majority of foreign private business loans. Where appropriate, tests were made of the sensitivity of results to changes in the opportunity cost of capital.

F. Traffic Forecasts

Traffic forecasting on the existing highway system posed a difficult problem, since it had become clear from previous studies and observations that the reliability of the station count data was suspect. Traffic trends were very erratic and numerous sections of the IHA-maintained road had no traffic data at all. The General Road Study forecasts were examined and those for 1969, 1970, and 1971 compared with the actual IHA counts. It was recognized by the GRS consultants that the data base was poor and trend forecasting was difficult. Exhibit V-22 shows the annual road network AADT and annual percentage increase. The exhibit indicates how erratic the traffic has been. The approach used in the former study was to determine an annual percentage growth based on the historical trend and then fit a log-linear curve though the past data points. The fit over a 10-year period was usually poor, and shorter periods were used until a good visual fit was obtained. However, when count station data for 1969, 1970, and 1971 were compared to the GRS forecasts, serious descrepancies were found, and it was obvious that these forecasts for the existing system would not be usable for the maintenance study. Therefore, new forecasts were derived.

Initially, it was hoped that a technique could be developed where traffic was a function of some independent variable such as agriculture or foreign trade. Accordingly, road sections were categorized in agricultural districts, and an attempt was made to correlate traffic to agricultural production, imports and exports, and population. Significant results were found for the roads serving the coffee region, and for those serving the southern agricultural provinces. However, the roads of the north and southeast did not have satisfactory relationships to the independent variables tested. Further difficulty arose when it was discovered that forecasts of the independent variables such as coffee and foreign trade were not available on a regional level. Some estimates were found for the future production of grains and pulses, but these variables did not apply to all regions. Therefore, the regional

EXHIBIT V-22

NETWORK TOTALS, AADT 1957 TO 1971, AND ANNUAL GROWTH

Year	Total	Cars	Buses	Trucks	Truck-Trailers
1957	8,921.00	3,398.50	1,210.00	3,524.00	787.50
1958	9,609.00	3,540.00	1,256.00	3,858.00	907.50
1959	8,707.50	3,370.50	1,452.00	3,100.50	784.50
1960	7,687.00	3,011.00	1,468.50	2,624.00	585.50
1961	8,357.50	3,032.50	1,694.00	2,907.00	704.00
1962	10,039.50	3,316.50	2,462.00	3,408.50	851.00
1963	12,327.50	4,335.00	2,958.50	4,139.50	865.50
1964	12,168.00	5,080.50	2,818.50	3,471.50	804.50
1965	13,293.50	5,561.50	3,030.50	3,763.50	949.00
1966	15,629.50	6,564.50	3,564.00	4,385.50	1,120.00
1967	16,594.50	6,768.50	4,256.00	4,456.50	1,169.00
1968	19,048.50	8,974.50	4,429.00	4,389.00	1,274.00
1969	20,159.00	9,381.00	4,716.00	4,672.50	1,389.50
1970	21,788.00	10,234.00	4,520.50	5,771.00	1,251.00
1971	22,978.50	10,087.00	4,993.00	6,549.50	1,345.50

Annual Percentage Growth for Network AADT

Year	Total	Cars	Buses	Trucks	Truck-Trailers
1958	7.71	4.16	3.80	9.48	15.24
1959	-9.38	-4.79	15.61	-19.63	-13.55
1960	-11.72	-10.67	1.14	-15.37	-25.37
1961	8.72	0.71	15.36	10.79	20.24
1962	20.13	9.37	45.34	17.25	20.88
1963	22.79	30.71	20.17	21.45	1.70
1964	-1.29	17.20	-4.73	-16.14	-7.05
1965	9.25	9.47	7.52	8.41	17.96
1966	17.57	18.03	17.60	16.53	18.02
1967	6.17	3.11	19.42	1.62	4.37
1968	14.78	32.59	4.06	-1.51	8.98
1969	5.84	4.53	6.48	6.46	9.07
1970	8.07	9.09	-4.15	23.51	-9.97
1971	5.47	-1.44	10.45	13.49	7.55

forecasting investigation was dropped. It was necessary to consider the system in total.

In conjunction with the above analysis, all count station data 1957 to 1971 had been punched on computer cards and a program developed which could provide the following outputs:

1. The annual percentage AADT growth by total traffic and vehicle type at each station.
2. The ratio of the station AADT by total traffic and vehicle type to the system totals for AADT.
3. A linear time-trend regression forecast of the AADT by total and by vehicle type at each station, and a forecast of the system AADT.
4. The above three outputs in terms of vehicle kilometers (VKM) by count station leg. Legs were determined by the distance between count stations. Traffic was averaged in two directions where possible.
5. Forecasts of AADT and VKM by total and by type of vehicle at each station by three methods. The first was the station's historical percentage of an independently derived forecast of system traffic. The second was the station's historical percentage of an internally generated time-trend traffic forecast for the entire system. The third was a time-trend traffic regression forecast for each individual station.

The three forecast methods were described in detail below. First, however, a brief description of some of the difficulties is warranted, as the evolution of the techniques was directly dependent on the problems.

Once all the count station daily traffic was keypunched, the program was run and the output evaluated. As stated before, the annual percentage growth for any individual station's ADT and VKM was extremely erratic. The recent years' experience demonstrated that an exponential annual growth rate was unrealistic for short term forecasts. The program calculated the regression equation and correlation coefficient for the ADT and VKM for each station and for the total system.

Approximately 40 percent of the stations had correlation coefficients less than .65 when the total traffic was considered. An even greater percentage had poor correlation coefficients when the individual vehicle types (ADT and VKM) were correlated against time, and the poor growth trends for specific vehicle types made the forecast by vehicle type impractical. The vehicle mix on the heavily used segments was relatively constant, however, and permitted a forecast of total vehicles and a subsequent breakdown into vehicle types. The historical traffix mix on each segment is shown in the Economic Appendix. The system totals for ADT and VKM were found to be highly linearly correlated against time, and the results for the system are shown below.

	Total	Cars	Buses	Trucks	Truck-Trailers
ADT Correlation Coefficient R	.953	.939	.983	.820	.872
VKM Correlation Coefficient R	.910	.992	.975	.658	.904

With all stations having erratic annual growth it was concluded that a bottom-up forecast, where each count station or count station leg was forecast individually, was not feasible. Therefore, techniques were sought which would permit results where the sum of the station ADT and VKM forecasts were compatible with system forecasts of these parameters.

The first method developed depended upon the importance of count station in respect to the entire system. This was accomplished by taking the mean and standard deviation of the ratio of the station vehicle kilometers to the system total. Approximately 70 percent of the station legs showed a statistically consistent percentage of the system total. That is a mean with a standard deviation of less than 20 percent. By utilizing new vehicle population forecasts and a forecast of average utilization for each vehicle type, a new projection of system vehicle kilometers was generated.

With this data it was possible to apply the station's historical percentage of system vehicle kilometers to the forecast total system vehicle kilometers to obtain a count station leg forecast. This method

had statistical validity, as stated earlier, for approximately 70 percent of the system. The count station leg forecasts were then coverted to AADT by dividing the forecast VKM by the count station leg distance. This method was used when a count station had a relatively consistent share of the system traffic, and a time-trend pattern of increasing traffic. The annual growth rate for stations in this category is 7.5 percent.

The second output of the forecasting program which was utilized in developing the final forecasts was the time-trend linear regression forecast of VKM for the system. The VKM forecasts by this method are statistically valid, but were considered to understate the future traffic volumes, as a linear forecast increases at a decreasing rate. The historical percentage of this lower VKM forecast was used for those stations that had a consistent share of the system traffic but whose historical pattern of leveling-off or of decreasing traffic did not warrant the high growth rate of 7.5 percent. In these cases, a growth rate of 3.5 percent annually was used. This rate represents a linear forecast rate for the entire system.

The third projection derived from the traffic forecasting program was a linear time-trend regression forecast for each individual station's AADT and station leg, by station total and vehicle type. There were a few cases where the station's historical percentage of the system AADT and VKM was poor, but the time-trend regression analysis for the station was statistically significant. In these cases, rather than use the lower system growth rate (3.5 percent) a rate unique to the station count leg was used.

In addition to the stations covered by the techniques discussed above, there were 10 stations and associated count legs that had declining traffic in recent years. These stations are located in the north, and the regional problems there have definitely affected traffic growth. Upon observing the historical data for these stations, it was noticed that in the past traffic was declining or constant. Therefore, for these 10 stations a low growth rate of one percent a year was assumed.

The forecasts for the complete system were based on the above techniques. As the high growth rate (7.5 percent) reflects the growth in monetary gross domestic product and applies to 70 percent of the traffic, some account is taken of the projected increased agricultural activity.

An attempt was made to forecast some road sections on the basis of agricultural output. Data was collected on the minimum-package agricultural programs and from the National Coffee Board on future output. In the former case, the maximum marketable surplus of one package was estimated at three trucks per day. This was assuming a 60 percent load factor for trucks. No indication was available of where the marketable surplus would be transported. Historical data on the movement of coffee trucks into Addis Ababa were not consistent enough for short term forecasts. Annual increases in coffee truck arrivals at markets ranged from plus 48 percent in 1962/63 to minus 15 percent in 1965/66, with the years from 1968/69 to 1970/71 being relatively constant.

The location and schedule of minimum package programs (MPP) was also considered. However, discussions with the Ministry of Agriculture brought out the fact that the surplus and shortage areas and agricultural outputs as defined by the GRS were inaccurate and should not be used for forecasting. A detailed agricultural origin-destination survey was in process at the time of the study but results were still lacking and no information was available for analysis.

Two considerations led the consultants to minimize the possible effects of the MMPs on traffic. The first was the lack of origin-destination data, and the second was the fact that load factors for trucks in Ethiopia are low. Both the GRS and IHA conducted studies which indicated that the trucks have surplus capacity. The GRS consultants developed a factor of 3.8 to be applied to truck traffic to generate the total direct and induced volume on new roads. No basis or validation of this number was found; therefore it was not used.

At a 70 percent load factor, the existing truck traffic, on the segments where MPP's currently are in existence, can easily handle

the increased tonnage. On new links the IHA forecasts of traffic were used. The minimization of the traffic generated by the MPP's produced more conservative traffic forecasts, and the Consultants felt that this would be more appropriate for both the cost-benefit and ranking processes.

For roads constructed during the Fourth and Fifth Highway Programs, the annual traffic projections on the improved or new roads were taken from the feasibility studies. No attempt was made to authenticate or modify these figures. Generally, it was felt that the forecasts were acceptable since the overall annual traffic increases for most of these projects were 6 to 8 percent. Only in those cases where the volume of traffic was less than 10 vehicles a day were growth rates abnormally high. However, these high growth rates still do not generate significant daily traffic at these stations when only a 5-year period is considered.

Summarizing, the basic forecast used for the existing road system was a combination of the projections based on the system growth which is a function of GDP, the historical growth of individual stations, consideration of agricultural schemes, the IHA forecasts for new projects, and the GRS traffic counts on minor roads. The effect of this forecast is to regionalize the growth rates. Heavily-used segments near Addis Ababa and on the Addis-Asseb route have the highest growth rates. As the distance from urban centers increases the growth percentages decline at different rates depending on the population and agricultural distribution along the route.

There were 35 segments where no recent traffic was available. Exhibit V-23 lists these segments. It is appropriate to state here that the traffic counting technique used within IHA makes no provision for estimating vehicle turnoff on long count station legs. As a minimum improvement, traffic turnoff estimates along major routes should be taken at least once a year to permit more thorough analysis of the actual traffic on sections. For each of the techniques described above, the station count legs were averaged whenever counts were taken at

EXHIBIT V-23

SECTIONS WITH NO RECENT TRAFFIC COUNTS

Section	Section
Debarek - Adiarki	Teseney - Sudan
Adiarki - Axum	Shashamane - Adaba
Gonder - Debarek	Mekele - Worko Aoula
Bedele - Gore	Terramini - Decamere
Nazreth - Bekonji	Debre Libanos Road
Alemgena - Butajira	Molale - Mehal Meda
Harer - Jijiga	Debre Sina - Molale
Adaba - Goba	Debre Sina - Seladengie
Robey - Goro	Alem Ketema
Jimma - Bonga	Debre Berhan - Jihur
Bonga - Wush Wush	Sodere Road
Wondo - Dilla	Dejen - Mota
Dilla - Agere Maryam	Tis Abat Falls
Agere Maryam - Yabello	Debre Berhan - Ankober
Yabello - Moyale	Asseb Airport Road
Sodo - Shashamane	Kuni - Gelemso
Sodo - Arbaminch	Adi Ugri - Areza
	Erer - Mieso

both ends of a leg and the distance was short. In this manner some of the vehicle turnoff is compensated for. However, if the count stations at both ends of a leg are close to urban centers, then a serious distortion arises from the use of averages. Averages were not taken in these cases and segments were identified in such a manner as to help account for intra-urban traffic. Traffic forecasts for each section by each technique for present count station legs are contained in the Economics Appendix. The base traffic data is also shown in that appendix.

Developing traffic estimates for the ranking of the new projects was also difficult because forecasts were not available for most of the Feeder and Service-to-Traffic routes, and these represented a majority of the new length. Only those projects which were included in the Fourth and Fifth Highway loans had any traffic projections. For the other future roads, the Consultants checked to see if any traffic estimates had been made within the IHA. None were available for projects of the Direct Labor Branch program. Market origin-destination data from the Ministry of Agriculture was reviewed, but was found to be too sparse and general to be of help at the time of the study. It was understood that a marketing report from that ministry will be available in late 1972.

To ensure some equality in the ranking process, it was decided that for roads without any traffic projections, the average daily traffic would be established by the standard of the road. Based on the Consultants' field observations and historical IHA traffic counts, it was estimated that the feeder roads would have an average daily traffic of 40 vehicles. Service-to-Traffic roads were estimated to have a daily traffic of 20 vehicles. It was recognized that these figures would be unrealistic in several specific cases, and would lead to distorted maintenance priority rankings. However, no better solution was found for approximating traffic on roads not yet in existence, or which would offer much easier travel than present trails along the same routes.

G. Maintenance Ranking Procedure

The following steps were followed in the maintenance ranking of the existing and proposed systems of roads.

1. The road systems were classified into segments. Each segment was identified as to location, length, surface standard, topography and climate zone.
2. Routine, periodic and special maintenance costs were developed for each segment.
3. The life of each surface type to deteriorate from the best potential condition to the next surface type was determined.
4. The economic vehicle operating cost range on each surface type was determined (dependent on type of surface and terrain). The range varied from Condition 1 to Condition 4 on paved surfaces, from Condition 2 to Condition 6 on gravel roads of primary or feeder standard, and from Condition 3 to Condition 7 on service-to-traffic roads.
5. The traffic forecast by vehicle type was determined on each segment.
6. Shadow cost factors for the maintenance cost were derived.
7. Utilizing a computer program and the above inputs, the following calculations were made (see Economics Appendix for program inputs and program):
   a. Total annual economic maintenance cost by segment.
   b. Total annual incremental economic VOC by vehicle type and total VOC by segment.
   c. The difference between the total economic maintenance costs and the incremental economic VOC. This was termed the "net benefit."
   d. The present value of the net benefit at the opportunity cost of capital.
8. Segments were then grouped into maintenance sections, and the net benefit and the present value net benefit summed for each section. The groupings on the existing system are shown in Exhibit V-24.
9. Utilizing a second computer program, maintenance sections were then ranked in order from the highest present value

EXHIBIT V-24

ROUTES AND SECTIONS FOR MAINTENANCE PRIORITY RANKING

EXISTING ROAD SYSTEM (IHA-MAINTAINED IN 1972/73)

Section	Segments
Route 01	
Addis Ababa - Combolcia	01 0 01 - 01 0 16
Combolcia - Dessie	01 0 17 - 01 0 18
Dessie - Quiha	01 0 19 - 01 0 46
Quiha - Adigrat	01 0 47 - 01 0 56
Adigrat - Asmara	01 0 57 - 01 0 66
Asmara - Massawa	01 0 67 - 01 0 72
Route 02	
Combolcia - Jct. Rte. 18 (Tendaho)	02 0 01 - 02 0 06
Jct. Rte. 18 (Tendaho) - Asseb	02 0 07 - 02 0 13
Route 03	
Addis Ababa - Debre Markos	03 0 01 - 03 0 08
Debre Markos - Bahir Dar	03 0 09 - 03 0 22
Bahir Dar - Azezo	03 0 23 - 03 0 30
Azezo - Gonder	03 0 31 - 03 0 32
Gonder - Axum	03 0 33 - 03 0 54
Axum - Asmara	03 0 55 - 03 0 72
Route 04	
Addis Ababa - Jct. Rte. 18 (Awash Sta.)	04 0 01 - 04 0 12
Jct. Rte. 18 - Harer	04 0 15 - 04 0 36
Harer - Jijiga	04 0 37 - 04 0 43
Route 05	
Addis Ababa - Lekempty	05 0 01 - 05 0 08
Lekempty - Ghimbi	05 0 09 - 05 0 13
Route 06	
Modjo - Shashamane	06 0 01 - 06 0 04
Shashamane - Dilla	06 0 05 - 06 0 08

EXHIBIT V-24
(Continued)

Section	Segments
Route 07	
Addis Ababa - Jimma	07 0 01 - 07 0 15
Jimma - Bonga Junction	07 0 16 - 07 0 20
Bonga Junction - km 485	07 0 21 - 07 0 22
Route 08	
Nazreth - Assela	08 0 01 - 08 0 06
Dodola - Goba	08 0 25 - 08 0 28
Route 09	
Alemgena - Kersa R. Bridge	09 0 01
Sodo - Arbaminch	09 0 30 - 09 0 34
Route 10	
Nefasit - Decamere	10 0 01 - 10 0 03
Route 11	
Asmara - Keren	11 0 01 - 11 0 05
Keren - Teseney Junction	11 0 06 - 11 0 11
Teseney Junction - Sebderat	11 0 12
Route 12	
Massawa - Agip	12 0 01
Route 14	
Tarmaber - Molale	14 0 01 - 14 0 02
Route 15	
Adigrat - Adi Abun	15 0 01 - 15 0 05
Route 16	
Debre Berhan - Ankober	16 0 01
Route 17	
Adi Ugri - Areza	17 0 01 - 17 0 05

EXHIBIT V-24
(Continued)

Section	Segments
Route 20	
Mieso - Dire Dawa	20 0 03 - 20 0 04
Route 23	
Dejen - Bichena	23 0 01
Route 27	
Gonder Airport - Gorgora	27 0 01 - 27 0 05
Route 28	
Debre Berhan - Jihur	28 0 01 - 28 0 02
Route 30	
Jijiga - Degenbur	30 0 01
Route 33	
Goncer - Setit	33 0 01 - 33 0 02
Route 35	
Kuni - Gelemso	35 0 01 - 35 0 07
Route 40	
Shashamane - Dodola	40 0 01 - 40 0 03
Route 41	
Shashamane - Sodo	41 0 01 - 41 0 04
Route 43	
Jimma - Bedele	43 0 01 - 43 0 09
Route 44	
Wondo - Negele	44 0 01 - 44 0 05
Route 49	
Tarmaber - Seladengie	49 0 01 - 40 0 03
Route 50	
Terramini - Decamere	50 0 01 - 50 0 02

EXHIBIT V-24
(Continued)

Section	Segments
Route 51	
Bahir Dar - Tis Abat	51 0 01
Route 01-1	
Quiha - Mekele	01 1 01 - 01 1 02
Route 01-2	
Mekele - Maimekden	01 2 01
Route 01-3	
Massawa - Gurgussum	01 3 01
Route 02-1	
Asseb - Asseb Airport	02 1 01
Route 03-1	
Mukutere - Alem	03 1 01
Route 03-2	
Debre Libanos Road	03 2 01
Route 03-3	
Cement Quarry Road	03 3 01
Route 03-4	
Adi Abun - Adwa	03 4 01
Route 04-1	
Koka Dam Road Access Road	04 1 01
Route 04-3	
Kobo - Deder	04 3 01
Route 04-4	
Dengego - Dire Dawa	04 4 01 - 04 4 02
Route 06-1	
Yergalem Spur	06 1 01

EXHIBIT V-24
(Concluded)

Section	Segments
Route 07-1	
Ghimbo Access Road	07 1 01
Route 07-2	
Bonga Spur	07 2 01
Route 08-1	
Sodere Spur	08 1 01
Route 11-1	
Teseney Access Road	11 1 01
Route 14-1	
Mehal Meda Road	14 1 01

net benefit to the lowest. Also, the sections were ranked from the highest present value net benefit per kilometer to the lowest.

H. Ranking Evaluation

The previous sections describe the inputs, techniques, and outputs of the methodology developed to rank the present and future road systems in Ethiopia. The results were found to be of interest and significance, though there were indications that they should be used with some care. The indices given by the process were strictly a relative ranking of the system. A large negative present value net benefit for a segment does not imply that the segment should not be maintained, or that it has no worth to the country. Neither does a large positive benefit mean that the segment is important to the country from all economic aspects. The relative ranking indicates which sections should be maintained to provide the greatest benefit to the actual users of the road. Thus, a flat paved section presently in good condition, located in a dry area, and with low traffic may be ranked very low because maintenance ensures only slight savings to the user. Conversely, a mountainous gravel section located in a high rainfall area with medium traffic may have high positive benefits since the user would incur large incremental operating costs if no maintenance functions were performed. Given these conditions, it is possible that two contiguous segments of road, one paved and one gravel, with identical traffic, will show that the maintenance of the gravel segment has the higher benefits.

The ranking shows where, given some resource constraint, maintenance could be delayed or stopped at the least cost to the users of the system. However, it was pointed out earlier that maintenance could not actually be stopped on any existing segment since traffic patterns would change quickly if the road became difficult or impassable. New patterns of movement would evolve and the entire ranking order would then change.

1. Relative Ranking of the Present Road System

With respect to traffic patterns and surface types, the present system was ranked assuming completion of scheduled and funded improvements to the primary network. This was necessary as it was not considered logical to rank the "as is" system if the improvements had already been demonstrated as being needed and programmed for accomplishment. The ranking would otherwise give results such as a high priority for the Combolcia-Tendaho section of route 2. This section was clearly important in 1972/73, but its priority will be reduced by the opening of the Awash-Tendaho road, with its diversionary effects. Similarly, gravel roads that were to be paved might rank high with their present surfaces and then drop sharply with an improved surface. Therefore, the decision was made to rank the present basic system taking these changes into account.

The candidate roads of the existing system (IHA-maintained in 1972/73) were divided into viable routes, sections, and links by grouping the appropriate route segments. The resulting road sections were the units which were ranked by summing the net benefits of their segments. Exhibit V-24 shows this grouping of segments into analysis sections, and Exhibit V-25 repeats the same list of sections, but ordered by their comparative rankings of present value net benefit (PVNB) per kilometer, from highest to lowest. The last exhibit shows that, in general, the high commercial-traffic roads rank first. Next are the gravel roads with high traffic, then the paved roads with medium traffic. These are followed by the gravel roads with light traffic and the paved roads with light traffic. Last are the gravel and paved roads that have almost no traffic and whose purpose is to provide access to main routes.

2. Sensitivity of the Method

The sensitivity of the rankings to changes in the opportunity cost of capital was investigated and it was found that the overall rankings would change very little with different interest rates. Other variables were tested for sensitivity but each case proved to be different.

EXHIBIT V-25

RELATIVE MAINTENANCE RANKING OF ROAD SECTIONS
EXISTING HIGHWAY SYSTEM (1972/73)

Route Sections	Segments	PVNB* E$ per km @ 10%	Ranking
Jct. Rte. 18 (near Tendaho) - Asseb	02007 - 02013	76,203	1
Addis Ababa - Jct Rte. 18 (Awash Sta.)	04001 - 04012	72,597	2
Dengego - Dire Dawa	04401 - 04402	50,366	3
Yergalem Spur	06101	28,186	4
Asmara - Massawa	01067 - 01072	26,411	5
Módjo - Shashamane	06001 - 06004	22,738	6
Alemgena - Kersa R. Bridge	09001	15,069	7
Nazreth - Assela	08001 - 08006	8,693	8
Dessie - Quiha	01019 - 01046	8,446	9
Addis Ababa - Jimma	07001 - 07015	8,208	10
Shashamane - Sodo	41001 - 41004	7,368	11
Massawa - Gurgussum	01301	6,330	12
Harer - Jijiga	04037 - 04043	5,277	13
Addis Ababa - Combolcia	01001 - 01016	4,770	14
Addis Ababa - Lekempty	05001 - 05008	4,759	15
Mekele - Maimekden	01201	3,987	16
Jct. Rte. 18 - Harer	04015 - 04036	3,787	17
Shashamane - Dilla	06005 - 06008	3,398	18
Adigrat - Asmara	01057 - 01066	2,509	19
Gonder - Axum	03033 - 03054	2,423	20
Keren - Teseney Jct.	11006 - 11012	1,674	21
Shashamane - Dodola	40001 - 40003	1,635	22
Lekempty - Ghimbi	05009 - 05013	451	23
Bonga Spur	07201	204	24
Teseney Access	11101	84	25
Jimma - Bedele	43002 - 43009	62	26
Axum - Asmara	03055 - 03072	46	27
Mieso - Dire Dawa	20003 - 20004	(181)**	28
Massawa - Agip	12001	(190)	29
Adi Abun - Adwa	03401	(399)	30
Ghimbo Access Road	07101	(595)	31
Asmara - Keren	11001 - 11005	(677)	32
Combolcia - Dessie	01017 - 01018	(1,631)	33
Dejen - Bichena	23001	(1,891)	34

EXHIBIT V-25
(Continued)

Route Sections	Segments	PVNK* E$ per km @ 10%	Ranking
Debre Markos - Bahir Dar	03009 - 03022	(1,914)	35
Addis Ababa - Debre Markos	03001 - 03008	(2,580)	36
Jijiga - Degenbur	30001	(2,771)	37
Jimma - Bonga Junction	07016 - 07020	(3,184)	38
Quiha - Adigrat	01047 - 01056	(3,193)	39
Mukutere - Alem	03101	(3,237)	40
Bahir Dar - Tis Abat	51001	(3,620)	41
Terramini - Decamere	50001 - 50002	(3,659)	42
Wondo - Negele	44001 - 44005	(4,155)	43
Gonder - Setit	33001 - 33002	(4,330)	44
Dodola - Goba	08025 - 08028	(4,454)	45
Cement Quarry Road	03301	(4,649)	46
Debre Berhan - Jihur	28001 - 28002	(5,325)	47
Adi Ugri - Areza	17001 - 17005	(5,503)	48
Tarmaber - Seladengie	49001 - 49003	(5,602)	49
Kuni - Gelemso	35001 - 35007	(5,771)	50
Debre Berhan - Ankober	16001	(5,835)	51
Sodere Spur	08101	(5,928)	52
Azezo - Gonder	03031 - 03032	(6,069)	53
Tarmaber - Molale	14001 - 14002	(6,370)	54
Mehal Meda Road	14101	(6,907)	55
Quiha - Mekele	01101 - 01102	(6,957)	56
Kobo - Deder	04301	(8,011)	57
Bahir Dar - Azezo	03023 - 03030	(8,169)	58
Sodo - Arbaminch	09030 - 09034	(8,335)	59
Asseb Airport Road	02101	(8,801)	60
Bonga Jct. - km 485	07021 - 07022	(8,967)	61
Combolcia - Jct. Rte. 18 (Tendaho)	02001 - 02006	(10,240)	62
Gonder Airport - Gorgera	27001 - 27005	(11,259)	63
Adigrat - Adi Abun	15001 - 15005	(11,361)	64
Debre Libanos Road	03201	(12,668)	65
Nefasit - Decamere	10001 - 10003	(13,468)	66
Koka Dam Access Road	14101	(13,734)	67

* PVNB - Present Value Net Benefit
** Parentheses indicate negative PVNB

Rolling or mountainous gravel roads were sensitive to the volume of truck traffic, whereas flat or paved roads were not. Similarly the sensitivity of the paved roads to the assumed life of the road was minimal. Increases in VOC and traffic of up to 20 percent were made without affecting the relative rankings significantly. Each individual maintenance section was not tested, but some generalizations were found possible. On low-volume gravel roads, AADT had to be over 100, with a large percentage of trucks, before the relative ranking changed. The increase in traffic on paved roads had to be much greater than a similar change on gravel to induce a ranking change. Passenger car traffic was the most insensitive variable.

As an example of sensitivity, if the incremental VOC or the traffic were to be doubled on the Dejen-Bichena road the ranking would change from 34th to 32nd. This is a service-to-traffic road with low AADT. As might be expected, maintenance cost per kilometer is always a sensitive number, especially on gravel roads. However, 62.6 percent of the kilometers in the present system have positive present value net benefits. This means that any modification of the maintenance costs would only affect 37.4 percent of the system. An overall percentage reduction in maintenance costs on gravel roads would not change the relative ranking of the gravel roads, even though the net benefit per kilometer might become positive.

3. Relative Ranking of New Highway Projects

Exhibit V-26 illustrates the priority ranking of future additions to the present road system, computed in the same manner. Of these routes and sections, only 20.5 percent of the total kilometers of the proposed new road have a positive net benefit. The reasons for this are simple. The majority of the new projects consist of feeder or service-to-traffic roads which are extensions to the present system. As such, they are on the fringes of traffic. Even on some roads which are being funded from approved highway loans, there is not enough traffic to make the ranking criteria positive. Also, most of the roads

EXHIBIT V-26

RELATIVE MAINTENANCE RANKING OF ROAD SECTIONS
FUTURE ADDITIONS

Route Sections	Segments	PVNB* E$ per km @ 10%	Ranking
Relocation (Akaki-Nazreth)	04006	83,041	1
Awash River Br. - Tendaho	18001 - 18011	20,131	2
Butajira - L. Zuway	09101 - 09102	18,184	3
Alemgena - Hosaina	09002	3.822	4
Aseela - Dodola	08007 - 08011	2,504	5
Gelemso - Mechara	35008 - 35009	(8(1) *	6
Jimma - Suntu	37001	(1,393)	7
Kebre Dehar - Ferfer	30006 - 30009	(1,511)	8
Teseney - Humera-Royan	25001 - 25003	(1,606)	9
Babile - Fik	04701 - 04707	(1,617)	10
Areza - Barentu	17006	(1,622)	11
Degenbur - Kebre Dehar	30002 - 30005	(1,634)	12
Azezo - Metema	21001 - 21005	(1,961)	13
Bonga - Mizan Teferi	07023 - 07027	(1,990)	14
Ghimbi - Kurmuk	05014	(2,210)	15
Agaro - Chira	43101	(3,015)	16
Welkite - Hosaina	13001 - 13009	(3,184)	17
Goba - Meslo	36001 - 36002	(3,959)	18
Modjo Access	01501	(5,276)	19
Bichena - Mota	23002 - 23003	(5,538)	20
Robey - Ghinir	08029 - 08034	(5,539)	21
Mega - Moyale	06025 - 06029	(7,246)	22
Yabello - Mega	06020 - 06024	(7.273)	23
Local Access Road	04601	(9,135)	24
Agere Maryam - Yabello	06016 - 06019	(9,450)	25
Bedele - Metu	43010 - 43017	(9,699)	26
Dilla - Agere Maryam	06009 - 06015	(9,736)	27
Butajira - Hosaina	09003	(11,454)	28

* PVNB - Present Value Net Benefit
** Parentheses indicate negative PVNB

are justified on the basis of agricultural output or other objectives, such as national unity and access. Once again, caution must be used in utilizing the rankings. They do not fully reflect the importance of the road segments in the national economy. They only provide a basis for judging where maintenance expenditures are most effective in slowing or preventing increases in vehicle operating costs.

4. Application of the Rankings

The steps discussed in this report section provided comparative indices of maintenance priority for all candidate roads to be considered, both present and future. Previous sections have already supplied the estimated costs of maintaining all routes, individually. Thus, budgetary costs can be obtained for priority road systems, and compared with available funds. This is the subject of Section VIII, Resource Implications and Constraints.

Section VI
REHABILITATION NEEDS AND COSTS

A. Definitions of "Normal" and "Urgent"

The contract for the present study required that the final recommended program "...be divided into the parts covering those roads which:

- require urgent attention, and;
- would fall within a normal program."

In the course of the study it was considered that maintenance itself should never be viewed as having degrees of urgency, because of the need to continue such activities continuously at minimum adequate levels. All maintenance was therefore taken to fall within normal programs. In contrast to this, any road sections which were found to be so deteriorated that restoration would require an effort and cost beyond the limits of ordinary maintenance would need some different treatment. The urgency of corrective work would depend on whether the condition had become semi-stable or was continuing to deteriorate, and on the traffic volume, which would be a measure of the increased costs to road users.

The term "Rehabilitation" was applied to all projects involving work in excess of normal maintenance. This was defined to be work on specific lengths of deteriorated road, for the purpose of restoring those sections to their original (or highest former) standards. All such projects were considered to be potentially urgent, and to constitute the only work falling within the category of "urgent."

B. Identification of Rehabilitation Needs

As indicated previously in Section IV of the report, all roads presently maintained by the IHA were rated for present condition. These were, necessarily, general ratings applying to relatively long sections, and related to the average effects on VOC. Whenever these ratings suggested a need for rehabilitation, additional information was assembled to evaluate the need.

The GRS inventories, the IHA District "Condition Surveys" and the Consultants' own field notes were reviewed. If this data did not furnish a sufficient basis for defining the work required, special field inspections were made. These reviews and inspections were used to:

1. Verify and refine the general condition ratings.
2. Establish the limits of sections to be analyzed for rehabilitation.
3. Determine the types and quantities of work required.

C. Rehabilitation Projects Considered

As a result of the above evaluations, a total of eleven candidate projects were identified. These are described below.

1. Paved Routes

a. Route No. 1, Addis Ababa to Debre Berhan

Km 5 to km 136; length 131 km
Present condition: 5% rated Condition 2; 47% Condition 3; 48% Condition 4.

b. Route No. 2, Tendaho to Asseb

Km 640 to km 760; length 120 km
Present condition: 100% rated Condition 3.

c. Route No. 3, Addis Ababa to Dejen

Km 2 to km 230; length 228 km
Present condition: 51% rated Condition 1; 3% Condition 2, 46% Condition 3.

d. Route No. 5, Addis Ababa to Agrehiwot

Km 7 to km 126; length 119 km
Present condition: 45% rated Condition 3; 55% Condition 4.

e. Route No. 7, Addis Ababa to Welkite

Km 6 to km 115; length 109 km

Present condition: 71% rated Condition 3; 29% Condition 4.

2. Gravel-Surfaced Routes

a. Route No. 1, Tarmaber to Woldia

Km 228 to 360 and km 670 to 435; length 367 km

Present condition: 100% rated Condition 4.

b. Route No. 7, Jimma to Bonga Junction

Km 335 to km 440; length 105 km

Present condition: 43% rated Condition 5, 57% Condition 6.

c. Route No. 8, Dofole to Goba

Km 348 to km 465; length 117 km

Present condition: 100% rated Condition 4

d. Route No. 40, Shashamane to Kofole

Km 247 to km 348; length 101 km

Present condition: 36% rated Condition 5; 64% Condition 6.

e. Route No. 41, Shashamane to Sodo

Km 250 to km 390; length 140 km

Present condition: 46% rated Condition 4; 54% Condition 5.

f. Route No. 44, Wondo to Kebremengist

Km 333 to km 471; length 138 km

Present condition: 100% rated Condition 4

An examination of the condition ratings of all presently-maintained roads (see Exhibit III-D of the Engineering Appendix) will disclose other road sections with ratings as low as those of the foregoing lists. All were considered for prospective rehabilitation, but only the above sections were selected for analysis. Of the others, some were too short to make viable

projects and some were in a stable or borderline condition so that improved normal maintenance could restore the surfaces within a reasonable period of time. Additional sections now in poor condition had already been programmed or proposed for improvement to higher standards by contract or force account, or were scheduled for rehabilitation by IHA maintenance forces during Fiscal Year 1972/73.

D. Work Items

The types of work and quantities for each of the candidate projects are described below.

1. Paved Routes

a. Route 1, Addis Ababa to Debre Berhan

Emergency Rehabilitation Sections Identified

Km 8.3 to km 29.9	=	21.6 km
Km 36.1 to km 39.8	=	3.7 km
Km 43.3 to km 46.3	=	3.0 km
Km 57.1 to km 131.2	=	74.1 km
Total	=	102.4 kms.

General Work Requirements

Base and surface restoration with double bituminous surface treatment on worst sections; leveling course and seal coat on remaining length.

Quantities Estimated

Remove failed base sections	6,840 m^3
Scarify roadbed and shoulders	431,200 m^2
Crushed aggregate base	111,758 m^3
D.B.S.T. prime coat	481.6 tons
D.B.S.T. bituminous applications	1,396.6 tons
D.B.S.T. cover aggregate (3/4")	6,999 m^3

D. B. S. T. cover aggregate (3/8")	2, 890 m^3
Leveling course tack coat	235. 2 tons
Leveling course bituminous mix	6, 745 m^3
Seal coat bituminous material	270. 5 tons
Seal coat cover aggregate (3/8")	1, 725 m^3

b. Route 2, Tendaho to Asseb

General Work Requirements

Base repair on small areas of failure, with cold mix surface. Leveling course to correct settlement and distortion on extensive sections. Seal coat full length.

Quantities Estimated

Remove failed base sections	49, 613 m^3
Crushed aggregate base	59, 536 m^3
Prime coat/tack coat bitumen	294 tons
Leveling course bituminous mix	14, 700 m^3
Seal coat bituminous material	845 tons
Seal coat cover aggregate (3/8")	5, 390 m^3

c. Route 3, Addis Ababa to Dejen

Emergency Rehabilitation Sections Identified

Km 5. 0 to km 70. 0	=	65. 0 km
Km 200. 9 to km 231. 4	=	30. 5 km
Total	=	95. 5 kms.

General Work Requirement

Base and surface restoration with double bituminous surface treatment on worst sections; leveling course and seal coat on remaining length.

Quantities Estimated

Remove failed base sections	12, 762 m^3
Scarify roadbed and shoulders	367, 200 m^2

Crushed aggregate base	92,082 m^3
D.B.S.T. prime coat	305.2 tons
D.B.S.T. bituminous applications	885.1 tons
D.B.S.T. cover aggregate (3/4")	4,436 m^3
D.B.S.T. cover aggregate (3/8")	1,831 m^3
Leveling course tack coat	347.2 tons
Leveling course bituminous mix	21,940 m^3
Seal coat bituminous material	417.8 tons
Seal coat cover aggregate (3/8")	2,664 m^3

d. Route 5, Addis Ababa to Agrehiwot

Emergency Rehabilitation Sections Identified

Km 7.0 to km 79.7	=	72.7 km
Km 97.5 to km 131.4	=	33.9 km
Total	=	106.6 kms

General Work Requirement

Base and surface restoration with double bituminous surface treatment on worst sections; leveling course and seal coat on remaining length.

Quantities Estimated

Remove failed base sections	720 m^3
Scarify roadbed and shoulders	348,000 m^2
Crushed aggregate base	57,372 m^3
D.B.S.T. prime coat	332.5 tons
D.B.S.T. bituminous applications	964.3 tons
D.B.S.T. cover aggregate (3/4")	4,934 m^3
D.B.S.T. cover aggregate (3/8")	2,037 m^3
Leveling course tack coat	367.5 tons
Leveling course bituminous mix	12,600 m^3
Seal coat bituminous material	465.3 tons
Seal coat cover aggregate	2,967 m^3

e. Route 7, Addis Ababa to Welkite

Emergency Rehabilitation Sections Identified

Km 8.0 to km 25.0	=	17.0 km
Km 35.0 to km 115.0	=	80.0 km
Total	=	97.0 kms

General Work Requirements

Base and surface restoration with double bituminous surface treatment on worst sections; leveling course and seal coat on remaining length.

Quantities Estimated

Remove failed base sections	18,000 m^3
Scarify roadbed and shoulders	44,800 m^2
Crushed aggregate base	32,739 m^3
D.B.S.T. prime coat	288.4 tons
D.B.S.T. bituminous applications	836.4 tons
D.B.S.T. cover aggregate (3/4")	4,191 m^3
D.B.S.T. cover aggregate (3/8")	1,730 m^3
Leveling course tack coat	95.2 tons
Leveling course bituminous mix	1,904 m^3
Seal coat bituminous material	392.8 tons
Seal coat over aggregate	2,505 m^3
Pit-run embankment material	12,150 m^3

2. Gravel-surfaced Routes

a. Route 1, Tarmaber to Woldia

Emergency Rehabilitation Sections Identified

Km 228 to km 360	=	132 km
Km 670 to km 435	=	235 km
Total	=	367 kms.

Quantities Estimated

Scarify roadbed and shoulders	960, 000 m^2
Pit-run select material base	115, 200 m^3
Processed select material surface	308, 280 m^3

b. Route 7, Jimma to Bonga Junction

Emergency Rehabilitation Sections Identified

Km 335 to km 440	=	105 km

Quantities Estimated

Scarify roadbed and shoulders	329, 400 m^2
Pit-run select material base	104, 436 m^3
Processed select material surface	88, 200 m^3

c. Route 8, Kofole to Goba (Feeder Standard)

Emergency Rehabilitation Sections Identified

Km 348 to km 465	=	117 km

Quantities Estimated

Scarify roadbed and shoulders	819, 000 m^2
Pit-run select material base and surface	126, 360 m^3

d. Route 40, Shashamane to Kofole

Emergency Rehabilitation Sections Identified

Km 247 to km 283	=	36 km (Primary - 7m wide)
Km 283 to km 348	=	65 km (Feeder - 6m wide)

Quantities Estimated

Scarify roadbed and shoulders	743, 000 m^2
Pit-run select material base and surface	116, 460 m^3
Processed select material surface	30, 240 m^3

e. Route 41, Shashamane to Sodo

Emergency Rehabilitation Sections Identified

Km 250 to km 390	=	140 km

Quantities Estimated

Scarify roadbed and shoulders	1,120,000 m^2
Pit-run select material base	42,000 m^3
Processed select material surface	117,000 m^3

f. Route 44, Wondo to Kebremengist

Emergency Rehabilitation Sections Identified

Km 330 to km 470	=	140 km

Quantities Estimated

Scarify roadbed and shoulders	560,000 m^2
Pit-run select material base	38,400 m^3
Processed select material surface	117,600 m^3

E. Estimated Unit Costs

1. Contract unit cost items were obtained from the Contract Division of the IHA except for the case of leveling courses, which was computed by the Consultants. The cost figures used as a basis for program evaluation were as follows, with all prices in Ethiopian dollars as of 1972.

Contractor Unit Prices for Materials in Place

Description	Unit of Measure	Unit Price
Remove failed base sections	m^3	E$ 2.50
Crushed aggregate base (2-1/2")	m^3	29.41
Crushed aggregate base or surface (1-1/2")	m^3	29.41
Scarify roadbed and shoulders	m^2	0.43

Leveling course tack coat	ton	E$375.50
Leveling course bituminous mix	m^3	55.87
Seal coat bituminous material	ton	373.00
Seal coat cover aggregate (3/8")	m^3	20.25
D.B.S.T. prime coat	ton	375.50
D.B.S.T. bituminous applications	ton	373.00
D.B.S.T. cover aggregate (3/4")	m^3	20.25
D.B.S.T. cover aggregate (3/8")	m^3	20.25
Pit-run material for embankment	m^3	10.50
Pit-run select base or surface	m^3	10.50
Processed select material surface	m^3	29.41

2. Force Account unit costs were compiled by the Consulting Engineers, in cooperation with the various branches of IHA using:

   a. Personnel pay rates including fringe benefits and desert allowance where applicable.

   b. Material costs as supplied by the IHA or computed by the Consultants.

   c. 21.1% overhead cost as developed in previous sections of the report.

The force account unit costs utilized are shown in the list below:

Force Account Unit Prices for Materials in Place

Description	Unit of Measure	Unit Price
Remove failed base sections	m^3	E$ 6.07
Crushed aggregate base (2-1/2")	m^3	18.55
Crushed aggregate surface (1-1/2")	m^3	20.65
Scarify roadbed and shoulders	m^2	0.21
Leveling course tack coat	ton	371.41
Leveling course bituminous mix	m^3	57.04
Seal coat bituminous material	ton	371.41

Seal coat cover aggregate (3/8")	m^3	46.15
D.B.S.T. prime coat	ton	371.41
D.B.S.T. bituminous applications	ton	371.41
D.B.S.T. cover aggregate (3/4")	m^3	43.15
D.B.S.T. cover aggregate (3/8")	m^3	46.15
Pit-run material for enbankment	m^3	10.81
Pit-run select base or surface	m^3	10.81
Processed select material surface	m^3	18.22

3. Basis of Estimated Unit Costs

Although the unit prices for contract work given above were largely taken from data on record, those for work by government forces had to be developed. The procedure in almost all cases followed that used in maintenance cost estimating, of fixing a logical work crew of men and equipment, and approximating the daily production rate for the group. Wages and equipment rental rates on force account operations were identical to those used for maintenance. The 21.1% District level overhead was also the same, applied to the production of aggregates by IHA crews and to purchased materials at the time of utilization. It was not applied to IHA-produced materials at the time of placement by road crews. The unit costs of aggregates given in Section III (Road Maintenance) were used for estimating the costs of rehabilitation work to be done by IHA forces, but for the purpose of evaluating least-cost procedures, it was assumed that similar aggregates could be purchased from suppliers, for placement by IHA crews, at roughly equal prices.

F. Minimum Cost Operations

In order to determine the most economical and feasible means of doing the candidate rehabilitation projects, a complete cost analysis was

made for every individual road. Each work item of each project was calculated for comparative cost by contract and by force account, separately, and examined for resource requirements. All projects were considered for probable work phasing and time schedules.

In addition to costing the work quantities, it was assumed that contract totals should be increased by 8% to provide engineering supervision for any operations to be done by that means. Three percent was added to force account totals for design effort, assuming that some minimum surveys and other engineering support would be needed.

Taking the work phases individually, for paved routes it was found that the base repairs (removal and replacement) would be much cheaper if done by IHA personnel. The cost advantage was about 30%. In contrast to this, double bituminous surface treatment would cost roughly 20% less by contract, and seal coating around 26% less. The placement of thin leveling courses on distorted pavements was almost the same by either method, with contract costs about 4% higher.

The rehabilitation of gravel roads was clearly more economical by force account, with a cost advantage or 35 to 40%.

These findings suggested what seemed to the Consultants a logical and feasible division of work for any rehabilitation projects found to be economically justified. Surface (and base) restoration on gravel roads, urgent but not so critical in terms of potential investment losses, should be done by IHA crews as soon as practical, but with secondary priority. Base failures on asphalt roads should be corrected by force account since this would not only be cheaper but would avoid the problem of writing specifications and delimiting such work for bidding. The succeeding phases of pavement rehabilitation should be contract work, grouping all the asphalt items into operations much easier to define and control, and at minimum total cost. Obviously, the force account and contract phases on paved routes would have to be closely coordinated but, nevertheless, it appeared feasible and advantageous to perform the work in this manner.

G. Candidate Rehabilitation Projects

Based on the foregoing data and rationale, composite cost estimates were made up for paved sections, and force account estimates for all gravel roads to be considered, so that these proposed projects could be subjected to economic analysis. The quantities and cost for each are given below.

1. Paved Routes

a. Route No. 1, Addis Ababa to Debre Berhan

	Contract	Force Account
Remove failed base sections		
6,840 m^3 x E$6.07		E$ 41,519
Scarify roadbed and shoulders		
431,200 m^2 x E$0.21		90,552
Crushed aggregate base		
111,758 m^3 x E$20.65		2,307,803
D.B.S.T. prime coat		
481.6 tons x E$375.50	E$ 180,841	
D.B.S.T. bituminous applications		
1,396.6 tons x E$373.00	520,932	
D.B.S.T. cover aggregate (3/4")		
6,999 m^3 x E$20.25	141,730	
D.B.S.T. cover aggregate (3/8")		
2,890 m^3 x E$20.25	58,522	
Leveling course tack coat		
235.2 tons x E$375.50	88,318	
Leveling course bituminous mix		
6,745 m^3 x E$55.87	376,843	
Seal coat bituminous material		
270.5 tons x E$373.00	100,896	

Seal coat cover aggregate (3/8")		
1,725 m^3 x E$20.25	34,931	
Sub-totals	1,503,013	2,439,874
Design effort @ 3%		73,196
Engineering supervision @ 8%	120,241	
Contingencies @ 10%	150,301	243,987
Sub-totals	1,773,555	2,757,057
Combined project total (rounded)	E$4,530,600	

b. Route No. 3, Addis Ababa to Dejen

	Contract	Force Account
Remove failed base sections		
12,762 m^3 x E$6.07		E$ 77,465
Scarify roadbed and shoulders		
367,200 m^2 x E$0.21		77,112
Crushed aggregate base		
92,082 m^3 x E$20.65		1,901,493
D.B.S.T. prime coat		
305.2 tons x E$375.50	E$ 114,603	
D.B.S.T. bituminous applications		
885.1 tons x E$373.00	330,142	
D.B.S.T. cover aggregate (3/4")		
4,436 m^3 x E$20.25	89,829	
D.B.S.T. cover aggregate (3/8")		
1,831 m^3 x E$20.25	37,078	
Leveling course tack coat		
347.2 tons x E$375.50	130,374	
Leveling course bituminous mix		
21,941 m^3 x E$55.87	1,225,788	
Seal coat bituminous material		
417.8 tons x E$373.00	155,840	
Seal coat cover aggregate (3/8")		
2,664 m^3 x E$20.25	53,946	
Sub-totals	2,137,600	2,056,070

Design effort @ 3%		61, 682
Engineering supervision @ 8%	171, 008	
Contingencies @ 10%	213, 760	205, 607
Sub-totals	2, 522, 368	2, 323, 359
Combined project total (rounded)	E$4, 845, 700	

c. Route No. 5, Addis Ababa to Agerehiwot

	Contract	Force Account
Remove failed base sections		
720 m^3 x E$6. 07		E$ 4, 371
Scarify roadbed and shoulders		
348, 000 m^2 x E$0. 21		73, 080
Crushed aggregate base		
57, 372 m^3 x E$20. 65		1, 184, 732
D. B. S. T. prime coat		
332. 5 tons x E$375. 50	E$ 124, 854	
D. B. S. T. bituminous applications		
964. 3 tons x E$373. 00	359, 684	
D. B. S. T. cover aggregate (3/4")		
4, 934 m^3 x E$20. 25	99, 914	
D. B. S. T. cover aggregate (3/8")		
2, 037 m^3 x E$20. 25	41, 249	
Leveling course tack coat		
367. 5 tons x E$375. 50	137, 996	
Leveling course bituminous mix		
12, 600 m^3 x E$55. 87	703, 962	
Seal coat bituminous material		
465. 3 tons x E$373. 00	173, 557	
Seal coat cover aggregate (3/8")		
2, 967 m^3 x E$20. 25	60, 082	
Sub-totals	1, 701, 298	1, 262, 183
Design effort @ 3%		37, 866

Engineering supervision @ 8%	136, 104	
Contingencies @ 10%	170, 130	126, 218
Sub-totals	2, 007, 532	1, 426, 267
Combined project total (rounded)	E$3, 433, 800	

d. Route No. 7 Addis Ababa to Welkite

	Contract	Force Account
Remove failed base sections		
18, 000 m^3 x E$6. 07		E$ 109, 260
Scarify roadbed and shoulders		
44, 800 m^2 x E$0. 21		9, 408
Crushed aggregate base		
32, 739 m^3 x E$20. 65		676, 060
Pit-run material for embankment		
12, 150 m^3 x E$10. 81		131, 342
D. B. S. T. prime coat		
288. 4 tons x E$375. 50	E$ 108, 294	
D. B. S. T. bituminous applications		
836. 4 tons E$373. 00	311, 977	
D. B. S. T. cover aggregate (3/4")		
4, 191 m^3 x E$20. 25	84, 868	
D. B. S. T. cover aggregate (3/8")		
1, 730 m^3 x E$20. 25	35. 033	
Leveling course tack coat		
95. 2 tons x E$375. 50	35, 747	
Leveling course bituminous mix		
1, 904 m^3 x E$55. 87	106, 377	
Seal coat bituminous material		
392. 8 tons x E$373. 00	146, 514	
Seal coat cover aggregate (3/8")		
2, 505 m^3 x E$20. 25	50, 726	
Sub-totals	879, 536	926, 070

Design effort @ 3%		27,782
Engineering supervision @ 8%	70,363	
Contingencies @ 10%	87,954	92,607
Sub-totals	1,037,853	1,046,459
Combined project total (rounded)	E$2,084,300	

e. Route No. 2, Tendaho to Asseb

	Contract	Force Account
Remove failed base sections		
49,613 m^3 x E$6.07		E$ 301,151
Crushed aggregate base		
59,536 m^3 x E$20.65		1,229,418
Leveling course tack coat		
294 tons x E$375.50	E$ 110,397	
Leveling course bituminous mix		
14,700 m^3 x E$55.87	725,004	
Seal coat bituminous material		
845 tons x E$373.00	315,185	
Seal coat cover aggregate (3/8")		
5,390 m^3 x E$20.25	109,148	
Sub-totals	1,259,734	1,530,569
Design effort @ 3%		45,917
Engineering supervision @ 8%	100,779	
Contingencies @ 10%	125,973	153,057
Sub-totals	1,486,486	1,729,543
Combined project total (rounded)	E$3,216,000	

2. Gravel Roads

a. Route No. 1, Tarmaber to Woldia

	Force Account
Scarify roadbed and shoulders	
960,000 m^2 x E$0.21	E$ 201,600

Pit-run select base	
115, 200 m^3 x E$10.81	1, 245, 312
Processed select material surface	
308, 280 m^3 x E$18.22	5, 616, 862
Sub-total	7, 063, 774
Design effort @ 3%	211, 913
Contingencies @ 10%	706, 377
TOTAL	7, 982, 064
Project total (rounded)	E$7, 982, 100

b. Route No. 7, Jimma to Bonga Junction

	Force Account
Scarify roadbed and shoulders	
329, 400 m^2 x E$0.21	E$ 69, 174
Pit-run select base	
104, 436 m^3 x E$10.81	1, 128, 953
Processed select material surface	
88, 200 m^3 x E$18.22	1, 607, 004
Sub-total	2, 805, 131
Design effort @ 3%	84, 154
Contingencies @ 10%	280, 513
TOTAL	3, 169, 798
Project total (rounded)	E$3, 169, 800

c. Route No. 8, Kofole to Goba

	Force Account
Scarify roadbed and shoulders	
819, 000 m^2 E$0.21	E$ 169, 890
Pit-run select base or surface	
126, 360 m^3 x E$10.81	1, 365, 952
Sub-total	1, 535, 842
Design effort @ 3%	46, 075

Contingencies @ 10%	153, 584
TOTAL	1, 735, 501
Project total (rounded)	E$1, 735, 500

d. Route No. 40, Shashamane to Kofole

	Force Account
Scarify roadbed and shoulders	
743, 000 m^2 x E$0. 21	E$ 156, 030
Pit-run select base or surface	
116, 460 m^3 x E$10. 81	1, 258, 933
Processed select material surface	
30, 240 m^3 x E$18. 22	550, 973
Sub-total	1, 965, 936
Design effort @ 3%	58, 978
Contingencies @ 10%	196, 594
TOTAL	2, 221, 508
Project total (rounded)	E$2, 221, 500

e. Route No. 41, Shashamane to Sodo

	Force Account
Scarify roadbed and shoulders	
1, 120, 000 m^2 x E$0. 21	E$ 235, 200
Pit-run select base	
42, 000 m^3 x E$10. 81	454, 020
Processed select material surface	
117, 000 m^3 x E$18. 22	2, 131, 740
Sub-total	2, 820, 960
Design effort @ 3%	84, 629
Contingencies @ 10%	282, 096
TOTAL	3, 187, 685
Project total (rounded)	E$3, 187, 700

f. Route No. 44, Wondo to Kebremengist

	Force Account
Scarify roadbed and shoulders	
560, 000 m^2 x E$0.21	E$ 117, 600
Pit-run select base	
38, 400 m^3 x E$10.81	415, 104
Processed select material surface	
117, 600 m^3 x E$18.22	2, 142, 672
Sub-total	2, 675, 376
Design effort @ 3%	80, 261
Contingencies @ 10%	267, 538
TOTAL	3, 023, 175
Project total (rounded)	E$3, 023, 200

Section VII
REHABILITATION RANKING

A. Synopsis

The preceding section describes five asphalt routes and six gravel roads that were found to be in seriously deteriorated condition, and in need of rehabilitation. While work of this class is most often programmed by administrative decision, under the terms of reference for this study its justification was examined on the basis of economic criteria. As each of the roads serves multiple purposes in the national and local economy, it was not possible to quantify the overall economic contribution of each, or the national benefits generated. In compliance with the language of the contract, the Consultants used the common criteria of vehicle operating cost in determining the feasibility of the various candidate projects.

Three significant problems were recognized in the ranking of these proposed work programs. The first was that the life of such rehabilitations is almost impossible to establish without extensive engineering analysis of each road to determine the structural elements and their adequacy. If they were structurally sound, then normal maintenance after restoration would preserve them indefinitely. If they were not, they would fail again after rehabilitation, unless this included reinforcement, which would be added capital investment. In many cases the original design criteria and the ages of the roads were not known. This fact made any estimates of the lives of the roads themselves, and their associated rehabilitations, quite questionable and open to criticism.

The second problem was that rehabilitation is, in a real sense, the catching up of "deferred maintenance." Maintenance might have been postponed due to lack of resources, or to a conscious calculation on the part of the government that the required funds could produce, or create, greater economic benefits elsewhere. The lack of or delay of maintenance could not then be considered an economic cost if the benefits obtained elsewhere

outweighed the increased vehicle operator's cost plus the incremental extra cost necessary later to bring the road back to its earlier standard.

Theoretically, any important road, if properly designed, would have a life of at least 15 years, given proper maintenance. The assumption in this study was that the roads would, in the future, be properly maintained, and therefore the rehabilitations would have lives equal to those of the roads. As this was an indeterminate figure for most roads, another method of ranking rehabilitations was sought in place of the conventional internal rate of return.

The third problem was that IHA maintenance accounts are not kept by specific road sections and it was not possible to determine what was being spent currently on any specific road or type of road. Therefore, the cost difference between the Consultants' recommended maintenance levels and the established practices for any specific section of road could not be calculated.

The approach that was used to rank the rehabilitation projects was to determine what the annual differential in vehicle operating cost (VOC) would be with and without rehabilitation. Then the cumulative number of years necessary to make the present value of the incremental VOC equal to the initial rehabilitation outlay was calculated. The opportunity cost of capital was used in the present value calculation. Engineering judgment was then employed to determine whether this payout life would indicate an attractive project, in technical and financial terms.

The incremental VOC was determined on the assumption that the present maintenance practices would hold the road in a given condition. Therefore, the VOC difference between the present condition and the condition that would be maintained after rehabilitation, under the Consultants' recommended practices, was taken to be the benefit of maintenance. Paved roads were assumed to be improved from their present condition to condition 1. Type 3 and 4 gravel roads were also assumed to be improved to condition 1. Because of lower levels of standard recommended maintenance, type 5 gravel roads would be brought to condition 2, and type 6 gravel roads to condition 3.

Cost ranges for these increments of condition were determined from the vehicle costs as shown in Section V.

There are two other costs which should enter the rehabilitation ranking procedure, but both are undefined and, for the purposes of ranking, are considered to be offsetting. The first is the cost of preserving the present condition. As stated, it was assumed that the present maintenance practices would hold the roads ad they are. Obviously the present effort has not previously maintained the road in a static condition, and deterioration has taken place. To hold the road would require increased resources. As present costs and practices, by section, are unknown this determination is not possible. However, this cost would be added to VOC as a benefit, or a prevented cost associated with rehabilitation.

The second cost is the maintenance expenditure differential due to the recommended practices. If greater than present expenditures, it should be added to the rehabilitation cost. If less than the present expenditure, it should be added to the VOC as a cost savings. Again, as specific maintenance costs cannot be derived from available data, this figure could not be calculated.

However, the assumption is made that the increased costs to hold the road "as is" and the maintenance cost differential between present and recommended maintenance are offsetting. Therefore, in ranking procedure, only the initial rehabilitation cost and the incremental VOC were considered.

B. Ranking Procedure

The following steps constitute the ranking procedure.

1. Road segments identified as needing rehabilitation are grouped into rehabilitation sections. This is based on engineering judgment.
2. The associated surface classifications, lengths and other data for each segment are taken from Exhibit III-D of the Engineering Appendix.
3. Traffic estimates and the annual traffic growth rates are then taken from the forecasts as described in Section V-F.

4. The incremental VOC is calculated for each surface type and range of conditions, assuming that the present condition is improved to the best condition which would result if rehabilitation occurred, and that recommended maintenance is then initiated.
5. The incremental vehicle operating cost savings are calculated for each rehabilitated segment for a period of ten years.
6. The present value of the incremental VOC is calculated for each segment at the opportunity cost of capital for each of the ten years.
7. The present value of the incremental VOC is summed for all the segments of rehabilitation section, by years.
8. The yearly present values of the incremental VOC for a section are summed from the initial year forward until the sum of the present value net benefit is equal to or greater than the rehabilitation costs.
9. The number of years it takes for the present value of the incremental VOC to be equal to or greater than the rehabilitation cost is evaluated in engineering terms.
10. If the number of years is considered to be within the engineering life of the rehabilitation for a specific section, considering such factors as the age of the road, traffic, and so on, then the project is considered for ranking.
11. Rehabilitation projects are then ordered in terms of the time it takes to achieve the above described equality. For the purposes of this analysis, projects for which more than 10 years were required to achieve equality were considered unacceptable.

C. Rehabilitation Ranking Results

1. Paved Roads

The following list shows the rehabilitation cost, the present value of the incremental VOC for approximately equality, and the year in which that incremental VOC is achieved.

Section	Rehabilitation Cost E$	Present Value Incremental VOC	Year Achieved
Addis Ababa-Welkite	$2, 084, 300	$2, 522, 929	2nd
Addis Ababa-Agrehiwot	3, 433, 800	3, 296, 107	3rd
Tendaho-Asseb	3, 216, 000	3, 459, 240	4th
Addis Ababa-D/Berhan	4, 530, 600	4, 776, 882	6th
Addis Ababa-Dejen	4, 845, 700	--	12 plus

Of these sections, it can be seen that the last falls into the unacceptable category. It must be emphasized that acceptability is calculated solely in terms of savings to vehicle operators. This may or may not be the most important criterion for any specific segment.

2. Gravel Roads

The following list shows the gravel roads considered for rehabilitation, the rehabilitation cost, the present value of the incremental VOC which gives approximate equality, and the year in which this is reached.

Section	Rehabilitation Cost E$	Present Value Incremental VOC	Year Achieved
Tarmaber-Woldia	$7, 982, 100	$10, 761, 791	2nd
Shashamane-Sodo	3, 187, 700	4, 107, 634	3rd
Shashamane-Kofole	2, 221, 500	2, 103, 519	3rd
Wondo-Kebremengist	3, 023, 200	3, 064, 260	5th
Jimma-Bonga	3, 169, 800	3, 049, 771	5th
Kofole-Goba	1, 735, 500	--	20 plus

The last of these, Kofole-Goba, has an extremely long break-even period. This is due to the low traffic forecast on the section.

Section VIII

RESOURCE IMPLICATIONS AND CONSTRAINTS

It would be desirable to insure that all roads of the candidate lists were adequately maintained, since they represent valuable economic assets, purchased at considerable cost (actual or programmed) in public funds. For the same reasons, any rehabilitations which would be paid for by savings to road users in a short period should be done if possible. The fact that maintenance of the present system apparently has not been sufficient in recent years, and that some road sections have become seriously distressed, indicates that resource limitations, real or artificial, have been operating to prevent those goals from being achieved. Furthermore, the projected steady growth of the road system in the future will obviously increase the need for maintenance expenditures. Consequently, it is necessary to summarize the resource needs for the total candidate programs identified, and to compare those total needs with the resources which are available, or which might logically be made available. If it is found that adequate minimum maintenance of all routes is beyond the resource capacity of the IHA, or of the IEG in general, then either some part of the burden must be shifted to other levels of government, or some added cost imposed on the public in the form of higher taxes or increased costs of road use. If the economically attractive rehabilitations cannot be funded, vehicle operating costs will continue at abnormal levels, and some loss of investment may occur. In any case, programs must be matched realistically against capacities, and the ranking processes described in the foregoing sections can furnish a guide to priorities. As a first step, the total requirements had to be determined.

A. Financial Cost For Candidate Programs

1. Maintenance of the Roads

The four cost components to be taken into account for maintenance are labor, equipment, purchased materials and overheads (the

last including undistributed operational expenses). Regarding equipment rental, the part representing depreciation may not be an expenditure item at the level of the Maintenance Branch, but is nevertheless a real cost to the IEG and must be capitalized in some manner. It is therefore included in the program costs. The original procurement of an equipment fleet, or extensive fleet additions, may call for a large capital outlay, but this is not considered at this time because it is not a recurring annual expense.

The overheads referred to are those of the District office and lower levels of operations. The costs of the Addis Ababa headquarters and the general administration of the IHA might be taken as another overhead layer, but in this study such costs were usually classed as a part of the general expenses of government. They are excluded here.

The total financial cost to maintain the existing (1972/73) road system is derived by summing all figures of the last column of Exhibit III-D, found in the Engineering Appendix. The incremental annual costs for future years, through 1977/78, are obtained from Exhibit III-E. The figures of the column headed "total annual cost change" in Exhibit III-E indicate, for existing routes, the net effect on maintenance cost of scheduled improvements. For new roads, the column gives the added maintenance cost. The total annual financial costs for the maintenance of all candidate routes would be as follows:

Ethiopian	Gregorian	Total Annual Cost (1972 E$)
1965	1972/73	25,850,320
1966	1973/74	27,242,640
1967	1974/75	28,274,985
1968	1975/76	29,302,668
1969	1976/77	29,804,333
1970	1977/78	29,844,103

2. Candidate Rehabilitations

Discarding the two projects which were found to have very long payout lives (Addis Ababa - Dejen and Kofole - Goba) the rehabilitation work which should be carried out if funds permit had an estimated total cost of E$32,849,000. Assuming adoption of the most economical methods, part of the program would be done by IHA forces and the remainder by contract. Contractual services, including engineering costs, would therefore be added to the labor, equipment, purchased material and overhead components previously identified.

A tentative schedule was worked out for the rehabilitations, beginning in July, 1973. This provided rounded estimates of expenditures by years for the work, as given below. The combined maintenance and rehabilitation costs by years are then shown, for future years.

Ethiopian	Gregorian	Rehabilitation Costs by Years (1972 E$)
1966	1973/74	15,242,800
1967	1974/75	13,925,800
1968	1975/76	3,680,500

		Combined Program Costs
1966	1973/74	42,485,440
1967	1974/75	42,200,785
1968	1975/76	32,983,168
1969	1976/77	29,804,333
1970	1977/78	29,844,103

B. Resource Constraints, Financial

The following paragraphs describe the past amounts and future projections of funds from those sources which are traditionally used to finance road maintenance and construction. In this discussion the Consultants have limited the analysis to the existing Ethiopian road

user sources. The IEG currently imposes all of the common taxes on highway users and, historically, the revenues generated from these sources have been greater than the combined IHA expenditures for maintenance and construction. Any change in the scope or applied rates of such taxes should be evaluated from the following viewpoints.

First, the administrative problems of any recommended changes would have to be investigated. Would the change be administratively feasible? How would the revenues be used? These questions would require extensive study of the existing institutions, legislation and facilities.

Secondly, any change ought to be reviewed for its impact on competing transport modes and dependent non-transportation industries. The induced effects of any changes in direct or indirect road user taxes should be traced to determine whether side effects such as industrial location, commodity distribution, balance of payments, and viability of other transport-related industries would be affected. Quite obviously, the possible results of such changes could not be evaluated in a study primarily designed to examine highway maintenance practices.

Third, government policy concerning the use of such revenues would have to be considered. It is generally accepted that national road user charges should be structured to finance highways of general national importance, and not necessarily the lesser roads related to agricultural production or local access. In Ethiopia, where the majority of proposed new roads are of tertiary class or are tied to agricultural schemes, it is by no means clear that all the funding for an expanded system, both construction and maintenance, should come from the national user revenues. In terms of "economies of scale," the IHA maintenance organization would be best suited to provide the necessary services for these roads, yet it would be unrealistic to suggest that separate accounts be kept by the function of the road, if some were to be supported from other fund sources. A related question; government policy must determine whether user charges are to be founded basically on the use of paved or of non-paved roads. Taxes on fuels tend to make the costs of using non-paved roads relatively higher,

although these roads may be the more important ones in the country's overall transport picture.

The above discussion is intended to highlight some of the broad considerations relating to road user charges. The following paragraphs concern themselves with the actual and potential revenues from the present user tax structure.

1. Revenues from Existing Road User Charges

Exhibit VIII-1 illustrates the historical revenues from those sources. Exhibit VIII-2 is a graph of the total past and projected user tax receipts. Exhibit VIII-3 shows the historical percentage from each of three major categories. The exhibits taken together indicate that the total future revenues from road user charges should increase at an annual rate of about 7.25 percent, although the rate from 1961/62 to 1971/72 was around 9.5 percent. The more conservative increase is assumed due to the fact that fuel tax revenues are definitely understated. They are based on a linear forecast of the volumes of fuel sold, and of revenues from the fuel excise taxes. However, oil industry reports of total fuel sales in the past are much greater than the volume of fuels reported as taxes by the IEG. The volume of benzine taxed is approximately 84 percent of the benzine sold. This difference may be explained by government and other non-highway use of the fuel. More seriously, the diesel fuel taxed is only about 50 percent of the volume sold. No reason could be found for this discrepancy. Total fuel tax revenues would increase by about 50 percent if all fuel sold were to be taxes. If historical patterns are used as a base, and one-half the industry-projected volumes of diesel fuel are assumed to be taxed, and if these revenues are added to the estimated tax on benzine, a number results which is within 5 percent of the linear projection of total fuel volumes and tax revenues. The more historically realistic and conservative number for fuel tax revenues is used since no basis could be found for justifying tax receipts based on total volumes of fuel.

Other differences that show up in the percentage makeup of road user charge revenues, Exhibit VIII-3, are due to the fact that prior

EXHIBIT VIII-1

ROAD USER CHARGES

(IN THOUSANDS OF ETHIOPIAN DOLLARS)

Fiscal Year		Motor Fuel Taxes	Duties on Vehicles, Tires and Spare Parts	Registration, Driver License Fees and Other Charges*	Total
Ethiopian	Gregorian				
1949	1956/57	2,400	4,046.7**	34.0**	6,480.7
1950	1957/58	13,100	5,309.5**	40.8**	18,450.3
1951	1958/59	14,200	5,768.7**	405.0**	20,373.7
1952	1959/60	12,500	6,199.2**	335.0**	19,034.2
1953	1960/61	15,900	6,113.1**	410.0**	22,423.1
1954	1961/62	16,700	6,801.9**	460.0**	23,961.9
1955	1962/63	19,104	7,090.2	1,005.0**	27,199.2
1956	1963/64	20,316	9,271.6	1,005.0**	30,592.6
1957	1964/65	22,624	10,309.7**	1,110.0**	34,043.7
1958	1965/66	25,281	14,114.0	764.5	40,165.5
1959	1966/67	27,800	15,580.0	784.0	45,164.0
1960	1967/68	31,902	14,091.0	1,028.0	47,021.0
1961	1968/69	32,393	16,203.0	1,130.0	49,726.0
1962	1969/70	34,587	20,213.0	1,038.0	55,838.0
1963	1970/71	38,605	18,538.0	2,588.0	59,731.0
1964	1971/72	41,969***	20,000.0 (est)	2,536.0	64,505.0

* Municipal inspection and drivers license not included prior to 1966/67 sales and transaction tax not available for vehicles 1956/57-1971-72.
** Estimates based on budget and import [illegible], and their rates.
*** Includes duties on local purchase if used vehicles.

Source: IHA Planning and Programming Branch Customs Office, Statistics Section Ministry of Finance.

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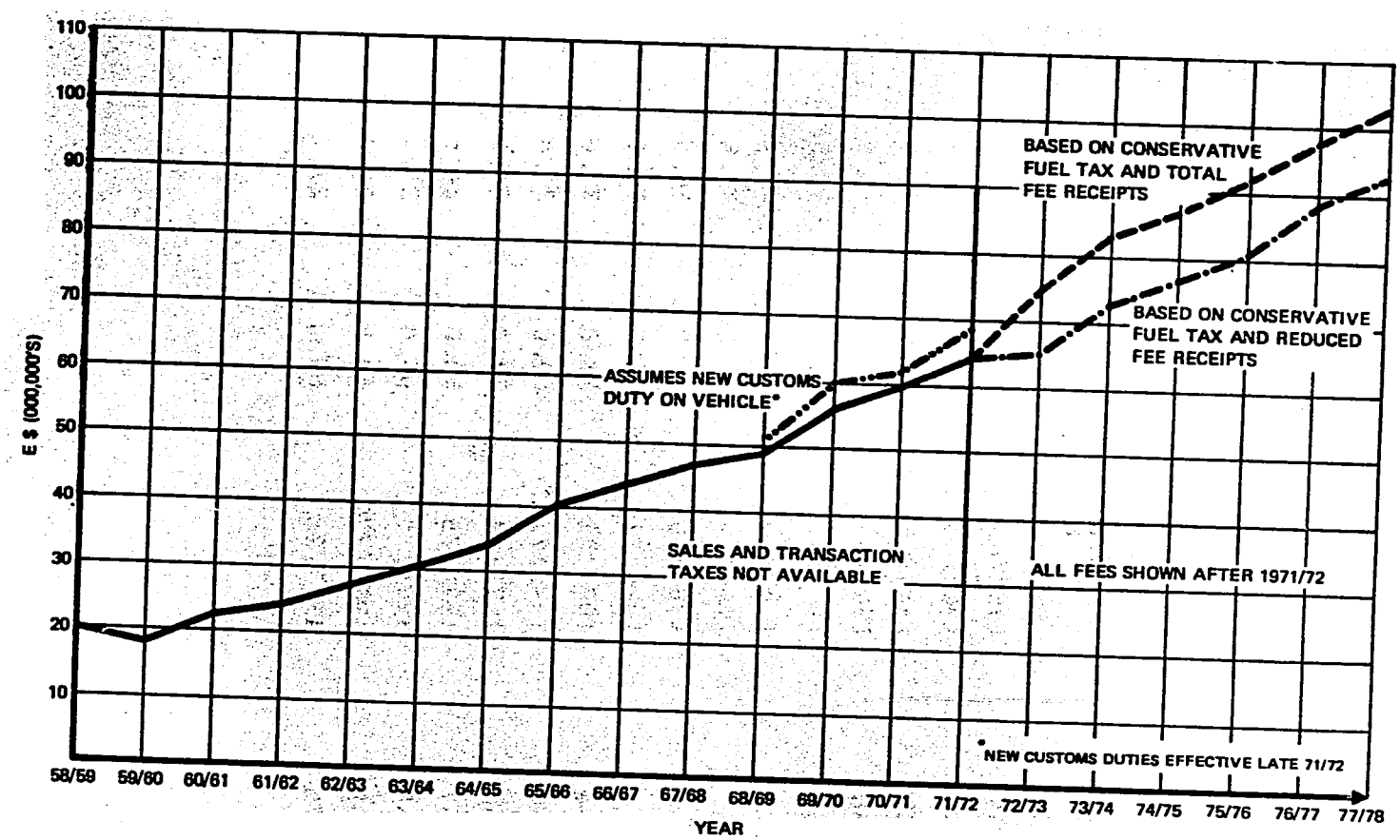

EXHIBIT VIII-2 ROAD USER CHARGES - ACTUAL AND PROJECTED

EXHIBIT VIII-3

PERCENTAGE MAKEUP OF ROAD USER TAX REVENUES

Fiscal Year		Motor Fuel Taxes	Customs Duties	Fees-Registration, License, etc.*
Ethiopian	Gregorian			
1951	1958/59	69.5	28.3	2.2
1952	1959/60	66.0	32.0	2.0
1953	1960/61	71.0	27.0	2.0
1954	1961/62	69.5	28.3	2.2
1955	1962/63	70.0	26.0	4.0
1956	1963/64	66.0	30.5	3.5
1957	1964/65	66.0	30.6	3.4
1958	1965/66	63.0	35.0	2.0
1959	1966/67	62.0	34.5	3.5
1960	1967/68	67.5	30.0	2.5
1961	1968/69	65.0	32.5	3.5
1962	1969/70	62.0	36.5	1.5
1963	1970/71	64.5	31.0	4.5
1964	1971/72**	65.0	31.0	4.0
1965	1972/73	60.0	23.0	17.0***
1966	1973/74	59.0	24.5	16.5
1967	1974/75	60.0	24.5	16.5
1968	1975/76	60.0	24.0	16.0
1969	1976/77	60.5	23.0	16.5
1970	1977/78	60.3	23.2	16.5

* Does not include municipal fees 1956/57-1965/66.
** New Customs duties introduced 1971/72.
*** Assumes collection and reporting of all fees 1972/73-1977/78.

to 1966/67 no data was available for municipal vehicle inspection fees. Also, no specific vehicle data is kept on municipal sales and transaction taxes. The 1972/73-1977/78 projections do include these revenues.

2. Forecast of Road User Revenues

Each of the fund sources shown on Exhibit VIII-4 were forecast independently to generate the total forecast. Nevertheless, all of the items except fuel tax revenues are dependent on either the forecast of the total vehicle fleet or the number of vehicles imported. Exhibit VIII-5 shows the current and forecast vehicle fleet, and Exhibit VIII-6 shows the predicted numbers of vehicles to be imported, by type. These exhibits are based on the calculations shown in the Economics Appendix of this report.

Customs duties are based on the numbers of taxable imported vehicles. Exhibit VIII-7 is a graph illustrating the past and projected revenues from vehicle-related customs duties. Details of these calculations are shown in the Economics Appendix. The duties are based on the historical CIF prices of vehicles, and in these calculations and others that follow the tax rates are applied to the CIF prices as determined from customs department data.

The transactions tax, 15 percent of the CIF value, and the municipality tax of 1 percent of the CIF value, are determined on the basis of the numbers of imported vehicles. Some distortion in the time stream of revenues occurs since all vehicles are not sold in the year they are imported. However, over a five-year period of time such errors should average out.

Sales taxes imposed are 2 percent of the list prices. These prices were determined from interviews with local dealers. The prices for trucks and cars appear to be realistic, but a wide variety of bus types are imported and customs data does not permit a detailed breakdown of these. As sales tax revenues from buses are only 6 percent of the total road user revenues, further investigation did not appear to be warranted.

Exhibit VIII-4

PROJECTED REVENUE FROM ROAD USER CHARGES
(Ethiopian Dollars)

Year	Customs Duties	Transaction & Municipality Taxes	Permanent Number Plates	Sales Tax	Annual Inspection & License Fees	Driving License Fees	Fuel Tax	Total
1971/72	17,434,325	6,734,950	57,978	2,056,870	3,453,531	130,553	45,290,100	75,158,307
1972/73	20,317,322	7,876,062	67,536	2,372,590	3,711,299	131,017	48,812,100	83,287,926
1973/74	20,584,616	7,668,647	69,633	2,311,126	3,991,518	131,481	52,334,100	87,091,121
1974/75	21,640,644	8,359,767	72,081	2,509,897	4,303,537	131,946	55,856,100	92,873,972
1975/76	22,797,340	8,825,153	75,816	2,666,836	4,630,071	132,410	59,378,100	98,505,726
1976/77	24,295,867	8,806,633	83,854	2,688,630	4,994,992	132,875	62,900,100	103,901,951
1977/78	29,437,581	10,535,532	90,225	3,147,430	5,396,978	133,339	66,422,100	115,163,185

Source: Consultant's Analysis.

Exhibit VIII-5

FORECAST OF VEHICLE FLEET

Passenger Cars	1972	1973	1974	1975	1976	1977	1978
In use end of last year	33,046	34,565	37,122	39,912	42,934	46,265	50,063
Imported	4,670	5,382	5,840	5,760	6,064	7,150	7,204
Diplomatic/Government	483	529	584	576	606	715	720
Scrapped	(3,634)	(3,364)	(3,634)	(3,314)	(3,339)	(4,067)	(3,740)
Total in Use	34,565	37,122	39,912	42,934	46,265	50,063	54,247
	4.5%	7.4%	7.6%	7.8%	7.7%		
Buses							
In use end of last year	2,191	2,395	2,575	2,770	2,985	3,215	3,460
Imported	322	335	307	341	385	370	440
Scrapped	(118)	(155)	(112)	(126)	(155)	(125)	(170)
Total in Use	2,395	2,575	2,770	2,985	3,215	3,460	3,730
Trucks							
In use end of last year	7,968	8,382	9,012	9,695	10,477	11,252	12,110
Imported	1,435	1,772	1,575	1,893	1,960	1,671	2,266
Diplomatic/Government	144	177	160	190	200	170	230
Scrapped	(1,175)	(1,320)	(1,052)	(1,301)	(1,385)	(983)	(1,551)
Total in Use	8,382	9,012	9,695	10,477	11,252	12,110	13,055

Source: Consultant's Analysis.

Exhibit VIII-6

PROJECTED VEHICLE IMPORTS BY TYPE

Vehicle Type	1972	1973	1974	1975	1976	1977	1978
Passenger Cars under 1000 kg.	3,035	3,498	3,796	3,744	3,942	4,647	4,683
Passenger Cars over 1000 kg.	1,635	1,884	2,044	2,016	2,122	2,503	2,521
Land Rovers	674	832	740	890	921	785	1,065
Micro-Buses	64	67	60	68	77	74	88
Mini/Omnibuses	258	268	247	273	308	296	352
Trucks, Capacity under 1500 kg.	216	267	237	284	294	251	440
Lorries Capacity over 1500 kg.	545	673	598	719	745	635	861
Trailers	15	15	15	15	15	15	15

Source: Consultant's Analysis.

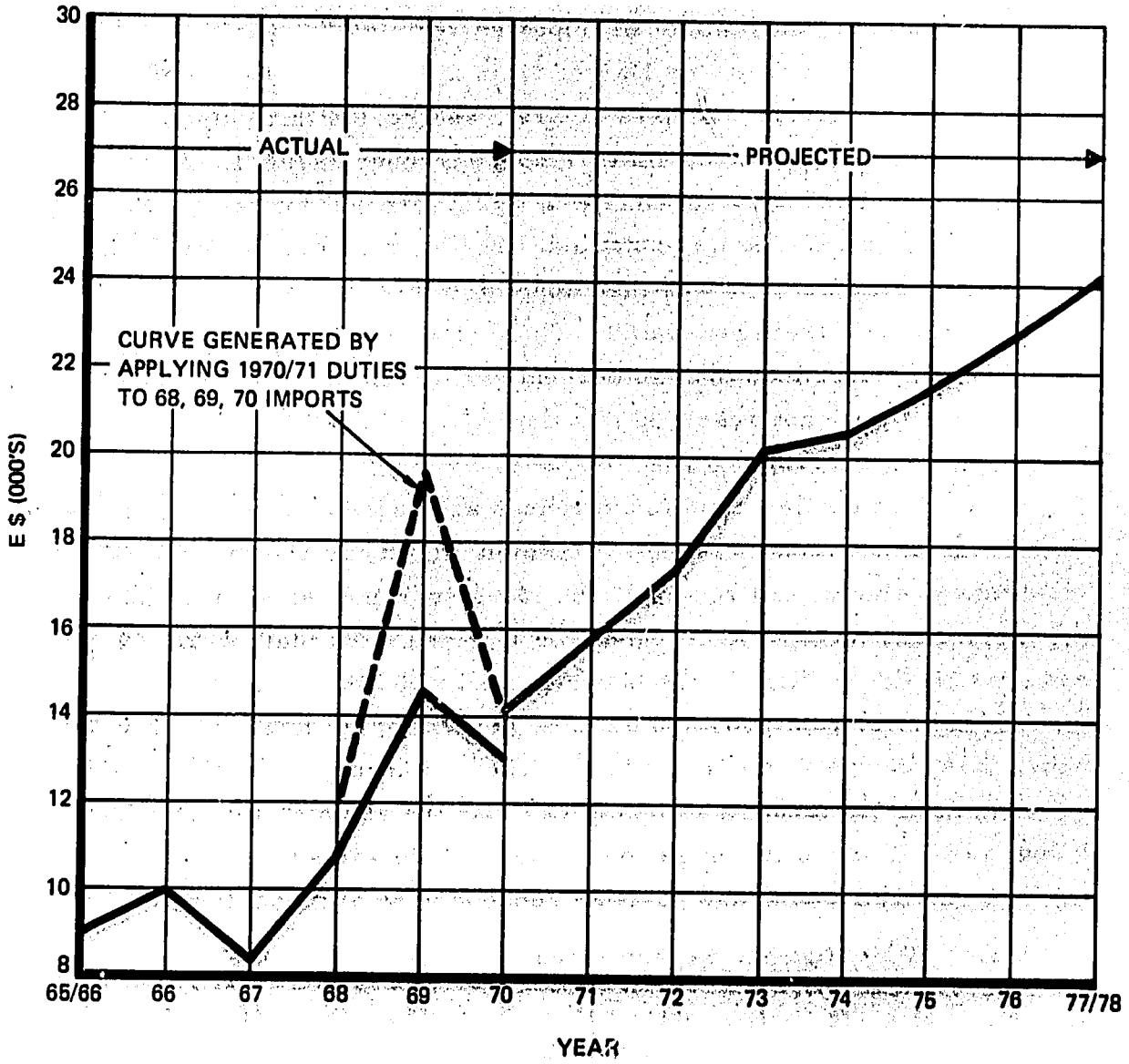

EXHIBIT VIII-7 HISTORICAL AND PROJECTED CUSTOMS DUTY REVENUE FROM VEHICLE IMPORTS

Permanent number plates are sold at E$9.00 per plate. This cost was applied to the number of imported vehicles per year.

Driver license fees are derived from a time-trend linear regression analysis. The numbers of first, second and third class licenses were totaled for the years 1965/66 through 1970/71. A trend line was determined for total licenses, and a forecast for the years 1971/72 through 1977/78 was obtained. The average of fees for first and second class licenses was then applied to this forecast and the revenue stream generated. Third class (diesel engine truck) licenses comprised less than 10 percent of the licenses issued annually, so those fees were not averaged into the basic fee used for forecasting purposes.

As stated earlier, fuel tax revenues are based on a linear projection of the taxed volume of fuel. In Exhibit VIII-8 are shown the historical taxed volumes and receipts, the industry-reported volumes and the theoretical receipts which would be realized if all fuels were taxed, and the percentage differences between these two amounts. As fuel taxes have in the past provided 60 to 65 percent of the total user revenues, it is obviously of interest to the IHA to determine why the taxable volumes of diesel fuel are so much less than the volumes reported as being sold. Lines of investigation should include sales to the government, to the railroads, and possible nonroad uses of diesel fuel.

3. Past Highway Expenditures

Having examined the record of receipts from road user charges, it is pertinent to inquire what part of those revenues were allocated to IHA programs in the last few years; that is, what amounts were spent on the major budget classifications. Despite the significance of this question, and the Consultants' interest in the expenditures, the effort to determine them was only partially successful. The cost-accounts of past years did not provide information complete enough to reconstruct the accomplishments and costs, and it was established that maintenance, betterment and construction disbursements were not clearly separated.

EXHIBIT VIII-8

COMPARISON, INDUSTRY-REPORTED AND IEG-TAXED FUELS

Year	Benzine				
	000's Liters		000's E$		Percentage Actual/ Theoretical
	Industry Volumes	Taxed Volumes	Theoretical Receipts	Actual Receipts	
1968/69	86, 337	67, 525	19, 426	15, 193	78
1969/70	91, 425	77, 213	20, 570	17, 372	85
1970/71	98, 103	83, 600	22, 073	18, 810	85
1971/72	102, 237	86, 350	23, 003	19, 430	85

* Average Revenue per liter = E$0. 225

	Diesel Fuel (Gasoil)				
1968/69	165, 519	92, 969	30, 621	17, 200	56
1969/70	174, 582	93, 009	32, 298	17, 215	53. 5
1970/71	196, 365	107, 002	36, 327	19, 795	54
1971/72	246, 450	119, 537	45, 593	22, 115	48. 5

* Average Revenue per liter = E$0. 185

Sources: Ministry of Finance, Oil Refinery Reports, and Consultants' Analysis.

a. Maintenance

Utilizing all available data with care and judgment, it was concluded that maintenance expenditures from 1966/67 through 1970/71 were approximately as given in Exhibit VIII-9. At the time the basic work was done for the study, year-end accounts were not yet available for 1971/72.

b. Construction and Other Costs

Expenditures for construction and related activities in former years were approximately those shown in Exhibit VIII-10. Summary figures from Exhibits VIII-9 and 10 are presented in Exhibit VIII-11, with their relative values, expressed in percentages of the combined totals. Total annual figures are also given for the earlier fiscal years 1965 and 1966.

c. IHA Budgets Compared to IEG and to User Revenues

Using the data collected, the relationships between IHA program costs and overall IEG expenditures for the 5 years 1965/66 through 1969/70 are shown in Exhibit VIII-12. Combined construction and maintenance expenditures, as percentages of total road user revenues, are indicated in Exhibit VIII-13, for the longer time span 1964/65 to 1970/71.

The data which can be presented on road construction and maintenance is limited to that reported on Exhibits VIII-9 through VIII-13. The Consultants were unable to prepare a tabulation and analysis of construction and maintenance costs for recently constructed roads and those presently under construction, as called for in Article III-C-5 of the contract. Although an extensive effort was made to obtain the necessary data from the IHA records, it was not found available with the degree of detail required to present a meaningful response to the contract. Appropriate notice of the Consultant's findings on this matter was given at a meeting held on

EXHIBIT VIII-9

IHA ROAD MAINTENANCE COSTS REPORTED BY MAJOR EXPENSE ITEM AND BY DISTRICTS, 1966/67 THROUGH 1970/71
(Ethiopian Dollars)

	1966/67	1967/68	1968/69	1969/70	1970/71	Total
Labor	2,821,619.01	2,468,455.10	2,731,591.04	2,965,894.24	3,236,452.27	14,224,011.66
Materials	3,545,449.76	1,048,620.44	1,596,529.72	2,156,226.21	1,687,027.10	10,033,853.23
Plant and Equipment	3,593,173.09	5,196,909.07	6,019,663.87	6,468,971.01	6,208,734.45	27,487,451.49
Overhead	4,126,196.31	5,268,103.60	3,393,399.36	3,791,216.35	4,579,548.11	21,158,463.73
Total	14,086,438.17	13,982,088.21	13,741,183.99	15,382,307.81	15,711,761.93	72,903,780.11
District						
Alemgena	3,302,499.83	3,116,852.30	2,688,545.15	4,209,047.25	3,908,911.79	17,225,856.32
Combolcia	2,418,616.91	2,054,356.35	2,064,423.51	2,035,156.45	1,924,526.64	10,497,079.86
Adigrat	1,152,566.91	914,656.55	878,543.90	935,189.75	966,240.77	4,847,197.70
Dire Dawa	1,111,882.43	1,312,217.33	1,244,020.33	1,037,540.33	1,908,616.36	6,614,276.78
Gonder	1,087,878.37	1,228,122.58	1,272,891.83	1,352,685.76	1,237,078.06	6,178,656.60
Shashamane	1,014,853.63	1,281,849.30	1,512,403.16	1,857,889.96	1,693,473.45	7,360,469.50
Jimma	689,733.60	807,254.58	879,743.36	880,144.65	1,189,885.49	4,446,761.68
Asmara	2,416,526.66	2,494,846.34	2,380,526.99	2,325,066.88	2,007,537.12	11,624,503.99
Debre Markos	891,880.01	771,932.88	820,085.76	749,586.78	875,492.25	4,108,977.68
Total	14,086,438.17	13,982,088.21	13,741,183.99	15,382,307.81	15,711,761.93	72,903,780.11

Source: IHA Cost Accounts Branch.

EXHIBIT VIII-10

REPORTED IHA PRIOR-YEAR PROGRAM EXPENDITURES FOR CONSTRUCTION AND OTHER ACTIVITIES 1966/67 THROUGH 1970/71
(Ethiopian Dollars)

	1966/67	1967/68	1968/69	1969/70	1970/71
Construction	15,528,045	12,874,789	2,176,244	13,578,726	33,510,391
Betterments	5,621,015	5,153,798	3,079,503	2,037,688	1,426,283
Other:					
Ground Surveys	1,439,323	1,451,891	1,673,768	1,854,738	2,873,646
Special Projects	3,453,130	4,093,265	5,239,981	4,344,086	3,561,476
Total	26,041,513	23,573,743	12,169,496	21,815,238	41,371,796

Source: IHA Cost Accounts Branch.

EXHIBIT VIII-11

COMBINED IHA EXPENDITURES

(THOUSANDS OF ETHIOPIAN DOLLARS)

Year	Construction and Other		Maintenance		Total E$	
	Amount	%	Amount	%	Amount	%
1964/65	22,425	67.8	10,663	32.2	33,088	100.0
1965/66	24,112	66.0	12,397	34.0	36,509	100.0
1966/67	26,041	64.9	14,086	35.1	40,127	100.0
1967/68	23,574	62.8	13,982	37.2	37,556	100.0
1968/69	12,169	47.0	13,741	53.0	25,910	100.0
1969/70	21,815	58.6	15,382	41.4	37,197	100.0
1970/71	41,372	72.5	15,712	27.5	57,084	100.0

Source: IHA Cost Accounts Branch.

EXHIBIT VIII-12

COMPARISON OF IEG AND IHA ANNUAL EXPENDITURES
(Millions of Ethiopian Dollars)

	1965/66	1966/67	1967/68	1968/69	1969/70
IEG Expenditures*	394.4	416.8	442.2	454.5	473.6
IHA Expenditures:					
Construction	24.1	26.0	23.6	12.2	21.8
Maintenance	12.4	14.1	14.0	13.7	15.4
Total	36.5	40.1	37.6	25.9	37.2
IHA Total Expenditures As Percent of IEG Expenditures	9.3	9.6	8.5	5.7	7.9
IHA Maintenance as Percent of IEG Budget	3.1	3.4	3.2	3.0	3.2

*Includes salary and operating cost only.

Source: For IEG Expenditure, Central Statistical Abstract, 1970; for IHA Expenditure, IHA Planning and Programming.

EXHIBIT VIII-13

IHA EXPENDITURES AS A PERCENTAGE OF ROAD USER CHARGES

Year	Road User Charges (E$000)	IHA Expenditures (E$000)	Percentage
1964/65	34,044	33,088	97.2
1965/66	40,165	36,509	90.9
1966/67	45,164	40,127	88.8
1967/68	47,021	37,556	79.9
1968/69	49,726	25,910	52.1
1969/70	55,838	37,197	66.6
1970/71	59,731	57,084	95.6

Source: IHA Cost Accounts Branch and Consultant's Analysis.

August 4, 1972 with representatives of the IHA, the Planning Commission Office, the Ministry of Finance and USAID.

d. Equipment Acquisitions

IHA data relating to the procurement of road maintenance equipment over the past five years was incomplete and was judged to be generally unreliable. Audit reports and accounts filed by independent certified accountants following annual studies of IHA fiscal operations have cited wide discrepancies between physical inventories and the accounting and equipment inventory records. These reports include the auditors' findings on the actual cost of additions to the IHA equipment fleet. Because these auditors' reports represent a reconciliation of accounting records with physical inventories, the Consultants elected to use summary cost data from the audits. The one exception was that data for 1972 was obtained from the IHA accounting records.

Additions to IHA Equipment Fleet

Year	Description	Amount
1967/68	Construction and Transport	E$6,163,360
1968/69	Road Machinery, Passenger Cars and Transport	2,324,643
1969/70	Road Machinery, Passenger Cars and Transport	2,552,753
1970/71	Road Machinery, Passenger Cars and Transport	2,398,653
1971/72	Road Machinery, Passenger Cars and Transport (Received through March 31, 1972)	1,207,615
	Total	E$14,647,024

The records indicate that equipment items are acquired with budgeted funds for both maintenance and construction programs. The actual assignment of equipment to construction or maintenance varies through the year depending on the District Engineer's judgment on program priorities. Although maintenance equipment types would normally differ in

some respects from construction units, the interchange still affects any assessment of the adequacy of the inventory represented in the above data for maintenance programs.

4. Potential Revenues and Budget Constraints

The IHA is supported by annual budgets which must be approved at higher levels of the Ethiopian Government. At present, there is no dedication or "earmarking" which would automatically assign predictable amounts to the highway agency. The Consultants' views on dedicated funds are offered in Section XIV.

Since the IHA budgets are fixed annually by administrative and legislative decision, there is no determinate "constraint" which sets a limit, upper or lower, to these allocations. Presumably, past budgets have been determined by IHA needs, to the extent that they could be convincingly demonstrated, and by desirable system improvements, all in competition with the requests from other sections of government.

Lacking a determinate limit, it was concluded that three separate avenues should be explored for guidance as to a rational financial constraint on future maintenance spending. The first was projection of the historical relationship of maintenance programs as a percentage of total IEG expenditures. The second, a direct extension into the future of average past maintenance costs per kilometer, applied to the increasing kilometerage. The third was a projection of maintenance as a percentage of gross road user revenues.

As was shown previously in Exhibit VIII-12, combined IHA expenditures have been a fairly constant percentage of the total IEG amounts. Disregarding the year 1968/69, when the construction program dropped to around one-half of that for other years, IHA expenditures averaged 8.87 percent of the total IEG expenditures. Maintenance was even more uniform as a percentage of the total, at about 3.18%.

Exhibit VIII-14 is a semi-logarithmic graph showing that IEG expenditures have, since about 1964/65, been rising at approximately 5% a year. On the same graph, probable future IEG spending is

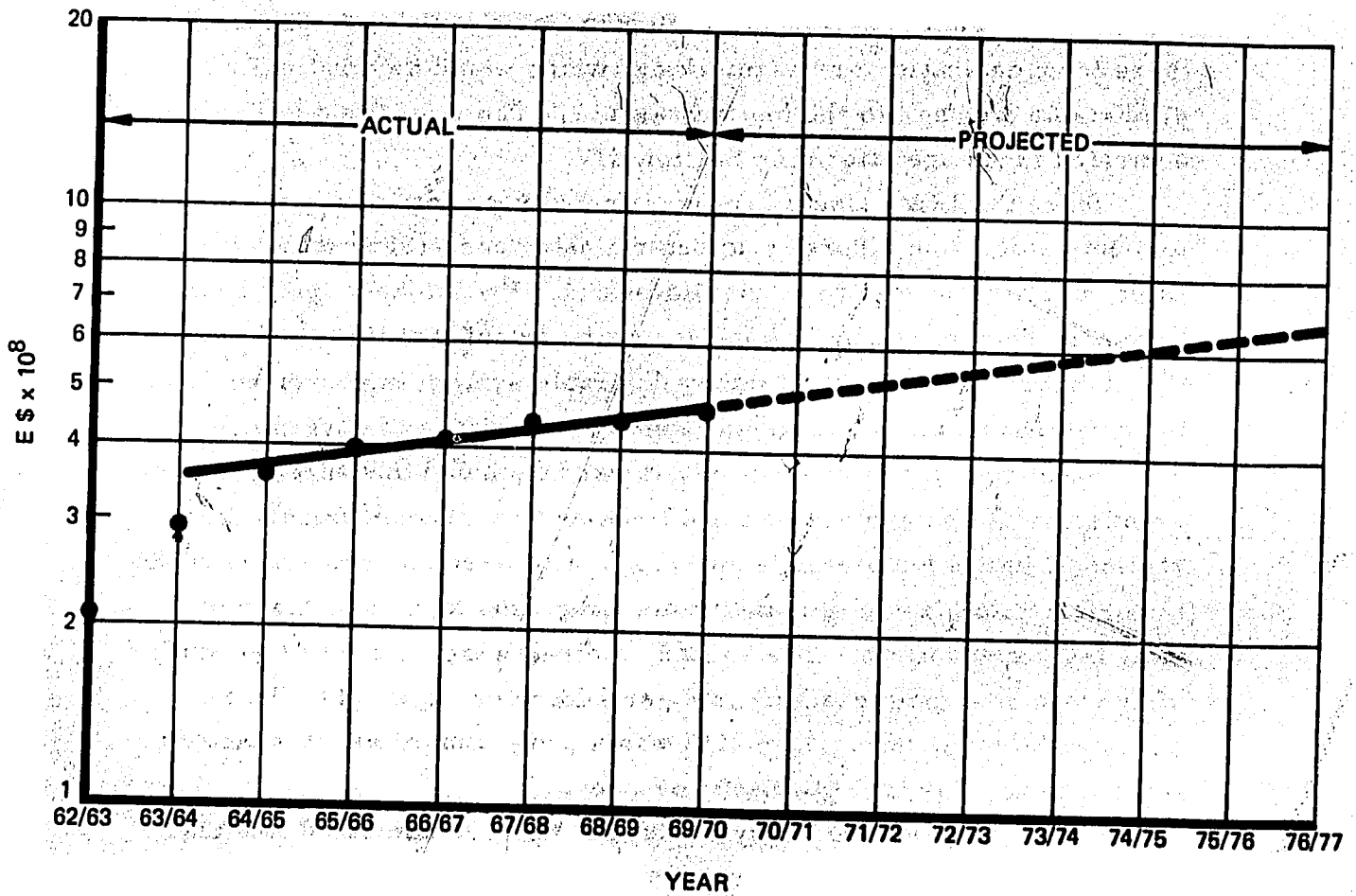

EXHIBIT VIII-14 PAST AND PROJECTED IEG EXPENDITURES
E$ x 10^8

projected at an equivalent rate. The resulting annual amounts are shown in the second column of Exhibit VIII-15, followed by the IHA budgets which would be generated at 8.8% of the total, and maintenance alone at 3.18%.

To determine whether the 3.18% would impose a constraint, the annual amounts required in future for the Consultants' recommended maintenance had to be added to the exhibit for comparison, but a difficulty existed. The figures given in the preceding discussions and exhibits for past IHA operational programs were taken from expenditure account records, and consequently did not include any capitalization of equipment or transfer payments for equipment depreciation. They were not, therefore, directly comparable with the Consultants' estimated maintenance costs for the current and future years. In order to establish a common base, the Consultants' costs were adjusted to exclude depreciations. The procedure involved totalling the equipment rental amount in each of the years and estimating the portion of this which represented depreciation. The estimate was necessarily approximate for two reasons: (1) the rental rates themselves had no firm empirical base, and; (2) depreciation as a percentage of total rental varies substantially for different types of equipment. Overall, a figure of 30% was estimated for this component of the total equipment rental cost in each year, and that quantity was compared with the maintenance program total. It was found to range from 18.9% to 19.8% through the years, with a simple average very near 19.5%. Accordingly, the Consultants' estimated annual costs for the maintenance of all candidate roads were multiplied by 80.5%, and the resulting figures were shown in a final column on Exhibit VIII-15.

As can be seen from the exhibit, the recommended maintenance exceeds the projected historical 3.18% of IEG expenditures in all future years, and by substantial amounts, although the two quantities are converging. The requirement is 120% of the projected 3.18% figure in 1972/73, declining to 108% in 1977/78. Despite the convergence, the significance is clear. If the forecast of IEG budgets is reasonably correct, and the historical-share for road maintenance is continued as

EXHIBIT VIII-15

PROJECTED IHA EXPENDITURES AS A PERCENTAGE IEG, AND COMPARISON WITH RECOMMENDED MAINTENANCE (E$000,000)

Year	IEG Total	Total at 8.87% of IEG	Maintenance at 3.18% of IEG	Recommended Maintenance (Adjusted)
1972/73	548	48.6	17.43	20.81
1973/74	575	51.0	18.28	21.93
1974/75	604	53.6	19.21	22.76
1975/76	634	56.2	20.16	23.59
1976/77	666	59.1	21.18	23.99
1977/78	699	62.0	22.23	24.02

Source: Consultants' Analysis.

a constraint, then the necessary maintenance of all candidate roads cannot be funded. If the maintenance is to be done, then a larger proportion of IEG budgets will have to be allocated for this program.

The second approach to establishing a possible limiting constraint consisted of calculating the average maintenance cost per kilometer for each of the past years 1964/65 through 1970/71, and then multiplying the overall average past expenditure per kilometer times the total future lengths of road proposed for maintenance. The program costs resulting from this exercise are shown in Exhibit VIII-16. It is interesting to note that this process generates numbers which are never more than 3% above or below those derived by taking 3.18% of projected IEG expenditures. Because the two sets are very close together, it is apparent that projecting past IHA costs per kilometer would also fall short of financing the maintenance of all candidate roads. This is to be expected, if it is agreed that maintenance effort during recent years has not been sufficient to prevent deterioration of the system. If the past maintenance cost per kilometer were to be adopted as a constraint, then further decline of the road system would follow, unless the operational efficiency could be raised substantially by some means, to make better use of the funds.

The third approach to constraint-fixing was independent of the historical patterns of allocations and expenditures for maintenance. Instead, it related past programs and future needs to the receipts from road user charges. In the earlier Exhibit VIII-13, combined IHA expenditures were shown as a percentage of past user revenue collections. The utilization by IHA ranged from 52.1% to 97.2%, but was generally 80 to 90%. However, the construction portion of this cost has varied considerably, and if maintenance alone is expressed as a percentage of the same reported receipts, as in Exhibit VIII-17, it presents a much more uniform progression. In 1964/65, maintenance utilized 31.3% of user charge revenues. This remained about the same through 1967/68, then dropped to 27.6% and 27.5% for the next two years, then to 26.3% in the last year for which data was available (1970/71).

EXHIBIT VIII-16

IHA PAST AND FUTURE MAINTENANCE
BASED ON COST PER KILOMETER

Year	Total Kms of Road	Maintenance (E$000)	E$/Km
1964/65	5,671	10,663	1,880
1965/66	5,855	12,397	2,117
1966/67	6,195	14,086	2,274
1967/68	6,826	13,982	2,048
1968/69	6,836	13,741	2,010
1969/70	6,848	15,832	2,312
1970/71	7,653	15,712	2,053
Approximate Average			2,100
Forecast			
1973/74	8,046	16,897	2,100
1974/75	8,834	18,551	2,100
1975/76	9,289	19,507	2,100
1976/77	9,708	20,387	2,100
1977/78	10,296	21,622	2,100

Source: IHA Maintenance Branch and Consultants' Analysis.

EXHIBIT VIII-17

PAST AND RECOMMENDED MAINTENANCE AS A PERCENTAGE OF USER REVENUES

Year	User Revenues* (E$000)	Maintenance Cost** (E$000)	Percent
1964/65	34,044	10,663	31.3
1965/66	40,165	12,397	30.9
1966/67	45,164	14,086	31.2
1967/68	47,021	13,982	29.7
1968/69	49,726	13,741	27.6
1969/70	55,838	15,382	27.5
1970/71	59,731	15,712	26.3
Forecast			
1971/72	64,505		
1972/73	73,366	20,809	28.4
1973/74	81,367	21,931	27.0
1974/75	85,030	22,761	26.8
1975/76	90,656	23,589	26.0
1976/77	96,125	23,992	25.0
1977/78	101,338	24,024	23.7

*Excluding Municipal Taxes
**Excluding Equipment Depreciation

Since user revenues increase with traffic, the declining percentage for maintenance suggests that the cost of keeping up the system was decreasing in relation to vehicle fleet and road usage or, alternatively that insufficient funds were being supplied for maintenance. However, since the types and rates of user taxes were undergoing change not too much meaning can be assigned to this decreasing percentage.

On the other hand, the projection of future user revenues, again in Exhibit VIII-17, together with the estimated costs for maintaining all candidate roads (adjusted to exclude equipment depreciation) presents a rather clear picture of maintenance program costs rising, but more slowly than revenues projected at uniform present rates, so that maintenance is a progressively lower percentage of the user charges. The maintenance, in this case, is that calculated to provide adequate protection for the roads. Furthermore, the projected revenues are not the totals shown previously in Exhibit VIII-4; they exclude those taxes which are municipal in origin.

Depreciation is a real cost of maintenance, because the equipment is used up in the course of the work. If the full program costs, derived in paragraph VIII-A-1 above, are compared with the projected user tax receipts it can be seen that the total recommended maintenance costs for the candidate roads represent a somewhat higher percentage of the revenues, starting at 35.2% in 1972/73 (if the program were now in force) and declining to 29.4% in 1977/78. This is shown in Exhibit VIII-18.

In the judgement of the Consultants, the historical levels of maintenance expenditure should not be imposed as a financial constraint on future programs, either in terms of controlled percentage of overall IEG budgets, or as a continuation of past average costs per kilometer. The Consultants could not perceive any rational tie between overall government functions, comprised of a multitude of programs variable, in part, from year to year, and the maintenance of a defined system of roads, which is a determinate obligation. Regarding the established past expenditure per kilometer, there was no evidence that the cost had been related to actual needs by calculation and, on the contrary, the

EXHIBIT VIII-18

TOTAL RECOMMENDED MAINTENANCE AS A PERCENTAGE OF USER REVENUES

Year	User Revenues* (E$000)	Maintenance Cost** (E$000)	Percent
1972/73	73,366	25,850	35.2
1973/74	81,367	27,243	33.5
1974/75	85,030	28,275	33.2
1975/76	90,656	29,303	32.3
1976/77	96,125	29,804	31.0
1977/78	101,338	29,844	29.4

*Excluding Municipal Taxes
**Equipment Depreciation Included

current condition of the highway system indicated that prior expenditures per kilometer had not been sufficient.

It appeared to the Consultants that there was no really definitive constraint on budget allocations to the IHA, except to the extent that there are never enough funds to meet all public requests and finance all desirable programs.

However, if the philosophy is accepted that taxes imposed on the traveling public, and related to the ownership and use of vehicles, should be utilized primarily to provide and care for the highways from which the revenues are derived, then IHA programs of demonstrable need and economic feasibility should have a first claim on those revenues. On the other hand, since Ethiopia imposes all the usual array of road user charges, there is an implication that IHA programs, in total, should not exceed the amounts of user revenues collected, as an average over the years.

In the view of the Consultants, the total of user revenues might logically be adopted as a limiting financial constraint on total IHA expenditures. Within this limitation, it appeared reasonable to allocate to maintenance those funds estimated to be necessary for adequate minimum protection of the road investments, and service to the users. For the operational costs of maintenance, this would represent about one-third of user taxes in 1973/74, the initial program year of this study, and would decrease to less than 30% in the fifth year. If it were considered appropriate to add a prorated share of IHA general administration to the operational costs of maintenance, previously calculated as 12.22% of operations, then maintenance as a percentage of user taxes would be 37.6% in 1973/74, declining again to 33.0% in 1977/78. The portion remaining available for construction and other IHA activities would be from three-fifths to two-thirds of revenues, and increasing. It was the conclusion of the Consultants that no imperative financial constraint existed to prevent the adequate maintenance of all candidate roads.

Two other factors were to be noted. First, the costs for the candidate rehabilitation projects were not included with the maintenance

programs in the foregoing discussions. As was seen in paragraph VIII-A-2, these costs are substantial, but the analysis in Section VII indicated that they would be favorable projects. Their further postponement would mean continuing abnormal costs to road users, and higher expense for eventual restoration. It was not determined whether the recommended maintenance combined with scheduled construction and other IHA expenditures during 1973/74 through 1975/76 would establish an effective financial constraint to prevent the rehabilitations from being carried out. However, since the distressed condition of these road sections was, in large part, due to curtailed maintenance effort in past years, with the required funds presumably put to other uses, it was considered appropriate to finance the rehabilitations now needed from general revenues or any other available sources. It was the opinion of the Consultants that no constraint should be placed on this necessary work.

The second factor requiring mention was that, while the estimated future maintenance costs of Exhibit VIII-18 included equipment depreciation and would therefore provide for repayment to an equipment capital fund, the initial procurement of additional equipment might require a large capital outlay not included in the preceding evaluation of constraints. These acquisitions might also require funding from other sources.

C. Equipment Constraints

Beyond the monetary needs to carry out the programs identified, there existed the question of whether the physical capacities of the IHA would be sufficient for the purpose. The requirements for labor, equipment and materials were quantified from the estimating processes, and it was apparent that, in general, the needs would be greater than the resources available. The deficiency in numbers of personnel might be a serious problem, especially in the skilled technical and supervisory positions, but the most obvious and pressing discrepancy was in equipment units, for direct functions and for the production of road materials. The evaluation of the existing equipment situation was a major effort of the study.

1. Present Equipment Fleet

Records of the IHA were examined to collect and evaluate information on the numbers of units on the books of the Highway Agency at the time of the study. This included a review of the types, ages and condition status. Study personnel traveled more than 8,500 km, visiting all Districts, to make physical inspections of the equipment, to interview supervisors, operators and mechanics, observe the operation of the machines, and to examine repair and servicing facilities.

The evaluation was limited to major units of what is normally classified as maintenance (or construction) equipment. Excluded were passenger cars and all other personnel carriers, small trucks for general or semi-administrative transport, and miscellaneous or service units such as pumps and welders.

Within this definition of "major units," the property records of the Equipment and Supply Branch showed approximately 1,200 machines, including equipment recommended for salvage but not disposed of or removed from the lists. At the time of the study (mid-1972) about 70% of the active fleet was assigned to Maintenance, and the remainder to the Direct Labor Construction Branch.

The Consultants' field inspections covered about 1,100 units, or roughly 90% of the total listed equipment. While much of this was known to be classed as salvage, representative numbers of such machines were examined to consider whether they might possibly be rehabilitated at acceptable cost. In general, the Team Specialist agreed that the units so classified should be disposed of, and removed from the property lists.

Some 825 major units of serviceable or repairable equipment were identified. Of these, 607 were being used by maintenance forces and 218 were assigned to construction. It was recognized that this distribution was, in practice, variable, with machines sometimes transferred between the two Branches. However, it was assumed that the assignment in effect at the time of inventory would continue.

Of the 607 maintenance units, most attention was given to those pieces of basic equipment which were essential to daily operations; the graders, dump trucks, loaders, rollers, asphalt maintenance

equipment, and crushers. These and some ancillary units were examined for age, make, model, utilization to date and condition. A judgmental estimate was made of the years of remaining life after 1972/73, assuming the provision of essential spare parts and servicing at minimum levels. The principal items are listed by model or year groups in Exhibit VIII-19. Further data on these items, and similar information on all units of the equipment lists, is available from the records of the IHA. Since regular equipment reports are subject to monthly revision, and are of considerable bulk, it was not considered necessary or practical to append one set to this report.

2. Equipment Condition and Availability

The estimates of units remaining in service in future years were founded on evaluations of the physical status of the individual machines, and the means employed to keep them in service.

a. Age and Condition

About 60% of the total IHA fleet is overage by ordinary standards and, in addition, much of it is in a poor state of repair. Consequently, machines spend a lot of time in the shop, and even when they are in service the productivity may be reduced. On the other hand, normal usage in present IHA maintenance was found to be only about 1,000 hours per year roughly 5 hours per day on actual maintenance tasks, for 200 working days per year. On this basis, equipment lives (in years) should be somewhat greater than the usual averages. Actual inspections of the units showed a complete range of serviceability and unused life, sometimes related to age (model year) and sometimes not.

As examples, all of the old jaw crushers were classed as uneconomical for continued use after present parts stocks are depleted. There are 29 of these units in maintenance (10 to 16 TPH ratings; without classifiers) and some date back to 1950 and 1951, but four units are less than 5 years old. All were found to be of limited productivity, their lives beyond 1972/73 were estimated to be zero, and they were not taken

Exhibit VIII-19

EXISTING SERVICEABLE EQUIPMENT FLEET

MAINTENANCE BRANCH ONLY

DUMP TRUCKS

Make	Model	Year	Number of Units	Estimated Remaining Life*
IH	B-170	1960	11	1 to 3 years
IH	B-172	1960	5	" " " "
IH	1600	1963	60	" " " "
IH	1600	1964	6	" " " "
Scania-Vabis	L-5638	1964	5	" " " "
Chevrolet	C-6203	1964	8	" " " "
Chevrolet	C-6203	1965	21	" " " "
Scania-Vabis	L-5638	1965	14	" " " "
Fiat	643-N	1966	3	over 5 years
IHC	RD-190	1967	4	" " "
IHC	1600	1967	25	" " "
Mercedes	LA-1920	1967	5	" " "
Fiat	643-N	1968	4	" " "
Mercedes	LK-911	1968	4	" " "
Mercedes	LK-1413	1969	7	" " "
Scania-Vabis	L-80	1970	2	" " "
Mercedes	LK-1413	1970	3	" " "
Scania-Vabis	L-8042	1971	48	" " "
Scania-Vabis	L-8042	1972	5	" " "
Mercedes	1924	1972	32	" " "
		Total	272	

CRAWLER TRACTORS

Caterpillar	D-4	1960	1	2 years
"	D-4	1962	1	" "
"	D-4	1963	5	3 years
"	D-4	1964	1	4 years
"	D-7E	1964	6	over 5 years
IH (British)	BTD-8	1965	3	3 years
Caterpillar	D-uE	1969	1	over 5 years
"	D-2	1971	2	" " "
		Total	20	

* After 1972/73

Exhibit VIII-19
(Continued)

MOTOR GRADERS

Make	Model	Year	Number of Units	Estimated Remaining Life*
Caterpillar	112E	1962	36	5 years
"	12E	1962	17	" "
"	112E	1963	4	" "
"	12E	1963	3	" "
"	112E	1964	1	" "
Wabco	440	1965	1	" "
"	440	1967	5	" "
Caterpillar	12F	1967	2	" "
"	12F	1970	1	" "
"	12F	1971	4	" "
		Total	74	

FRONT-END LOADERS

Michigan	75A	1960	4	2 to 3 years
Caterpillar	922B	1962	1	" " " "
"	922A	1962	5	" " " "
IH	TD-15	1962	1	" " " "
IH	H-40	1965	1	3 years
Caterpillar	922B	1966	1	over 5 years
"	933	1967	1	" " "
IH	HC-50	1967	3	" " "
Caterpillar	951B	1968	1	" " "
IH	HC-50	1969	4	" " "
Caterpillar	951B	1969	1	" " "
"	977K	1972	2	" " "
		Total	25	

PNEUMATIC ROLLERS

Hyster	A-78L	1964	1	5 years
Galion	C-500A	1964	1	" "
Hyster	C-530A	1972	2	over 5 years
		Total	4	

* After 1972/73

Exhibit VIII-19
(Continued)

3-WHEEL ROLLERS

Make	Model	Year	Capacity (tons)	Number of Units	Estimated Remaining Life*
German	-	1961	-	1	over 5 years
Galion	UD-282	1963	8-10	3	" " "
Huber	-	1963	8-10	1	" " "
Galion	T-810	1964	8-10	3	" " "
Huber	2055	1965	8-10	1	" " "
			Total	9	

TANDEM ROLLERS

Zett	VT-2	1967	small	1	over 5 years
"	VT-2	1968	"	16	" " "
"	VT-L	1971	"	21	" " "
			Total	38	

JAW CRUSHERS (10 to 16 ton per hour)

Pari	-	1950		1	phase out
Magu	-	1951		1	" "
Universal	-	1951		1	" "
"	18x24	1952		5	" "
"	-	1953		1	" "
Loro	Roll	1953		1	" "
Ital-Loro	-	1954		5	" "
Fior	400	1957		2	" "
Lippman	UD-236	1963		7	" "
Alum	1870-40	1967		1	" "
"	1870-25	1967		2	" "
Magu	-	1967		1	" "
Pari	-	1968		1	" "
			Total	29	

CRUSHING/SCREENING PLANTS (50 ton per hour)

Make	Model	Year	Number of Units	Estimated Remaining Life*
Universal	2399	1951	3	over 5 years
"	6-A	1951	1	" " "
"	6031-CR	1951	1	" " "
Hewitt-Robbins	-	1953	1	" " "
Universal	880	1960	1	" " "
"	2399	1964	2	over 5 years
"	538/100	1969	1	" " "
		Total	10	

* After 1972/73

Exhibit VIII-19
(Continued)

AIR COMPRESSORS

Make	Capacity (cu. ft/min.)	Year	Number of Units	Estimated Remaining Life*
Worthington	210	1950	2	1 to 3 years
"	315	1951	4	" " " "
"	500	1951	3	" " " "
Atlas	365	1955	1	" " " "
Roll	365	1957	1	5 years
Worthington	315	1958	1	" "
Chicago Pneumatic	315	1959	2	" "
Ingersoll	315	1959	1	" "
"	125	1963	9	" "
Chicago Pneumatic	600	1963	2	" "
Ingersoll	250	1966	1	" "
Worthington	600	1966	1	" "
Robt	315	1967	3	" "
Worthington	600	1968	5	" "
		Total	36	

WAGON DRILLS

Make	Model	Year	Number of Units	Estimated Remaining Life*
Worthington	VMW	1954	1	1 to 3 years
Gard	-	1963	1	over 5 years
Worthington	WB	1966	2	" " "
"	WB	1968	2	" " "
		Total	6	

ASPHALT DISTRIBUTORS (TRUCK-MOUNTED)

IH	DCO-202	1959	3	over 5 years
IH	DCO-202	1966	2	" " "
IH	DCO-202	1968	3	" " "
		Total	8	

ASPHALT RELAY TRUCKS

IH	DCO-202	1964	2	5 years

* After 1972/73

Exhibit VIII-19
(Concluded)

ASPHALT KETTLES

Make	Model	Year	Number of Units	Estimated Remaining Life*
-	-	1956	5	1 to 3 years
-	-	1957	2	" " " "
-	-	1958	6	" " " "
-	-	1959	5	" " " "
-	-	1960	2	5 years
Blac	UHS-175	1963	12	" "
Blac	URSKE-225	1969	10	" "
"	" "	1970	10	" "
		Total	52	

TOW-TYPE AGGREGATE SPREADERS

Highway	-	1960	5	5 years
Jersey	-	1962	1	" "
"	102	1964	1	" "
"	-	1965	1	" "
		Total	8	

* After 1972/73

into account for meeting future crushing needs. In contrast to this, the 1962 and 1963 Caterpillar Motor Graders (models 12E and 112E) presented a rather different picture, despite their ages. It appeared that parts supplies for these machines had never been adequate during the past 9 to 10 years, and their utilization was therefore abnormally low. Thirteen of these units had been stripped for parts or otherwise made unrepairable, and were classified as salvage. The remaining 66 units (60 in maintenance and 6 in construction) were found to be in a poor state of repair, but basically sound. As inventoried, 46 were operational while 20 were down for repairs. Of the 20 down, about 15 were deadlined for engine repairs only, with the other systems in relatively good shape. The Consultants concluded that the 60 graders of this group assigned to maintenance could economically be kept in service for 5 years or more beyond 72/73, with near-normal parts and servicing. This would avoid a huge amount of replacement expense.

Twelve crawler tractors in the 1954 to 1960 age group were inspected. All were estimated to have a life span of one year or less, although 5 were in operation. The other 7 were deadlined. None were shown in Exhibit VIII-19 or included in the count of 607 serviceable units for maintenance. Nine International Harvester dozers (model BTD-20) were also omitted from the list. Most of these were old 1960/61 models (although 2 were '65's and 1 was a '66) but the total utilization has been low due to deadlining for lack of parts. Despite the low hours of use, their condition was such that they were classed as uneconomical to repair.

Summarizing, most of the IHA maintenance fleet is in rather poor mechanical condition, and this is sometimes correlated with age and sometimes not.

b. Operation and Servicing

The IHA has gone to considerable trouble and expense to insure that equipment operators are trained and certified before they are assigned to field operations. The Alemgena Training Center has good courses and facilities, and the results are basically sound. However, the actual maintenance work after assignment presents a different set of demands and circumstances, and has often led to poor operator practices, abnormal wear or damage to the machines, and shortened life or decreased availability.

Fundamentally, the prevailing shortage of equipment in all classes (at least available equipment - in service and not in the shop) causes the units which are running to be worked beyond the point when they should be serviced, beyond the time when they should receive adjustments and minor repairs, and sometimes beyond a condition at which they can be repaired or rebuilt at normal cost. The lack of transport for operators often results in graders, loaders, rollers and so on being roaded long distances each day instead of being left at work sites or nearby guarded locations. This costs much time from the work-day and causes excessive damage to the equipment. When labor crews, large or small, have to be moved it is usually done with very expensive dump trucks. Having insufficient numbers of lowboy trailers forces machines to be transferred under their own power or in unsafe transport vehicles.

Many equipment breakdowns are due to lack of servicing and insufficient preventive maintenance. Facilities, supplies and personnel for this are inadequate out in the working locations. The operators have no tools for tightening nuts or giving other minor care to the units. Naturally, they are not supposed to adjust or work on any machinery, but all too often the mechanics are a long way off, and units are kept in operation even when it is clear that servicing or minor maintenance

is needed. Together with distance, the variety of machine types and models complicates the provision of filters, proper lubrication, and preventive maintenance.

The administrative management of the equipment has also caused difficulties in the use and servicing. This is discussed in other sections of the report, but some of the field problems are worth noting here. The operational forces do not have full control of the equipment since, in some important respects, it is under the jurisdiction of the Supply and Equipment Branch. This leads to some uncoordinated scheduling of service for key units, disturbing or shutting down maintenance operations. On the other hand, if a mechanic of Supply and Equipment is called to work on a unit and finds that it should be pulled out of service to prevent mechanical damage, or if he observes a unit working somewhere in a similar state, he has no authority to shut it down. Naturally, a field supervisor who is short of equipment may be very reluctant to lose a unit which he needs and which is still functioning, but unnecessary damage and cost may sometimes be the result.

c. Repair Program and Facilities

Once a piece of equipment is down its repair is the responsibility of the District Shops. If feasible, repairs may be made in the field or the section camps; otherwise the unit is moved to the District Headquarters. The section camps and other locations such as quarry sites have very limited facilities for working on equipment, sometimes not even covered space.

All the nine District Headquarters have new shop buildings under construction or recently completed. Each is scheduled to receive adequate shop equipment and tools,

some of which were being installed at the time of the study. The status of each shop at that time was as follows:

Alemgena	-	Shop complete except for new tools and equipment.
Asmara	-	Same as for Alemgena
Gonder	-	Shop under construction; nearly complete
Combolcia	-	Shop building under construction
Adigrat	-	Shop complete; no new equipment installed
Debre Markos	-	Shop will probably be finished in 1972
Dire Dawa	-	Shop building complete. No new equipment installed.
Shashamane	-	Same as Dire Dawa
Jimma	-	Shop under construction; to be completed in 1973.

In addition to the District facilities, there is a well-equipped central rebuild shop at Alemgena, for the repair and renewal of engines and other major components.

All District shops are to be provided with a good range of hand tools, gauges, stands, small power tools, testing devices, jacks and hoists, bench equipment, and such major items as a fork lift, a truck crane, hydraulic presses, brake drum lathes, welding machines and lube units. The central shop will, in addition, be supplied with more sophisticated testing, machining and rebuild equipment.

When this program has been carried out, it appeared to the Consultants that physical needs for equipment repair and servicing at the District Level would be quite adequate for the present and immediate future. The capacity of the Central Shop to handle the future work load seemed less certain, with a clear possibility that the shop may become over-loaded within 3 to 5 years. Service to the three northern districts is not very good at present because of transport distances and communications, and an increased shop-delay time added to this would make their problem serious. Consideration

should be given to adding another central rebuild shop in Asmara in about 1975 or 1976.

According to discussions with District personnel and a review of the records, the present organization for the repair of equipment has been successful in substantially reducing the down-time for serviceable units, and in returning repairable machines to operational status. Preventive and routine maintenance seemed to be less successful, because of distances, lack of field facilities and divided authority over the units. To the Consultants, it seemed clear that the expatriate mechanic-advisors in the Districts, and the HERF Program in general, have been of real assistance to the IHA in raising the availability factor of existing equipment, but at some cost in conflicts. Meshing of the HERF effort in IHA operations has not been entirely successful, and its full potential has, perhaps, not been realized.

With regard to staffing, it was the opinion of the Consultants that there were not enough trained mechanics to meet all needs for the District shops and for repairs and servicing in the field, even though personnel were sometimes idle for lack of parts or supplies.

d. Present Parts Program

A check was made on the parts situation in the Districts, which indicated that, as a rule, those shops now have only limited supplies of spare parts, and then only of items very commonly used. It was understood that, just prior to the study, a policy had been instituted of reducing the inventories in the Districts and consolidating most parts in the Central Warehouse. In consequence, the Districts are heavily dependent on the Addis Ababa Central Warehouse to fill their needs for repairs of any importance. Jimma was found to have few parts of any kind, and Adigrat practically none.

EXHIBIT VIII-20

PRESENT FLEET FORECAST
IHA EQUIPMENT UNITS ESTIMATED TO CONTINUE IN SERVICE
MAJOR MAINTENANCE ONLY, BY YEARS

Description	Existing	In Procurement	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Dump Trucks	272	--	272	227	183	139	139	139
Crawler Tractors	14	--	14	14	14	13	11	10
Motor Graders	74	--	74	74	74	74	74	74
Front-End Loaders	25	--	25	25	25	19	13	13
Rollers (over 5-ton rating)	13	4	17	17	17	17	17	17
Crushing/Screening Plants (50 TPH units)	10	--	10	10	10	10	10	10
Air Compressors (Equiv. 600 CFM units)	21	--	21	21	17	14	11	11
Wagon Drills	6	--	6	6	6	5	5	5
Asphalt Distributors	8	--	8	8	8	8	8	8
Asphalt Relay Trucks	2	--	2	2	2	2	2	2
Asphalt Kettles	52	15	67	67	61	55	49	49
Aggregate Spreaders	8	--	8	8	8	8	8	8

as grader circles, which seldom fail, or to little-used items of which there might be a 20-year supply at present use factors.

In some instances, critical items in continuous demand were found to be exhausted, with bin card data showing they had been out of stock for one to two years. Some obsolete parts showing no turnover in 10 or 12 years were still active on the cards.

It was evident that parts shortages have been, and continue to be, a serious impediment to full utilization of the existing equipment fleet. A related problem is the inadequacy of equivalence checking and cross-reference lists, which would reveal the interchangeability of parts and permit substitutions. At present, parts requests are returned marked "out of stock" if the Kardex shows that the item as specified is not on hand. Experienced mechanics of the Districts have often found that they can locate identical parts with different identifications provided they know how they are described by an alternate supplier or fabricator, or can find an opportunity to visit the warehouse and search for the parts.

Fund shortages over the years which have prevented the IHA from procuring adequate parts supplies, together with other procurement problems, have undoubtedly led to much higher monetary losses from down time and lost equipment than would have been the cost of the parts. In trying to determine the service history of the 1962 model 12E and 112E graders, the Consultants observed from the bin cards that some important parts items were depleted during the first 6 months the units were in operation and were never re-ordered in quantity. Only in 1971 were large parts orders placed for these units, with the intention of phasing out the graders as the new parts stocks are exhausted. The Consultants believe that stocks should be maintained for these machines, and that they should be kept in service. Frish

model graders and loaders only 5 years old are currently being phased out for lack of parts. The British-made IH tractors have had low utilization for the same reason. The 1967-year IH dump trucks (model 1600) offer another example. Fifteen engines for this model truck have been awaiting repair in the central rebuild shop for one to two years. Parts were arriving for these trucks in mid-1972, but several units had already been stripped and were beyond economical repair

The Consultants investigated local sources for parts and found that they were very limited. Among the manufacturers of interest to the IHA, only Caterpillar and Mercedes-Benz maintain in-country dealers offering service and some parts. Usually, the other principal fabricators have only sales representatives or agents. Nevertheless, the Caterpillar dealer stated to study personnel that he now furnishes some E$10,000 to E$20,000 per month in parts to the IHA, and would supply any parts not stocked within 7 days at normal price, including any necessary for the old model 12E and 112E motor graders. It was uncertain how much confidence could be placed in this commitment, but it would certainly seem to merit a fair trial.

e. Fleet Forecasts

An estimate was prepared of the principal units of maintenance equipment which would be in serviceable or repairable condition in the Fiscal Years 1972/73 through 1977/78. For the initial year, this was taken to include all items of Exhibit VIII-19, plus new units currently being acquired by IHA for maintenance, and either in shipment or under firm order. When the units existing or on order were much different in capacity from the average types used in the maintenance cost estimates, an arbitrary adjustment was made in the numbers on hand to equate these to the assumed production rates.

For the years 1973/74 and beyond the available units were reduced by the numbers of older machines expected to go out of service. No estimates were made of possible future procurements by IHA with IEG funds. It was considered possible that some of the equipment being acquired for the Teseney-Humera-Royan project might become available for maintenance after construction of the road. However, it seemed more likely that these machines would remain in the hands of the Direct Labor Construction Branch for other programs, and none were added to the maintenance fleet forecasts for 1966/77 or 1977/78. The forecasts by years are shown in Exhibit VIII-20.

f. Availability Factors

The estimates of annual maintenance effort developed in Report Section III included the operational hours for various equipment units actually required for the work. The summary determination of requirements for a particular road system by this process gives the total equipment hours (and rental cost) needed to maintain that system. However, conversion from this quantity to the numbers of units which must be assigned requires that some allowance be made for the time units are out of service for repairs and normal machine maintenance. This was achieved in the study by estimating "availability factors", or the percentage of normal annual working hours during which a unit would be operational. Application of this factor would indicate how many additional machines would have to be on hand for substitution to carry on the program.

The factors would obviously vary with the complexity of the individual machine types and, to some extent, with age. They would be even more affected by the adequacy of repair facilities, parts supplies and numbers of mechanics available. After considering all the present elements of

EXHIBIT VIII-20

PRESENT FLEET FORECAST
IHA EQUIPMENT UNITS ESTIMATED TO CONTINUE IN SERVICE
MAJOR MAINTENANCE ONLY, BY YEARS

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Motor Graders	74	--	74	74	74	74	74	74
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Rollers (over 5-ton rating)	13	4	17	17	17	17	17	17
Crushing/Screening Plants (50 TPH units)	10	--	10	10	10	10	10	10
Air Compressors (Equiv. 600 CFM units)	21	--	21	21	17	14	11	11
Wagon Drills	6	--	6	6	6	5	5	5
Asphalt Distributors	8	--	8	8	8	8	8	8
Asphalt Relay Trucks	2	--	2	2	2	2	2	2
Asphalt Kettles	52	15	67	67	61	55	49	49
Aggregate Spreaders	8	--	8	8	8	8	8	8

organization, operation, the probable mix of old and new equipment, historical availability, and the basic machine types identified as necessary for the IHA maintenance program, the following conclusions were reached:

(i) The availability factor for the two non-mechanical units, asphalt kettles and tow-type chip spreaders, should be set at 90%.

(ii) Since substitution would not be feasible for crushing and screening plants, the availability for these should be introduced by adjusting the average working hours per day during production runs.

(iii) For all other types of equipment, the factor under present circumstances would probably range from 60 to 70%, with an average of about 65%.

The present availability of existing equipment was discussed with administrators and mechanics of both the IHA and the HERF group. Estimates ranged from 30% to 80% for different classes of machines, with considerable variance of opinion between individuals. The 65% was taken to be a reasonable overall average.

Section IX
RECOMMENDED MAINTENANCE

The development of final recommendations regarding roads which should be maintained required an evaluation of the priorities established in Section V, the resource boundaries discussed in Section VIII, and the national economic and corollary effects of including or excluding roads.

A. Significance of Priority Rankings

Paragraph V-H-2 of the report presents the finding that, of the existing road system (IHA-maintained in 1972/73), sections representing 62.6% of the length had a present value net benefit (PVNB) which was positive, according to the maintenance priority methodology. The remaining 37.4% showed a negative PVNB. As might be expected, such important routes as the Addis Ababa-Nazreth-Awash and Asmara-Massawa highways ranked very high, while various spurs and local roads were near the bottom of the rankings. In contrast to this, the process also gave some results which were surprising, such as the high index for the Yergalem spur and the low ranking of the Asseb airport road, even though close examination gave explanations for these. More disturbing, the establishment of priorities for maintenance based only on vehicle operating costs was sometimes plainly in conflict with the recognized standing of different routes or sections. Thus, the seriously negative index for the Gonder-Azezo link had to be arbitrarily rejected, and the relative rankings of Asmara-Keren (negative) and Keren-Teseney (positive) were an obvious distortion of the real situation, resulting from the basics of the method. This ordering of the sections appears in the final exhibits of Section V.

The ranking model was adopted only after careful thought and various trials, and is believed to be a basically sound and useful indicator. Nevertheless, as was clearly stated in Section V-H, the priorities which result have a very closely circumscribed meaning, not suitable for broad interpretation. A review of all the rankings for present and future roads discloses

that most are reasonable and realistic. There are exceptions, however, and these anomalies, plus the rather narrow significance of the ratings, led to the conclusion that they should not be the sole determinant for inclusion or exclusion of candidate roads.

B. Zero-Sum Road Networks

The individual segments of all roads were analyzed separately, but the PVNB of each was not printed out for examination because it was obvious that short negative segments within long positive routes could not be abandoned, regardless of their rankings. Instead segments were grouped to make up viable sections and links which might, with more reason, be kept in or left out of a system. Grouping segments in this way, it was obvious that negative stretches might sometimes be "carried" by being averaged together with several positive segments.

The Consultants considered following the same procedure on a systems basis, using net positive benefits to support negative sections until parity was reached. Naturally, one objective would be to select a logical and continuous system, even if outer extremities might have to be dropped. In the course of approximations, it was found that the entire present system actually showed positive net benefits when all segments were summed, with some surplus to offset negatively-ranked routes of future additions.

This approach was discarded because, on reflection, it was apparent that the basic reasoning was fallacious. The costs of maintenance for all segments are real, and must be accepted if the roads are to be kept in good condition. The benefits of the ranking model, on the other hand, are purely hypothetical; they are merely an intermediate step in producing an index number which tells where maintenance is most effective in evading VOC increases. The proof of this lies in the fact that, in the model, all roads are necessarily assumed to start in their best possible condition, in terms of VOC. The ranking process quantifies the effects of interrupting maintenance on such roads. However, if they were in their best condition, and the maintenance were done, no real benefits whatever would result.

Genuine benefits would come from improved maintenance on roads not in their best potential condition. This quantification required a separate, later analysis, after a system had been selected and the actual condition of its segments had been determined. In this subsequent process, no benefits were taken for segments in their best condition.

C. Rationale and Conclusions

The basis for recommending a system was therefore reduced, in essence, to an evaluation of the broad economic, social and political effects of terminating maintenance on existing road sections of negative PVNB. It was apparent that these roads would generate benefits not quantified in the ranking procedure. It was previously established that there was no imperative constraint to prevent financing their maintenance. The exclusion of presently-maintained sections having a negative PVNB would mean the isolation of Dire Dawa, Keren, Bonga, Arbaminch, Negele and numbers of smaller communities. It would mean the abandonment of the entire highway link from Addis Ababa to Gonder, and long sections of other vital routes. Such a decision would clearly be politically untenable, and economically disastrous. Degrees of negative standing were of no assistance in choosing sections which might be maintained or discarded, because some links which might be dropped without serious consequences had much better relative indices than others of critical importance. For example, the Ghimbo access road (near Bonga) was ranked 31st in the total priority list, while the Bahir Dar-Azezo section of Route 3 was 58th, of the 67 sections ranked. Considering all factors, it was the conclusion of the Consultants that all segments of the present highway system should continue under IHA maintenance.

Regarding the proposed future additions to the road network, paragraph H-3 of Section V indicated that only 20.5% of the new length showed a positive PVNB. This figure was somewhat misleading, in that much of the programmed investment over the next five years would provide for paving sections of existing gravel road. These sections had already been ranked, with their future surface types and maintenance costs, and were not analyzed

a second time. Of the remaing future roads, twelve were projects of the Fourth and Fifth Highway Programs (6 from each), and the other 16 were to be constructed by the Direct Labor Construction Branch. The first twelve were supported by feasibility studies demonstrating their economic viability, with maintenance included in their long-term costs, and had been accepted for partial funding by external lending agencies. It seemed essential to include them in the maintenance system, regardless of their rankings (nine had a negative PVNB). As can be seen from the appropriate Exhibits of Section V, two of the D/L projects had positive rankings, and by this criterion should be included for maintenance.

Fourteen projects remained in question. An investigation was made to see what the maintenance cost of these projects would be, by years, as they were brought into the system, and what percentage they would represent of total maintenance for all candidate roads. The information was taken from Exhibit III-E of the Engineering Appendix, and the results are shown below.

MAINTENANCE COST OF D/L PROJECT
ROADS WITH NEGATIVE PVNB

Year	Total Cost, Candidate Programs	D/L Projects	Percent of Total
1973/74	E$ 27,242,640	E$ 429,385	1.58
1974/75	28,274.985	446,630	1.58
1975/76	29,302,668	689,630	2.35
1976/77	29,804.333	232,345	0.78
1977/78	29,844,103	500,285	1.68
5-year Total	E$144,468,729	E$2,298,275	1.59

The feasibility of these projects had not been demonstrated by formal studies and was therefore open to some question. However, construction was in progress on many, and the others were part of approved programs. Most were related to farm development and national economic integration.

There was little doubt that they would be highly useful for these purposes, whatever their rates of return might be as investments. Again, the ranking process could not quantify all their general benefits. With only one exception (Butajira-Hosaina), all were of Feeder or Service to Traffic standards, with low maintenance cost per kilometer. Considering their minimal addition to total program costs, the Consultants concluded that it would not be logical to exclude them from IHA maintenance responsibility. The only serious factor mediating against this conclusion was the fact that, being for the most part outward extensions of the road network, they would require a large spatial expansion of maintenance activities, including camps and other fixed facilities, with low concentrations of effort. This would raise their real costs of maintenance by some amount which was not estimated in the basic tables, and could not be due to the variability of this factor.

D. System Recommendations

In consideration of all the preceding facts, estimates and analyses, the Consultants recommend that the IHA continue the maintenance of all routes and sections now under the responsibility of that agency, as listed in Exhibit III-D of the Engineering Appendix. The Consultants recommend that the IHA undertake the future maintenance of all future candidate roads shown on Exhibit III-E of the same Appendix.

E. Alternative Program Levels

Article III-D-2 of the Maintenance Study contract calls for the Consultants to, "recommend a feasible and economically justifiable five-year maintenance and rehabilitation program, giving an order of priorities based on assumed actual budgetary availabilities and on availabilities 25% below the assumed actual figures...."

As was seen in Section VIII, the examination of possible budget constraints did not produce any set of figures which would conform to the meaning of "budgetary availabilities," unless this is taken to be the projection of past maintenance programs, either as a percentage of total IEG budgets or of IHA expenditures per kilometer. These two methods gave totals which

were in close agreement, but well below the requirements for adequate maintenance. Consequently, they were rejected as applicable constraints. In the absence of any guide as to what part of road user revenues, or total IEG revenues, might properly be allocated to maintenance, no figures were derived from these projections which might be deemed the amounts "available." If the allocation were to be set at 50% of user charges, for example, it would finance the maintenance of a network substantially larger than that subjected to priority analysis. At 25% of user tax receipts, the 1972/73 existing system could not be given adequate attention. The approach taken was to establish what the financial requirements would be for maintaining all good candidate roads, and compare these requirements with projected user revenues. The conclusion reached was that the necessary allocations would be reasonable and justified. The approach is believed to be defensible, but it does not furnish an indication of "available" funds.

In the early weeks of the study, it was assumed that the study would arrive at a much larger potential system, that this would then be reduced to viable program size by the application of a determined financial constraint, and that the resulting network could then be examined once more to see which routes and links would be best qualified for inclusion at a funding level 75% of the determined constraint. It was supposed that this was the intent of the contract. As the study progressed, a rather different picture emerged. The candidate systems were more closely defined, to be made up entirely of roads in which there was an obvious IHA interest through prior maintenance or programmed IHA funding. As it turned out, these entire candidate systems could be financed with a reasonable portion of user revenues, and to consider a revised system costing 25% less would present serious problems. If <u>all</u> of the future roads were rejected for maintenance, the 1977/78 program cost would be reduced by only about E$3, 994, 000, or 13. 38%. This would return the program to the requirement for the existing system. If that network were further reduced by deleting all spur and side roads, and all existing low-volume feeder and minor access roads, leaving only the primary and other principal highways, the cost would only be lowered

by another 4.95%. The combined effect of these two drastic measures would be to decrease program costs by 18.33%.

The obvious question then is, which of the main arteries of travel should be eliminated to achieve a program cost 75% of that for the total candidate list? The priority rankings furnish a guide to this, but the question itself seemed to have lost its significance in the changed definition of the system to be analyzed. It was the opinion of the Consultants that no attempt should be made to establish a "75 percent" program in terms of a specified system to be maintained at adequate levels.

If later circumstances force the IHA to adopt a lower-cost program, fixed at 75% of the total recommended budget or some other base, then the best procedure would be to transfer some of the least-critical routes to local responsibility, and to reduce the IHA maintenance effort on those remaining arterial sections of lowest traffic volume. This was not considered to be a really practical alternative plan, and no studies were made to see where these economies could be applied with minimum adverse effects on the economy.

Section X
RECOMMENDED REHABILITATIONS

A. Interpretation of the Rankings

The procedure outlined in Section VII indicates that candidate rehabilitations were ranked by a simple process of computing how long it would take for the savings in VOC to repay the cost of doing the work. This is not the usual format for determining the economic attractivess of an investment. Normally, all costs are compared to all proceeds over an estimated life, at a certain interest rate. The standard procedure could not be applied in these cases for three reasons:

- The first cost for these projects is not an investment in the ordinary sense of purchasing something which was not previously owned. It is more in the nature of exceptional maintenance of an owned facility.
- Since the purpose of the first cost here is the restoration of an existing facility, the "investment" has no life over which to compare benefits and costs, unless it is assumed that the facility will fail again in a certain period. This was not a logical assumption.
- In addition to the original cost of facilities, there is almost always a maintenance cost for the upkeep of the investment, whether it is a cornfield or a hydroelectric dam. In this case the distressed road sections were still being maintained, at some unknown cost level. The incremental cost to preserve the rehabilitations after completion might be more than or less than the current effort, but in either case would be "maintenance of maintenance," a contradiction.

The costs of doing the various rehabilitations could be estimated by the usual engineering methods. The VOC savings were available from the current condition ratings of the roads, in comparison with normal (restored)

condition. An interest rate could be established. These were the known quantities of the standard feasibility analysis structure. The quantities were utilized by computing the annual VOC savings (for the known traffic), converting these to present value at the adopted interest rate, and summing the savings year by year until the total was approximately equal to the rehabilitation cost. The number of years required was used, on the basis of judgment, to decide whether the work should be done. The conclusion reached was that 4 of th 5 candidate paved-road projects should be programmed, and 5 of the 6 projects analyzed on gravel roads.

B. Recommended Rehabilitations

In the opinion of the Consultants, the following candidate projects should be programmed and carried out, with the priorities and estimated costs shown:

RECOMMENDED REHABILITATION PROGRAM

Section	Net Project Length (km)	Estimated Cost, E$	Priority
Paved Routes			
Addis Ababa-Welkite	97.0	2,084,300	1st
Addis Ababa-Agrehiwot	106.6	3,433,800	2nd
Tendaho-Asseb	120	3,216,000	3rd
Addis Ababa-Debre Berhan	102.4	4,530,600	4th
Gravel Routes			
Tarmaber-Woldia	367	7,982,100	1st
Shashamane-Sodo	140	3,187,700	2nd
Shashamane-Kofole	101	2,221,500	3rd
Wondo-Kebremengist	140	3,023,200	4th
Jimma-Bonga Junction	105	3,169,800	5th

C. Other Distressed Road Sections

The two candidate road sections with excessively long payout lives (Addis Ababa-Dejen and Kofole-Goba) are in a deteriorated condition, as indicated by their condition ratings. There are other routes of the present system which might be classed as semi-distressed. Although the rehabilitation of these cannot be justified by present traffic volumes, or their conditions may be less serious, it is apparent that extra maintenance effort should be applied to prevent further decline and possible loss of investment. As a minimum, when more resources become available, they should be scheduled early for urgent repairs, and given priority for ordinary periodic maintenance: seal-coating for the pavements and resurfacing for the gravel sections.

Section XI

RESOURCE REQUIREMENTS

After developing program recommendation on the basis of economic priorities and financial capacities, a study was made of the resources which would be needed to carry out these programs. The basic elements were the numbers and types of equipment units, the labor forces, and the quantities of purchased materials. The probable costs of all these elements were assembled, including those for equipment acquisitions. The foreign and local components of cost were then derived.

A. Methodology for Regular Maintenance

The procedures used in quantifying the physical resource needs for maintenance and rehabilitation were different in detail, but similar in fundamentals. Naturally, the needs for regular maintenance were much larger in scale, and the calculations for such needs would have to be repeated and extended in future years as system changes occurred. Therefore, it was desirable to have a method which was as simple and flexible as possible.

In substance, the procedure used was the reverse of that employed to obtain maintenance costs per kilometer by road types. In that process (see Section III), the kinds of work to be done were identified, a standard crew was established for each activity, with its necessary equipment, a daily production rate was fixed, and the required materials determined. Each type of road would demand certain specific maintenance activities (e.g., asphalt patching or spot regraveling), and was estimated to need some fixed number of crew-days per kilometer per year. The numbers of days were dependent on climate, topography, and the other factors which determined the road type. The costs per crew-day were multiplied by the annual days required, and the expense for all activities summed to get annual cost per kilometer.

After the recommended road system had been established it was then possible to go back through the crew-day calculations to get the

resources needed. The total kilometers of each type of road were added up; that is, all of type 1-DF, all of type 3-MR, and so on. Knowing the kilometers of each type, and having the tables of crew-days for the maintenance of each type, it was then possible to multiply total kilometers times the tabular annual rates to get total crew-days per year for all kilometers of that road type, by maintenance activities. The total crew-days for each specific activity were then summed for all road types. The crew effort for special maintenance was obtained by an equivalent process.

The above produced a tabulation of total crew-days of different crews needed to maintain the system under consideration for one year (periodic maintenance had been prorated to annual increments). Following that, it was only necessary to apply the numbers of crew-days to each kind of crew make-up to get the numbers of annual work-hours for each personnel classification and each type of machine, plus the quantities of materials.

This was done first for the existing (1972/73) system, by Districts and then by system totals. For subsequent years, only the system revisions were considered, and these were of two kinds; changes in surface type, and additions of new length (there was one 5-km reduction in the length of a present route, due to relocation). Other possible revisions which might be encountered at some time are changes in standard (e.g. from 6-HR to 4-HR), or abandonments of maintained sections.

1. Quantification of Personnel Needs

Labor hours were converted to man-days in each classification, and then divided by an assumed 227 effective working days per year to get the numbers of personnel needed to perform the operations. The 227 figure was derived by subtracting from 365 all Sundays and 13 holidays, and an additional 73 days representing the average for annual leave, sick leave, Saturdays not devoted to maintenance tasks, and time lost due to weather and other factors. An exception to this was the conversion from man-days to the numbers of contract laborers required. In this case, 286 work days per year were used for the calculation.

Dividing the annual man-days required by the available days per man per year gave the arithmetical numbers of men needed, but some adjustments then had to be made. If, for example, in a particular District only a limited number of man-days were needed in an occupational specialty, resulting in a fractional requirement for that position in the District, it was often assumed that another personnel classification having excess time could substitute in the job. This assumed that some operators would be trained for multiple skills, so that an asphalt distributor driver could also drive a water truck when necessary, for example, or even a roller. Alternatively, when a District requirement was limited, it was sometimes assumed that an entire operation would be supplied by excess personnel (and equipment) from an adjoining District, as in the seal coating of short asphalt sections at intervals of several years. In general, a strict interpretation of the figures was taken, to limit personnel numbers to those really standardized staffing by IHA Road Sections, since that would have been inconsistent with the basic maintenance-estimating process used in the study.

2. Equipment Determination

The figure of 274 working days per year was used for the conversion from equipment days to equipment units. This was based on 365 days less all Sundays, all holidays, and the 52 Saturday half-days. It was recognized that some equipment does work Saturday mornings, but it was assumed that most units would not, or would have equivalent unproductive time at some other period during the week.

The annual work-days required for each equipment type divided by the 274 normal work days gave the numbers of units required to be in service. This whole or fractional quantity, as calculated, was then divided by the availability factors estimated in Section VIII. These factors were 65% for mechanical equipment and 90% for non-mechanical, with crushing and screening plants excluded. The result indicated how many units would have to be assigned to provide the in-service machines needed. The numbers of assigned units, whole or fractional, were next arbitrarily increased by 5% for graders, dump trucks, loaders and

rollers, and by 10% for all other types. The purpose was to make some overall provision for work dispersion with the Districts. This was considered necessary because, while numbers of crew-days and machine-days could be accumulated arithmetically, the operations would actually be somewhat scattered and the utilization of assigned equipment at 100% scheduling efficiency would not be possible. Following this final calculation, the numbers were examined and, in the usual case, rounded up to the next higher whole number of units. Small fractions were sometimes dropped, and a few arbitrary adjustments were made where it appeared necessary.

3. Materials Requirements

The annual quantities of gravel surfacing, patching mix, bitumens, cover aggregates and other materials were computed in a similar fashion, using the kilometers of road to be maintained, the crew-days needed per kilometer, and the amounts of materials used in a crew-day.

No further computations were made for purchased materials, but the quantities to be produced by IHA forces were used to determine the additional personnel and equipment needs. The in-place volumes derived from the crew-days of work on the roads were expanded to loose, or stockpile, volumes where applicable. The production of the stockpiled materials had been estimated from assumed forces in the pits and quarries, and this process was again reversed to break out personnel and equipment work-days and numbers.

B. Resource Quantification by Computer

The foregoing computations are obvious in their nature and follow a simple progression, but are voluminous for a system as large as that in Ethiopia. In this study the calculations were done by hand, a tedious process, because of limited computer capacity and, more decisively, conflicting demands for the available computer time.

If a verification of the study findings is desired, or a revised quantification with changed assumptions or values, the work can be

done with computers of modest storage capacity by using successive programs. Once the total kilometers of road are known for each of the different maintenance types (by total system, district, or other subsystem), the data on Exhibits III-B-1 through III-B-6 of the Engineering Appendix can be used as a matrix to give, with suitable identification, the necessary numbers of crew-days for the various activities on different kinds of road. Identical types of crew-days for different roads can be combined. A second matrix would have to be set up using the work activity estimate sheets of the Appendix, and the numbers of crew-days applied to these matrix values. A third step would be the conversion by computer from annual total man-days and machine-days to required personnel and units, using the factors given above, or substitutes. Final judgement on the resulting figures would be necessary, to adjust and round the values.

C. Resources for Rehabilitations

The personnel and equipment needs for the force account portions of the recommended rehabilitation program were quantified by assuming a logical crew make-up for the different operations, and analyzing the optimum number of crews to provide an economical scheduling. Obviously, large numbers of men and machines would be needed immediately if the program were to be carried out rapidly. Using fewer crews would reduce the initial resource requirement, but would prolong the time needed to complete all work.

The Consultants adopted a program schedule which would begin in July, 1973, the earliest starting date which seemed possible, and would continue through April, 1976. A majority of the paving rehabilitation could be accomplished in the first year, and most of the remaining work would be completed by July, 1975. Using this as a basis, the resource requirements were established for the operations of the first year (fiscal year 1973/74) and the reduced requirements for the succeeding years 1974/75 and 1975/76.

D. Total Resource Needs

The individual requirements for the recommended programs, in terms of physical resources, are given below. Comparisons with existing resources follow later in Section XII, together with recommendations on the action which should be taken.

1. Labor

To the extent that they are identified and quantified by the methodology used in this report, the personnel requirements for the regular maintenance of all recommended roads are shown in Exhibits XI-1 through XI-9, by District and by years. Exhibit XI-10 provides a summary for the total system.

The figures in the above exhibits do not include personnel for the stockpiling of aggregates and other materials. The labor forces needed for an interim program of materials production are shown in Exhibit XI-11. This staffing can provide all aggregates required for regular asphalt maintenance, but not the total volume needed for the upkeep of all gravel roads. The labor is based on a recommended materials program for gravel roads which is discussed in Section XII. The personnel of Exhibit XI-11 are not shown by District because they would, in part, be subject to inter-district assignments.

Resource needs were not quantified for the production of all necessary gravel surfacing, because the Consultants felt that such a program should not be implemented now. However, the required labor forces (and equipment) for 100% production were included in all estimates of total system maintenance cost including the annual budgets of Section XII. This was essential to provide a comparison figure for the later computation of net benefits from recommended maintenance.

The crews necessary for the rehabilitation program are shown in Exhibits XI-12 through XI-15 with a summary of the four districts in XI-16. The intention in arriving at these labor estimates was that, within a District having more than one project, the work would be scheduled so that a crew for a specific operation, such as the repair of base failures, would complete work on one highway and proceed to

EXHIBIT XI-1

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 20 - ALEMGANA

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	716	4	749	4	783	4	774	4	765	4	756	4
Labor Foreman	6,382	28	6,614	29	6,991	31	7,121	32	7,207	32	7,290	32
Mason Foreman	255	1	265	1	292	2	293	2	293	2	283	2
Mason II	985	5	1,018	5	1,106	5	1,111	5	1,111	5	1,111	5
Mason I	1,969	9	2,035	9	2,211	10	2,221	10	2,221	10	2,221	10
Laborer II	4,330	19	4,453	20	5,023	22	5,548	25	5,923	26	6,328	28
Laborer I	18,372	81	18,984	84	20,784	92	21,757	96	22,423	99	22,740	100
Helper II	3,132	14	3,308	15	3,422	15	3,276	15	3,150	14	3,016	14
Contract Laborer	45,322	159	46,991	164	49,629	174	49,808	174	49,829	174	49,806	174
Grader Operator	3,625	16	3,835	17	3,833	17	3,490	16	3,220	14	2,929	13
Dump Truck Driver	8,840	39	9,231	41	9,489	42	8,797	39	8,534	38	8,688	38
Loader Operator	2,814	13	2,923	13	3,087	14	3,549	16	3,617	16	3,690	16
Truck Driver	944	5	982	5	1,058	5	1,057	5	1,061	5	1,057	5
Water Truck Driver	762	4	808	4	764	4	638	3	543	3	441	2
Roller Operator	2,547	12	2,642	12	2,871	13	3,026	14	3,134	14	3,251	14
Asphalt Distributor Operator	335	2	345	2	400	2	455	2	494	2	536	3
Asphalt Relay Truck Operator	335	2	345	2	400	2	455	2	494	2	536	3
Dozer Operator	190	1	190	1	190	1	190	1	190	1	190	1

EXHIBIT XI-2

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 21 - ASMARA

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	286	2	286	2	291	2	291	2	318	2	318	2
Labor Foreman	2,567	12	2,567	12	2,587	12	2,587	12	2,710	12	2,710	12
Mason Foreman	69	1	69	1	72	1	72	1	80	1	80	1
Mason II	731	4	731	4	750	4	750	4	794	4	794	4
Mason I	1,462	7	1,462	7	1,500	7	1,500	7	1,587	7	1,587	7
Laborer II	2,658	12	2,658	12	2,676	12	2,676	12	2,720	12	2,720	12
Laborer I	8,864	39	8,864	39	8,978	40	8,978	40	9,409	42	9,409	42
Helper II	1,093	5	1,093	5	1,000	5	1,000	5	1,200	6	1,200	6
Contract Laborer	16,760	59	16,760	59	16,940	60	16,940	60	17,843	63	17,843	63
Loader Operator	992	5	992	5	1,045	5	1,045	5	1,299	6	1,299	6
Dump Truck Driver	9,280	15	9,280	15	3,340	15	3,340	15	3,669	16	3,669	16
Loader Operator	1,142	5	1,142	5	1,156	5	1,156	5	1,234	6	1,234	6
Truck Driver	434	2	434	2	444	2	444	2	470	2	470	2
Water Truck Driver	172	1	172	1	181	1	181	1	235	1	235	1
Roller Operator	1,215	6	1,215	6	1,223	6	1,223	6	1,277	6	1,277	6
Asphalt Distributor Operator	200	1	200	1	200	1	200	1	200	1	200	1
Asphalt Relay Truck Operator	200	1	200	1	200	1	200	1	200	1	200	1
Dozer Operator	17	0	17	0	17	0	17	0	17	0	17	0

EXHIBIT XI-3

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 22 - GONDER

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	150	1	157	1	173	1	173	1	173	1	173	1
Labor Foreman	1,957	9	1,987	9	2,082	10	2,082	10	2,082	10	2,082	10
Mason Foreman	65	1	69	1	80	1	80	1	80	1	80	1
Mason II	278	2	289	2	375	2	375	2	375	2	375	2
Mason I	556	3	612	3	749	4	749	4	749	4	749	4
Laborer II	278	2	400	2	468	2	468	2	468	2	468	2
Laborer I	2,701	12	3,059	14	3,468	16	3,468	16	3,468	16	3,468	16
Helper II	891	4	952	5	1,101	5	1,101	5	1,101	5	1,101	5
Contract Laborer	15,770	55	16,041	56	16,933	60	16,933	60	16,933	60	16,933	16
Grader Operator	1,514	7	1,593	7	1,775	8	1,775	8	1,775	8	1,775	8
Dump Truck Driver	2,800	13	3,007	14	3,229	15	3,229	15	3,229	15	3,229	15
Loader Operator	803	4	823	4	871	4	871	4	871	4	871	4
Truck Driver	253	2	268	2	305	2	305	2	305	2	305	2
Water Truck Driver	287	2	301	2	333	2	333	2	333	2	333	2
Roller Operator	331	2	345	2	378	2	378	2	378	2	378	2
Asphalt Distributor Operator	7	0	7	0	7	0	7	0	7	0	7	0
Asphalt Relay Truck Operator	7	0	7	0	7	0	7	0	7	0	7	0
Dozer Operator	345	2	345	2	345	2	345	2	345	2	345	2

EXHIBIT XI-4

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 23 - COMBOLCIA

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	280	2	280	2	289	2	289	2	289	2	289	2
Labor Foreman	2,578	12	2,578	12	2,654	12	2,654	12	2,654	12	2,654	12
Mason Foreman	71	1	71	1	74	1	74	1	74	1	74	1
Mason II	425	2	425	2	442	2	442	2	442	2	442	2
Mason I	850	4	850	4	885	4	885	4	885	4	885	4
Laborer II	2,021	9	2,021	9	2,128	9	2,128	9	2,128	9	2,128	9
Laborer I	7,541	33	7,541	33	7,879	35	7,879	35	7,879	35	7,879	35
Helper II	1,222	6	1,222	6	1,252	6	1,252	6	1,252	6	1,252	6
Contract Laborer	15,999	56	15,999	56	16,367	57	16,367	57	16,367	57	16,367	57
Grader Operator	1,487	7	1,487	7	1,497	7	1,497	7	1,497	7	1,497	7
Dump Truck Driver	3,845	17	3,845	17	4,035	18	4,035	18	4,035	18	4,035	18
Loader Operator	1,326	6	1,326	6	1,369	6	1,369	6	1,369	6	1,369	6
Truck Driver	348	2	348	2	359	2	359	2	359	2	359	2
Water Truck Driver	315	2	315	2	315	2	315	2	315	2	315	2
Roller Operator	1,091	5	1,091	5	1,340	5	1,340	5	1,340	5	1,340	5
Asphalt Distributor Operator	122	1	122	1	132	1	132	1	132	1	132	1
Asphalt Relay Truck Operator	122	1	122	1	132	1	132	1	132	1	132	1
Dozer Operator	255	2	255	2	265	2	265	2	265	2	265	2

EXHIBIT XI-5

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 24 - ADIGRAT

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	186	1	186	1	186	1	186	1	186	1	186	1
Labor Foreman	2,116	10	2,116	10	2,116	10	2,116	10	2,116	10	2,116	10
Mason Foreman	58	1	58	1	58	1	58	1	58	1	58	1
Mason II	332	2	332	2	332	2	332	2	332	2	332	2
Mason I	665	3	665	3	665	3	665	3	665	3	665	3
Laborer II	1,270	6	1,270	6	1,270	6	1,270	6	1,270	6	1,270	6
Laborer I	6,078	27	6,078	27	6,078	27	6,078	27	6,078	27	6,078	27
Helper II	975	5	975	5	975	5	975	5	975	5	975	5
Contract Laborer	16,076	56	16,076	56	16,076	56	16,076	56	16,076	56	16,076	56
Grader Operator	1,124	5	1,124	5	1,124	5	1,124	5	1,124	5	1,124	5
Dump Truck Driver	2,508	11	2,508	11	2,508	11	2,508	11	2,508	11	2,508	11
Loader Operator	753	4	753	4	753	4	753	4	753	4	753	4
Truck Driver	259	1	259	1	259	1	259	1	259	1	259	1
Water Truck Driver	220	1	220	1	220	1	220	1	220	1	220	1
Roller Operator	946	5	946	5	946	5	946	5	946	5	946	5
Asphalt Distributor Operator	75	0	75	0	75	0	75	0	75	0	75	0
Asphalt Relay Truck Operator	75	0	75	0	75	0	75	0	75	0	75	0
Dozer Operator	26	0	26	0	26	0	26	0	26	0	26	0

EXHIBIT XI-6

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 25 - DEBRE MARKOS

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	155	1	155	1	155	1	166	1	178	1	178	1
Labor Foreman	921	4	921	4	921	4	994	5	1,073	5	1,073	5
Mason Foreman	49	0	49	0	49	0	55	1	61	1	61	1
Mason II	160	1	160	1	160	1	182	1	205	1	205	1
Mason I	320	2	320	2	320	2	363	2	410	2	410	2
Laborer II	160	1	160	1	160	1	182	1	205	1	205	1
Laborer I	2,348	11	2,348	11	2,348	11	2,564	12	2,799	13	2,799	13
Helper II	848	4	848	4	848	4	923	4	1,005	5	1,005	5
Contract Laborer	7,497	26	7,497	26	7,497	26	8,397	30	9,151	32	9,151	32
Grader Operator	1,157	5	1,157	5	1,157	5	1,255	6	1,361	6	1,361	6
Dump Truck Driver	2,004	9	2,004	9	2,004	9	2,222	10	2,389	11	2,389	11
Loader Operator	452	2	452	2	452	2	484	2	518	3	518	3
Truck Driver	173	1	173	1	173	1	190	1	208	1	208	1
Water Truck Driver	309	2	309	2	309	2	331	2	356	2	356	2
Roller Operator	309	2	309	2	309	2	331	2	356	2	356	2
Asphalt Distributor Operator	--	--	--	--	--	--	--	--	--	--	--	--
Asphalt Relay Truck Operator	--	--	--	--	--	--	--	--	--	--	--	--
Dozer Operator	--	--	--	--	--	--	--	--	--	--	--	--

EXHIBIT XI-7

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 26 - DIRE DAWA

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	218	1	277	2	294	2	294	2	304	2	357	2
Labor Foreman	1,994	9	2,292	10	2,415	11	2,415	11	2,488	11	2,708	12
Mason Foreman	73	1	91	1	95	1	95	1	101	1	128	1
Mason II	347	2	450	2	477	3	477	3	499	3	659	3
Mason I	693	3	901	4	953	5	953	5	997	5	1,318	6
Laborer II	489	3	885	4	1,070	5	1,070	5	1,092	5	1,365	6
Laborer I	3,890	17	5,444	24	6,029	27	6,029	27	6,235	28	6,890	31
Helper II	1,367	6	1,599	7	1,651	8	1,651	8	1,717	8	2,542	12
Contract Laborer	15,523	55	16,891	59	17,830	63	17,830	63	18,749	66	20,041	71
Grader Operator	1,814	8	2,036	9	2,054	9	2,054	9	2,140	10	2,484	11
Dump Truck Driver	3,298	15	3,943	18	4,117	18	4,117	18	4,250	19	4,948	22
Loader Operator	754	4	974	5	1,051	5	1,051	5	1,080	5	1,255	6
Truck Driver	279	2	341	2	358	2	358	2	375	2	458	2
Water Truck Driver	394	2	446	2	446	2	446	2	466	3	550	3
Roller Operator	436	2	699	3	786	4	786	4	806	4	975	5
Asphalt Distributor Operator	21	0	54	1	71	1	71	1	71	1	83	1
Asphalt Relay Truck Operator	21	0	54	1	71	1	71	1	71	1	83	1
Dozer Operator	80	1	80	1	97	1	97	1	97	1	97	1

EXHIBIT XI-8

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 27 - SHASHAMANE

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	348	2	364	2	430	2	554	3	583	3	594	3
Labor Foreman	2,656	12	2,738	12	3,539	16	4,369	20	4,586	21	4,954	22
Mason Foreman	115	1	122	1	154	1	192	1	201	1	223	1
Mason II	475	2	497	3	613	3	786	4	841	4	923	4
Mason I	950	5	995	5	1,226	6	1,571	7	1,682	8	1,845	8
Laborer II	950	5	973	5	1,486	7	2,069	9	2,325	11	2,759	12
Laborer I	6,526	29	6,797	30	8,812	39	11,597	51	12,490	55	13,671	61
Helper II	1,944	9	2,040	9	2,313	10	2,912	13	3,040	14	3,017	14
Contract Laborer	22,262	78	23,003	81	29,451	103	35,083	123	36,279	127	39,359	138
Grader Operator	2,432	11	2,559	12	2,831	13	3,495	16	3,595	16	3,471	16
Dump Truck Driver	4,405	20	4,761	21	5,615	25	7,114	32	7,447	33	7,528	34
Loader Operator	1,078	5	1,124	5	1,380	6	1,801	8	1,921	9	2,004	9
Truck Driver	476	3	495	3	597	3	745	4	782	4	833	4
Water Truck Driver	560	3	591	3	642	3	792	4	807	4	753	4
Roller Operator	854	4	886	4	1,151	5	1,536	7	1,660	8	1,797	8
Asphalt Distributor Operator	68	0	68	0	110	1	158	1	180	1	216	1
Asphalt Relay Truck Operator	68	0	68	0	110	1	158	1	180	1	216	1
Dozer Operator	19	0	19	0	19	0	44	1	61	1	61	1

EXHIBIT XI-9

TOTAL MAN-DAYS AND MEN REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

DISTRICT NO. 28 - JIMMA

Position	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men	Man-Days	Men
Construction Foreman	209	1	262	2	264	2	269	2	276	2	272	2
Labor Foreman	1,492	7	2,135	10	2,232	10	2,392	11	2,519	11	2,791	13
Mason Foreman	64	1	88	1	91	1	97	1	104	1	113	1
Mason II	220	1	308	2	315	2	340	2	362	2	396	2
Mason I	441	2	616	3	631	3	679	3	724	4	792	4
Laborer II	299	2	855	4	1,110	5	1,266	6	1,528	7	1,881	9
Laborer I	3,318	15	5,214	23	5,760	26	6,184	28	7,288	32	7,605	34
Helper II	1,006	5	1,221	6	1,180	6	1,185	6	1,184	6	1,129	5
Contract Laborer	12,631	44	17,309	61	17,673	62	18,999	67	19,710	69	21,774	76
Grader Operator	1,365	6	1,558	7	1,436	7	1,406	7	1,338	6	1,167	6
Dump Truck Driver	2,683	12	3,447	16	3,390	15	3,442	15	3,467	16	3,380	15
Loader Operator	606	3	852	4	895	4	929	4	988	5	1,027	5
Truck Driver	248	2	327	2	332	2	348	2	371	2	376	2
Water Truck Driver	382	2	411	2	362	2	345	2	309	2	236	1
Roller Operator	443	2	707	3	792	4	846	4	940	5	1,039	5
Asphalt Distributor Operator	18	0	57	1	83	1	96	1	121	1	154	1
Asphalt Relay Truck Operator	18	0	57	1	83	1	96	1	121	1	154	1
Dozer Operator	0	0	0	0	0	0	0	0	0	0	0	0

EXHIBIT XI-10

TOTAL MANPOWER REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

Position	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Construction Foreman	15	17	17	18	18	18
Labor Foreman	103	108	16	123	124	128
Mason Foreman	8	8	9	10	10	10
Mason II	21	23	24	25	25	25
Mason I	37	40	44	45	47	48
Laborer II	59	63	69	75	79	85
Laborer I	270	285	13	332	347	360
Helper II	58	62	64	67	69	72
Contract Laborer	588	618	61	590	704	727
Grader Operator	70	74	76	79	78	78
Dump Truck Driver	151	162	68	173	177	180
Loader Operator	46	48	50	54	58	59
Truck Driver	20	20	20	21	21	21
Water Truck Driver	19	19	19	19	20	18
Roller Operator	40	42	46	49	51	52
Asphalt Distributor Operator	4	6	7	7	7	8
Asphalt Relay Truck Operator	4	6	7	7	7	8
Dozer Operator	6	6	6	7	7	7

EXHIBIT XI-11

MANPOWER REQUIRED FOR MATERIALS PRODUCTION
REGULAR MAINTENANCE OF RECOMMENDED ROADS

Position	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Quarry Supervisor	6	7	7	7	7	7
Quarry Foreman	10	11	11	11	11	11
Crusher Operator	10	12	12	12	12	12
Helper II	6	8	8	8	8	8
Dump Truck Driver	16	20	20	20	20	20
Loader Operator	16	18	18	18	18	18
Driller I	6	8	8	8	8	8
Laborer I	18	28	28	28	28	28
Dozer Operator	21	22	22	22	22	22
Powderman	6	7	7	7	7	7
Helper I	4	5	5	5	5	5
Contract Laborer	66	66	66	66	66	66
Labor Foreman	15	15	15	15	15	15

EXHIBIT XI-12

MANPOWER REQUIRED FOR REHABILITATIONS (INITIAL YEAR)

ALEMGENA DISTRICT

Position	Remove Base Failure	Replace Base Material	Scarify Road Shoulder	Place Crushed Aggregate	Total Man Power
Route No. 5; Addis Ababa - Agrenhiwot					
Construction Foreman	1/3	1/3	1/3	1	1
Labor Foreman	1	1	2	2	2
Dump Truck Driver	6	6	0	16	16
Grader Operator	0	0	3	3	3
Dozer Operator	1	1	1	0	1
Water Truck Driver	0	1	2	2	2
Loader Operator	1	0	0	2	2
Roller Operator	0	1	4	4	4
Laborer II	2	2	2	2	2
Contract Laborer	6	6	6	6	6
Helper II	0	0	3	3	3
Route No. 7; Addis Ababa - Welkite					
Construction Foreman	1/3	1/3	1/3	1	1
Labor Foreman	2	2	1	2	2
Dump Truck Driver	16	16	0	16	16
Grader Operator	0	0	3	3	3
Dozer Operator	2	2	1	0	2
Water Truck Driver	0	2	2	2	2
Loader Operator	4	2	0	2	4
Roller Operator	0	4	4	4	4
Laborer II	2	2	2	2	2
Contract Laborer	24	24	6	6	16*
Helper	0	0	3	3	3
Route No. 1; Addis Ababa - Debre Berhan					
Construction Foreman	1/3	1/3	1/3	1	1
Labor Foreman	2	2	2	2	2
Dump Truck Driver	16	16	0	16	16
Grader Operator	0	0	3	3	3
Dozer Operator	2	2	1	0	2
Water Truck Driver	0	2	2	2	2
Loader Operator	4	2	0	2	4
Roller Operator	0	4	4	4	4
Laborer II	2	2	2	2	2
Contractor Laborer	24	24	6	6	16*
Helper II	0	0	3	3	3

*Average number required.

EXHIBIT XI-13

MANPOWER REQUIRED FOR REHABILITATIONS
(INITIAL YEAR)

COMBOLCIA DISTRICT

Position	Remove Base Failure	Replace Base Material	Total Man Power
Route No. 2; Tendaho - Asseb			
Construction Foreman	1/2	1/2	1
Labor Foreman	2	2	2
Dump Truck Driver	16	16	16
Grader Operator	0	2	2
Dozer Operator	4	4	4
Water Truck Driver	0	2	2
Loader Operator	4	2	4
Roller Operator	0	4	4
Laborer II	2	2	2
Contract Laborer	24	24	24
Helper II	0	0	0

	Scarify Road Shoulder	Place Pit-Run Base	Place Surface Aggregate	Total Man Power
Route No. 1; Tarmaber - Woldia				
Construction Foreman	1/2	1/2	1	1
Labor Foreman	1	1	2	2
Dump Truck Driver	0	10	21	21
Grader Operator	2	2	3	4
Dozer Operator	1	0	0	1
Water Truck Driver	2	2	2	4
Loader Operator	0	1	2	2
Roller Operator	4	4	4	8
Laborer II	2	2	2	4
Contract Laborer	6	10	10	16
Helper II	2	2	3	4

EXHIBIT XI-14

MANPOWER REQUIRED FOR REHABILITATIONS
(INITIAL YEAR)

SHASHAMANE DISTRICT

Position	Scarify Road Shoulder	Place Pit-Run Base	Place Surface Aggregate	Total Man Power
Route No. 41; Shashamane - Sodo				
Construction Foreman	1	1	1	1
Labor Foreman	2	2	2	2
Dump Truck Driver	0	12	17	17
Grader Operator	3	3	3	3
Dozer Operator	1	0	0	1
Water Truck Driver	2	2	2	2
Loader Operator	0	1	2	2
Roller Operator	4	4	4	4
Laborer II	2	2	2	2
Contract Laborer	6	10	6	8*
Helper II	3	2	3	3
Route No. 40; Shashamane - Kofole				
Construction Foreman	1	1	1	1
Labor Foreman	2	2	2	2
Dump Truck Driver	0	14	17	17
Grader Operator	3	3	3	3
Dozer Operator	1	0	0	1
Water Truck Driver	2	2	2	2
Loader Operator	0	2	2	2
Roller Operator	4	4	4	4
Laborer II	2	2	2	2
Contract Laborer	6	10	6	8*
Helper II	3	3	3	3
Route No. 44; Wondo - Kebremengist				
Construction Foreman	1	1	1	1
Labor Foreman	1	2	2	2
Dump Truck Driver	0	11	13	13
Grader Operator	2	3	3	3
Dozer Operator	1	0	0	1
Water Truck Driver	2	2	2	2
Loader Operator	0	1	2	2
Roller Operator	4	4	4	4
Laborer II	2	2	2	2
Contract Laborer	6	10	10	10
Helper II	2	3	3	3

*Average number required

EXHIBIT XI-15

MANPOWER REQUIRED FOR REHABILITATIONS
(INITIAL YEAR)

JIMMA DISTRICT

Position	Scarify Base Shoulder	Place Pit-Run Base	Place Surface Aggregate	Total Man Power
Construction Foreman	1	1	1	1
Labor Foreman	1	2	2	2
Dump Truck Driver	0	12	12	12
Grader Operator	2	3	3	3
Dozer Operator	1	0	0	1
Water Truck Driver	2	2	2	2
Loader Operator	0	2	2	2
Roller Operator	4	4	4	4
Laborer II	2	2	2	2
Contract Laborer	10	10	10	10
Helper II	2	3	3	3

EXHIBIT XI-16

SUMMARY, TOTAL MANPOWER REQUIRED FOR REHABILITATIONS
(INITIAL YEAR)

Position	Alemgena District	Combolcia District	Shashamane District	Gimma District	Total
Construction Foreman	1	1	2	1	5
Labor Foreman	2	2	4	2	10
Dump Truck Driver	16	21	17	12	66
Grader Operator	3	4	6	3	16
Dozer Operator	2	4	1	1	8
Water Truck Driver	2	4	4	2	12
Loader Operator	4	4	4	2	14
Roller Operator	4	8	8	4	24
Laborer II	2	4	4	2	12
Contract Laborer	16	20	18	10	64
Helper II	3	4	6	3	16

the next. The total numbers shown on Exhibit XI-16 are therefore much less than the sum of all crews indicated. Furthermore, the forces shown are the peak numbers needed at the time of maximum operations, which would occur during the first year. The actual requirements would be slightly less in the first 60 to 90 days of that year (1973/74), a little less through most of 1974/75, and much lower in 1975/76, as the programs were concluded.

2. Equipment Needs

a. Regular Maintenance

Based on the activities identified and the estimating procedures used in this report, the equipment required for the regular maintenance of the recommended system of roads is that shown in Exhibit XI-17, by Districts and by years. A summary for the total system is provided in Exhibit XI-18.

b. IHA-Produced Materials

As in the case of labor, the equipment requirements shown above for regular maintenance do not include those for the production of aggregates and other materials. The additional units for pit and quarry operations, based on the interim program previously referred to and later described in Section XII, are as follows:

Units Required	Description
10	Crushing/Screening plants, 50 ton/hour
1	Crushing/Screening plants, 225 ton/hour
20	Dump Trucks
18	Front-end loaders
4	Self-powered conveyors
7	Air compressors, 600 C.F.M.
8	Wagon drills
15	Crawler tractors

EXHIBIT XI-17

EQUIPMENT WORK-DAYS AND UNITS REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

Description	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Work-Days	Units	Work-Days	Units	Work-Days	Units	Work-Days	Units	Work-Days	Units	Work-Days	Units
DISTRICT NO. 20 - ALEMGENA												
Motor Grader	3,625	22	3,835	23	3,833	23	3,490	21	3,220	19	2,929	18
Dump Truck	8,840	52	9,231	55	9,489	56	8,797	52	8,534	57	8,688	52
Front End Loader	2,814	17	2,923	17	3,087	18	3,549	21	3,617	22	3,690	22
2.5 Ton Truck	944	6	982	6	1,058	7	1,057	7	1,061	7	1,057	7
Roller	2,547	15	2,642	16	2,871	17	3,026	18	3,134	19	3,251	20
Water Truck	762	5	808	5	764	5	638	4	543	4	441	3
Crawler Tractor	190	2	190	2	190	2	190	2	190	2	190	2
Asphalt Heater	1,115	5	1,145	5	1,306	6	1,479	7	1,604	7	1,739	8
Asphalt Distributor	335	2	345	2	400	3	455	3	494	3	536	4
Asphalt Relay Truck	335	2	345	2	400	3	455	3	494	3	536	4
Aggregate Spreader	222	2	228	2	264	2	299	2	324	2	351	3
DISTRICT NO. 21 - ASMARA												
Motor Grader	992	6	992	6	1,045	7	1,045	7	1,299	8	1,299	8
Dump Truck	3,280	20	3,280	20	3,341	20	3,341	20	3,669	22	3,669	22
Front End Loader	1,142	7	1,142	7	1,156	7	1,156	7	1,234	8	1,234	8
2.5 Ton Truck	434	3	434	3	470	3	470	3	470	3	470	3
Roller	1,215	8	1,215	8	1,277	8	1,277	8	1,277	8	1,277	8
Water Truck	172	1	172	1	235	2	235	2	235	2	235	2
Crawler Tractor	17	0	17	0	17	0	17	0	17	0	17	0
Asphalt Heater	642	3	642	3	642	3	642	3	642	3	642	3
Asphalt Distributor	200	2	200	2	200	2	200	2	200	2	200	2
Asphalt Relay Truck	200	2	200	2	200	2	200	2	200	2	200	2
Aggregate Spreader	137	2	137	2	137	2	137	2	137	2	137	2
DISTRICT NO. 22 - GONDER												
Motor Grader	1,514	9	1,594	10	1,775	11	1,775	11	1,775	11	1,775	11
Dump Truck	2,800	17	3,007	18	3,229	19	3,229	19	3,229	19	3,229	19
Front End Loader	803	5	823	5	871	6	871	6	871	6	871	6
2.5 Ton Truck	253	2	268	2	305	2	305	2	305	2	305	2
Roller	331	2	345	2	378	3	378	3	378	3	378	3
Water Truck	287	2	301	2	333	2	333	2	333	2	333	2
Crawler Tractor	345	2	345	2	345	2	345	2	345	2	345	2
Asphalt Heater	31	1	32	1	32	1	32	1	32	1	32	1
Asphalt Distributor	7	0	7	0	7	0	7	0	7	0	7	0
Asphalt Relay Truck	7	0	7	0	7	0	7	0	7	0	7	0
Aggregate Spreader	4	0	4	0	4	0	4	0	4	0	4	0

EXHIBIT XI-17
(Continued)

Description	1972/73 Work-Days	1972/73 Units	1973/74 Work-Days	1973/74 Units	1974/75 Work-Days	1974/75 Units	1975/76 Work-Days	1975/76 Units	1976/77 Work-Days	1976/77 Units	1977/78 Work-Days	1977/78 Units
DISTRICT NO. 23 - COMBOLCIA												
Motor Grader	1,487	9	1,487	9	1,497	9	1,497	9	1,497	9	1,497	9
Dump Truck	3,845	23	3,845	23	4,035	24	4,035	24	4,035	24	4,035	24
Front End Loader	1,326	8	1,326	8	1,369	8	1,369	8	1,369	8	1,369	8
2.5 Ton Truck	348	2	348	2	359	3	359	3	359	3	359	3
Roller	1,091	7	1,091	7	1,340	8	1,340	8	1,340	8	1,340	8
Water Truck	315	2	315	2	315	2	315	2	315	2	315	2
Crawler Tractor	255	2	255	2	265	2	265	2	265	2	265	2
Asphalt Heater	532	3	532	3	562	3	562	3	562	2	562	3
Asphalt Distributor	122	1	122	1	132	1	132	1	132	1	132	1
Asphalt Relay Truck	122	1	122	1	132	1	132	1	132	1	132	1
Aggregate Spreader	112	1	112	1	121	1	121	1	121	1	121	1
DISTRICT NO. 24 - ADIGRAT												
Motor Grader	1,124	7	1,124	7	1,124	7	1,124	7	1,124	7	1,124	7
Dump Truck	2,508	15	2,508	15	2,508	15	2,508	15	2,508	15	2,508	15
Front End Loader	753	5	753	5	753	5	753	5	753	5	753	5
2.5 Ton Truck	259	1	259	1	259	1	259	1	259	1	259	1
Roller	946	6	946	6	946	6	946	6	946	6	946	6
Water Truck	220	2	220	2	220	2	220	2	220	2	220	2
Crawler Tractor	26	0	26	0	26	0	26	0	26	0	26	0
Asphalt Heater	312	2	312	2	312	2	312	2	312	2	312	2
Asphalt Distributor	75	1	75	1	75	1	75	1	75	1	75	1
Asphalt Relay Truck	75	1	75	1	75	1	75	1	75	1	75	1
Aggregate Spreader	110	1	110	1	110	1	110	1	110	1	110	1
DISTRICT NO. 25 - DEBRE MARKOS												
Motor Grader	1,157	7	1,157	7	1,157	7	1,255	8	1,361	8	1,361	8
Dump Truck	2,004	12	2,004	12	2,004	12	2,221	14	2,389	14	2,389	14
Front End Loader	452	3	452	3	452	3	484	3	518	4	518	4
2.5 Ton Truck	173	2	173	2	173	2	190	2	207	2	207	2
Roller	309	2	309	2	309	2	331	2	356	3	356	3
Water Truck	309	2	309	2	309	2	331	2	356	2	356	2
Crawler Tractor	--	--	--	--	--	--	--	--	--	--	--	--
Asphalt Heater	--	--	--	--	--	--	--	--	--	--	--	--
Asphalt Distributor	--	--	--	--	--	--	--	--	--	--	--	--
Asphalt Relay Truck	--	--	--	--	--	--	--	--	--	--	--	--
Aggregate Spreader	--	--	--	--	--	--	--	--	--	--	--	--

EXHIBIT XI-17
(Concluded)

Description	1972/73		1973/74		1974/75		1975/76		1976/77		1977/78	
	Work-Days	Units	Work-Days	Units	Work-Days	Units	Work-Days	Units	Work-Days	Units	Work-Days	Units
DISTRICT NO. 26 - DIRE DAWA												
Motor Grader	1,814	11	2,036	12	2,054	13	2,054	13	2,140	13	2,484	15
Dump Truck	3,298	20	3,943	24	4,117	25	4,117	25	4,258	26	4,948	30
Front End Loader	754	5	974	6	1,051	7	1,051	7	1,080	7	1,254	8
2.5 Ton Truck	279	2	341	2	358	3	358	3	375	3	458	3
Roller	436	3	699	5	786	5	786	5	806	5	976	6
Water Truck	394	3	446	3	446	3	446	3	466	3	550	4
Crawler Tractor	80	1	80	1	97	1	97	1	97	1	97	1
Asphalt Heater	48	1	145	1	198	1	198	1	198	1	236	1
Asphalt Distributor	0	0	54	1	71	1	71	1	71	1	83	1
Asphalt Relay Truck	0	0	54	1	71	1	71	1	71	1	83	1
Aggregate Spreader	14	0	44	1	61	1	61	1	61	1	61	1
DISTRICT NO. 27 - SHASHAMANE												
Motor Grader	2,432	15	2,559	15	2,831	17	3,495	21	3,595	22	3,471	21
Dump Truck	4,405	26	4,761	28	5,615	34	7,114	42	7,447	44	7,528	45
Front End Loader	1,078	7	1,124	7	1,380	9	1,801	11	1,921	12	2,004	12
2.5 Ton Truck	476	3	495	3	597	4	745	5	782	5	833	5
Roller	854	5	886	6	1,151	7	1,536	10	1,660	10	1,797	11
Water Truck	560	4	591	4	642	4	792	5	807	5	753	5
Crawler Tractor	19	1	19	1	19	1	44	1	61	1	61	1
Asphalt Heater	159	1	159	1	291	2	428	2	495	2	612	3
Asphalt Distributor	68	1	68	1	110	1	158	1	180	1	216	2
Asphalt Relay Truck	68	1	68	1	110	1	158	1	180	1	216	2
Aggregate Spreader	45	1	45	1	72	1	115	1	136	1	159	2
DISTRICT NO. 28 - JIMMA												
Motor Grader	1,365	8	1,558	10	1,436	9	1,406	9	1,338	8	1,167	7
Dump Truck	2,682	16	3,447	21	3,390	20	3,442	21	3,467	21	3,380	20
Front End Loader	606	4	852	5	895	6	930	6	988	6	1,027	7
2.5 Ton Truck	248	2	327	2	332	2	348	2	371	3	376	3
Roller	443	3	707	5	792	5	846	5	940	6	1,039	7
Water Truck	282	2	411	3	362	3	345	3	309	2	236	2
Crawler Tractor	0	0	0	0	0	0	0	0	0	0	0	0
Asphalt Heater	26	1	183	1	265	2	309	2	389	2	495	2
Asphalt Distributor	17	0	57	1	83	1	96	1	121	1	154	1
Asphalt Relay Truck	17	0	57	1	83	1	96	1	121	1	154	1
Aggregate Spreader	11	0	37	1	53	1	62	1	78	1	99	1

EXHIBIT XI-18

TOTAL EQUIPMENT UNITS REQUIRED FOR REGULAR MAINTENANCE
ALL RECOMMENDED ROADS

Description	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Motor Grader	94	99	103	106	105	104
Dump Truck	201	216	225	232	236	241
Front End Loader	61	63	69	74	78	80
2.5 Ton Truck	23	23	27	28	29	29
Roller	51	57	61	65	68	72
Water Truck	23	24	25	25	24	24
Crawler Tractor	8	8	8	8	8	8
Asphalt Heater	17	17	20	21	21	23
Asphalt Distributor	7	9	10	10	10	12
Asphalt Relay Truck	7	9	10	10	10	12
Aggregate Spreader	7	9	9	9	9	11

c. Additional for Rehabilitations

The equipment necessary to carry out the force account portions of the recommended rehabilitation projects is listed in Exhibit XI-19, by the appropriate Districts. The approximate date when the units would first be needed is also indicated, based on the adopted scheduling. Exhibit XI-19 also presents a summary of these needs.

As the rehabilitation projects were completed, this equipment would naturally become available for reassignment to regular maintenance. This factor is taken into account in the recommended equipment procurement described in Section XII. For several reasons, the availability factors developed for maintenance equipment were not applied to these units needed for rehabilitations. First, as will be seen later, this would lead to the acquisition of equipment which would subsequently be excess to the needs for regular maintenance. Second, it was believed that an optimistic view of in-service availability for the rehabilitation units could be partially justified by assuming that new equipment would be assigned to this work. Regarding the pavement restorations, this would be dictated by the urgency of the program and the necessity to coordinate with contractor's operations. Third, the tentative scheduling of the rehabilitation program included a fairly liberal allowance for lost time in general, and transfers of crews between individual projects. Part of this could be taken up in equipment down-time. Finally, in the gravel-road rehabilitations of the later program phases, delays for equipment repairs would stretch out the schedules, but this was considered preferable to increasing the equipment procurement for this specific, one-time effort.

3. Materials Requirements

a. Regular Maintenance

The common materials needed for road maintenance are of two kinds; Purchased and IHA-Produced. The main items of the first category are bitumens and portland cement. Cut stone (for masonry) and sand were also considered to be purchased materials in this study. All pit-run or processed gravels, and all crushed stone aggregates for

EXHIBIT XI-19

EQUIPMENT UNITS REQUIRED FOR REHABILITATIONS

Description	Units Required	Date Required
ALEMGENA DISTRICT		
Dump Truck	16	6 - July, 1973 10 - August, 1973
Motor Grader	3	3 - July, 1973
Crawler Tractor	2	1 - July, 1973 1 - October, 1973
Water Truck	2	2 - July, 1973
Front End Loader	4	1 - July, 1973 1 - August, 1973 2 - October, 1973
Roller	4	4 - July, 1973
COMBOLCIA DISTRICT		
Dump Truck	21	16 - July, 1973 5 - October, 1973
Motor Grader	4	3 - October, 1973 1 - November, 1973
Crawler Tractor	4	4 - July, 1973
Water Truck	4	2 - July, 1973 2 - October, 1973
Water Truck	4	2 - July, 1973 2 - October, 1973
Front End Loader	4	4 - July, 1973
Roller	8	2 - July, 1973 6 - October, 1973

EXHIBIT XI-19
(Continued)

Description	Units Required	Date Required
SHASHAMANE DISTRICT		
Dump Truck	17	11 - December, 1973 2 - February, 1974 4 - April 1974
Motor Grader	6	3 - July, 1973 3 - December, 1973
Crawler Tractor	1	1 - July, 1973
Water Truck	4	2 - July, 1973 2 - January, 1974
Front End Loader	4	1 - October, 1973 1 - February, 1974 2 - May, 1974
Roller	8	3 - July, 1973 1 - December, 1973 3 - February, 1974 1 - May, 1974
JIMMA DISTRICT		
Dump Trucks	12	12 - October, 1973
Motor Grader	3	2 - July, 1973 1 - October, 1973
Crawler Tractor	1	1 - July, 1973
Water Truck	2	2 - July, 1973
Front End Loader	2	2 - October, 1973
Roller	4	3 - July, 1973 1 - October, 1973

EXHIBIT XI-19
(Concluded)

SUMMARY: TOTAL EQUIPMENT UNITS REQUIRED FOR REHABILITATIONS

Description	Alemgena District No. 20	Combolcia District No. 23	Shashamane District No. 27	Jimma District No. 28	Total All Districts
Dump Truck	16	21	17	12	66
Motor Grader	3	4	6	3	16
Crawler Tractor	2	4	1	1	8
Water Truck	2	4	4	2	12
Front End Loader	4	4	4	2	14
Roller	4	8	8	4	24

normal maintenance, were assumed to be produced by IHA forces. One item, mixed asphaltic leveling course, consisted of purchased bitumen combined with IHA-produced aggregate, with the latter representing about 94 percent of the total weight.

The quantities of common materials required by Districts and by years are given in Exhibit XI-20, and are summarized in Exhibit XI-21.

b. Materials for Rehabilitations

The minimum-cost procedures for this program required that the pavement rehabilitations be divided into work of two kinds; some by contract and some by force account. The rehabilitations of gravel roads would cost less if done entirely by IHA forces. The materials quantities were determined separately for the two methods, within the normal limits of accuracy for preliminary cost estimates. Those to be supplied by contractors consisted mostly of bitumens and cover aggregates. The quantities of base and surface to be provided by the IHA were as follows:

Crushed Aggregate Base	261,400 m^3
Processed Select Material for Surfacing	661,300 m^3
Pit-Run Select Material for Subbase, Base or Surfacing	428,600 m^3

The prior estimates of labor and equipment for rehabilitations did not include the production of the above materials. Instead, it was assumed that they would be purchased. This is discussed in Section XII.

E. Financial Requirements

The operational expenditures necessary for the recommended maintenance and rehabilitation programs are those given previously in Paragraphs A-1 and A-2 of Section VIII. The rounded totals of the combined program costs, by years, are repeated below, expressed in 1972 Ethiopian dollars.

EXHIBIT XI-20

MATERIALS REQUIRED FOR REGULAR MAINTENANCE

Description	Units	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
ALEMGENA DISTRICT							
Seal Coat Bitumen	Ton*	669	687	750	887	958	1,039
Seal Coat Aggregate	M^3	15,556	15,973	16,628	20,884	22,621	24,503
Asphaltic Leveling Course	M^3	11,572	11,901	13,062	15,116	16,409	17,828
Leveling Course Tack Coat	Ton*	756	779	857	982	1,069	1,163
Pit-Run Select Material	M^3	72,137	72,754	84,793	96,568	99,080	101,798
Processed Select Material	M^3	175,777	188,904	174,598	135,319	115,157	93,392
Cut Stone	M^3	4,923	5,087	5,525	5,546	5,546	5,546
Sand	M^3	985	1,018	1,106	1,110	1,110	1,110
Cement (50-kg Bag)	Bag	2,954	3,053	3,316	3,329	3,329	3,329
ASMARA DISTRICT							
Seal Coat Bitumen	Ton*	1,483	1,483	1,483	1,483	1,483	1,483
Seal Coat Aggregate	M^3	9,426	9,426	9,426	9,426	9,426	9,426
Asphaltic Leveling Course	M^3	6,588	6,588	6,588	6,588	6,588	6,588
Leveling Course Tack Coat	Ton*	428	428	428	428	428	428
Pit-Run Select Material	M^3	20,938	20,938	23,596	23,596	26,323	26,323
Processed Select Material	M^3	42,544	42,544	42,544	42,544	42,544	42,544
Cut Stone	M^3	12,656	12,656	12,748	12,748	12,966	12,966
Sand	M^3	731	731	750	750	792	793
Cement (50-kg Bag)	Bag	2,193	2,193	2,249	2,249	2,380	2,380
GONDER DISTRICT							
Seal Coat Bitumen	Ton*	53	53	53	53	53	53
Seal Coat Aggregate	M^3	328	328	328	328	328	328
Asphaltic Leveling Course	M^3	274	274	274	274	274	274
Leveling Course Tack Coat	Ton*	16	16	16	16	16	16
Pit-Run Select Material	M^3	2,674	4,416	5,949	5,949	5,949	5,949
Processed Select Material	M^3	79,256	79,256	79,685	79,685	79,685	79,685
Cut Stone	M^3	1,389	1,538	1,871	1,871	1,871	1,871
Sand	M^3	278	306	374	374	374	374
Cement (50-kg Bag)	Bag	833	917	1,122	1,122	1,122	1,122

*Metric Ton

EXHIBIT XI-20
(Contined)

Description	Unit	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
COMBOLCIA DISTRICT							
Seal Coat Bitumen	Ton*	1,220	1,220	1,315	1,315	1,315	1,315
Seal Coat Aggregate	M^3	7,750	7,750	8,362	8,362	8,362	8,362
Asphaltic Leveling Course	M^3	2,776	2,776	2,895	2,895	2,895	2,895
Leveling Course Tack Coat	Ton*	86	86	88	88	88	88
Pit-Run Select Material	M^3	35,661	35,661	36,873	36,873	36,873	36,873
Processed Select Material	M^3	89,818	89,818	89,818	89,818	89,818	89,818
Cut Stone	M^3	2,126	2,126	2,211	2,211	2,211	2,211
Sand	M^3	425	425	442	442	442	442
Cement (50-kg Bag)	Bag	1,276	1,276	1,327	1,327	1,327	1,327
ADIGRAT DISTRICT							
Seal Coat Bitumen	Ton*	578	578	578	578	578	578
Seal Coat Aggregate	M^3	3,605	3,605	3,605	3,605	3,605	3,605
Asphaltic Leveling Course	M^3	2,949	2,949	2,949	2,949	2,949	2,949
Leveling Course Tack Coat	Ton*	182	182	182	182	182	182
Pit-Run Select Material	M^3	6,548	6,548	6,548	6,548	6,548	6,548
Processed Select Material	M^3	61,270	61,270	61,270	61,270	61,270	61,270
Cut Stone	M^3	1,662	1,662	1,662	1,662	1,662	1,662
Sand	M^3	332	332	332	332	332	332
Cement (50-kg Bag)	Bag	997	997	997	997	997	997
DEBRE MARKOS DISTRICT							
Seal Coat Bitumen	Ton*	0	0	0	0	0	0
Seal Coat Aggregate	M^3	0	0	0	0	0	0
Asphaltic Leveling Course	M^3	0	0	0	0	0	0
Leveling Course Tack Coat	Ton*	0	0	0	0	0	0
Pit-Run Select Material	M^3	9,005	9,005	9,005	15,312	22,168	22,168
Processed Select Material	M^3	78,932	78,932	78,932	78,932	78,932	78,932
Cut Stone	M^3	800	800	800	908	1,024	1,024
Sand	M^3	160	160	160	182	205	205
Cement (50-kg Bag)	Bag	419	419	419	474	535	535

*Metric Ton

EXHIBIT XI-20
(Concluded)

Description	Unit	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
DIRE DAWA DISTRICT							
Seal Coat Bitumen	Ton*	137	443	612	612	612	695
Seal Coat Aggregate	M^3	884	2,867	3,960	3,960	3,960	4,483
Asphaltic Leveling Course	M^3	662	1,184	1,396	1,396	1,396	1,805
Leveling Course Tack Coat	Ton*	49	67	69	69	69	97
Pit-Run Select Material	M^3	35,412	54,083	56,217	56,217	61,968	87,177
Processed Select Material	M^3	85,731	85,731	85,731	85,731	85,731	85,731
Cut Stone	M^3	1,733	2,251	2,382	2,382	2,492	3,292
Sand	M^3	347	450	476	476	498	658
Cement (50-kg Bag)	Bag	1,040	1,351	1,430	1,430	1,496	1,976
SHASHAMANE DISTRICT							
Seal Coat Bitumen	Ton*	460	460	752	1,175	1,387	1,647
Seal Coat Aggregate	M^3	2,964	2,964	4,817	7,559	8,933	10,573
Asphaltic Leveling Course	M^3	2,070	2,071	3,529	4,469	4,736	6,027
Leveling Course Tack Coat	Ton*	150	151	250	295	298	385
Pit-Run Select Material	M^3	28,787	37,716	54,755	73,443	80,375	102,726
Processed Select Material	M^3	134,974	134,974	134,974	163,945	163,945	109,275
Cut Stone	M^3	2,374	2,485	3,062	3,923	4,198	4,601
Sand	M^3	475	497	612	784	839	920
Cement (50-kg Bag)	Bag	1,424	1,491	1,837	2,353	2,518	2,760
JIMMA DISTRICT							
Seal Coat Bitumen	Ton*	125	280	406	473	595	758
Seal Coat Aggregate	M^3	788	1,769	2,569	2,993	3,768	4,797
Asphaltic Leveling Course	M^3	620	1,389	2,018	2,351	2,961	3,769
Leveling Course Tack Coat	Ton*	42	94	137	160	202	258
Pit-Run Select Material	M^3	7,845	17,486	18,637	23,980	31,731	38,525
Processed Select Material	M^3	102,065	102,065	88,287	78,664	62,011	39,637
Cut Stone	M^3	1,101	1,538	1,575	1,695	1,807	1,979
Sand	M^3	220	308	316	340	363	398
Cement (50-kg Bag)	Bag	661	923	945	1,017	1,084	1,187

*Metric Ton

EXHIBIT XI-21

MATERIALS REQUIRED FOR REGULAR MAINTENANCE
SUMMARY, ALL IHA DISTRICTS

Description	Unit	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Seal Coat Bitumen	Ton*	4,725	5,204	5,949	6,576	6,981	7,568
Seal Coat Aggregate	M^3	41,301	44,682	49,695	57,117	61,003	66,077
Asphaltic Leveling Course	M^3	27,511	29,132	32,711	36,038	38,208	42,135
Leveling Course Tack Coat	Ton*	1,709	1,803	2,027	2,220	2,352	2,617
Pit-Run Select Material	M^3	219,007	258,607	296,373	338,486	371,015	428,087
Processed Select Material	M^3	850,367	863,494	835,839	815,908	779,093	680,284
Cut Stone	M^3	28,764	30,143	31,836	2,946	33,777	35,152
Sand	M^3	3,953	4,227	4,568	4,790	4,956	5,232
Cement (50-kg Bag)	Bag	11,797	12,620	13,642	14,298	14,788	15,613

*Metric Ton

Fiscal Year		Combined Cost, Maintenance and Rehabilitations
Ethiopian	Gregorian	
1966	1973/74	$42,485,400
1967	1974/75	42,200,800
1968	1975/76	32,983,200
1969	1976/77	29,804,300
1970	1977/78	29,844,100

These figures are intended to provide for all the labor, equipment, material and direct overhead costs of carrying out the recommended programs, including equipment depreciations and contractual services. They do not include the maintenance branch portion of general IHA overheads (Addis Ababa headquarters), nor the capital expenditures necessary to initiate and support the programs. In Section XII, Programs and Budgets, the above costs are segregated on a line-item basis, with the equipment acquisitions quantified and added.

F. Foreign and Local Cost Components

1. Regular Maintenance

As a preliminary step in establishing the shadow price of maintenance, Section V-D of the report indicated that the financial costs of the program were made up of 20.5 percent labor, 10.7 percent materials, 39.6 percent plant and equipment, and 29.2 percent overheads.

All labor costs are, naturally, a local component. Materials were found to be 98.7 percent IHA-produced and 1.3 percent contract-purchased, or about 10.6 percent and 0.1 percent, respectively, of the overall total. According to the General Road Study, about three-quarters of the latter would be imported, representing 0.08 percent of overall maintenance.

The IHA-produced material costs were divided into 38.3 percent wages and 61.7 percent equipment utilization, which was in close agreement with the GRS findings. The 61.7 percent was made up of 22.2 percent depreciations (2.35 percent of overall maintenance) and 15.7 percent materials and spare parts for equipment, of which three-quarters would again be imported. Three-fourths of 15.7 percent times the 10.6 percent gave 1.25 percent of overall maintenance. The remainder of the 61.7 percent or 23.8 percent of IHA-materials, went for equipment repair wages and for fuels and lubricants.

Considering the 39.6 percent of maintenance costs devoted to plant and equipment, one-quarter was for depreciation, or 9.90 percent of the overall. Another 23.0 percent of this category was for spare parts and materials, of which three-quarters was again imported, giving 6.83 percent of overall maintenance costs. The rest of equipment costs was in repair wages, fuels and lubricants.

Within the overheads (29.2 percent of all maintenance) about 75 percent of one-twentieth of the category was estimated to be for imported supplies, indicating another 1.10 percent of overall financial cost.

Summing the various increments, it was estimated that approximately 21.5 percent of maintenance would be foreign costs, and the remaining 78.5 percent local.

2. Rehabilitation Projects

The total cost of the recommended program was about 19.2 percent contract work and 80.8 percent force account. However, if the aggregates necessary for the force account portion were to be contractor-produced, as recommended, the program percentages would change to 53.2 percent contract and 46.8 percent force account.

The work by IHA forces was considered to be equivalent to maintenance, with 21.5 percent foreign and 78.5 percent local components of cost.

The GRS report found that contract costs on Ethiopian Highways were around 28.4 percent foreign and 71.6 percent local for asphalt

projects, and 22.5 percent foreign to 77.5 percent local for gravel roads. Applying these to the approximate mix of work involved shows that, of the rehabilitation work to be done by contract, some 24.6 percent would represent foreign costs. For the combined program, it was calculated that 23.1 percent of all costs would be foreign in origin, and 76.9 percent would be local.

Section XII

PROGRAMS AND BUDGETS

The recommended programs of maintenance and highway rehabilitation have been carefully defined in preceding sections, their costs estimated, and details presented on the resources needed to carry them out. What remains is to discuss these in terms of action programs, with schedules, to compare existing resources with those that are required, and to present all the implied costs in budgetary form, for the individual years.

A. Scheduling of Maintenance Program

This was considered to be comprised of two separate parts; the conservation of the roads through regular and periodic activities, and the production and stockpiling of materials in support of those activities.

1. Regular Maintenance

In view of the present condition of the road system, it is recommended that the procedures and levels of effort described in this report be instituted as soon as practical. Full implementation would require the purchase of additional equipment, significant changes in staffing, completion of the District Shops, and the training of more personnel in some categories. It was apparent that few of these goals could be met by the end of the fiscal year in which the study was conducted, but equipment procurement and personnel training should be put in progress at the earliest date.

It was considered unlikely that all preparations could be made by the beginning of Fiscal Year 1973/74, and perhaps not even by the mid-point of the year, in January 1974. The obstacles would be formidable and the competing demands of the rehabilitation program severe during that initial period. Every effort should be made, however; delay would clearly result in further deterioration of the roads. Implementation should be energetic and the necessary action taken to insure that the program would be fully effective not later than July, 1974.

2. Materials Production

One serious impediment to putting the maintenance program in full force is the uncertainty regarding the best means of providing gravel surfacing for Type 3 and 4 roads. It was seen in Exhibit XI-21 of the preceding section that the crushed stone aggregates for periodic asphalt maintenance total about 78,000 m^3 in 1973/74 (with the leveling-course stone expanded to loose volume). This quantity can be provided by 6 of the existing ten crushing and screening plants (50 TPH) operating at reasonable efficiency, leaving 4 plants available to produce gravel surfacing.

Exhibit XI-21 further showed the need for roughly 1,000,000 m^3 of processed select material in the same year (loose volume), all of which would be used for surfacing on the Type 3 and 4 roads. Another 300,000 m^3 of pit-run select would be required for the surfaces of Type 5 and 6 roads, and for shoulder maintenance on asphalt highways.

It was estimated conservatively that the 4 present crushing and screening plants not needed for asphalt-road aggregates could stockpile about 200,000 m^3 annually of processed select. This was based on a production rate of 180 m^3 in a 5-1/2 hour day (giving substantial allowance for equipment down-time) and 274 work-days per year. To provide the volume for a single road section with reasonable haul distances (assumed to be 60 km total length, or 15 km average haul), each plant would have to remain at one location for well over a year, so the annual time loss for moving between sites would be negligible.

In developing the per-kilometer annual maintenance costs for high-type gravel roads, it was assumed that select material would have to be used for the surfaces, and that the material would continue to come from the present known sources. However, it was considered essential to process this pit-run stone to obtain an acceptable gradation and normal vehicle operating costs. The unit cost of surfacing was predicated on the use of 75 ton per hour plants, as a compromise between present equipment and the larger, high-capacity plants which were under consideration. The daily production of processed select from the 75-ton

plant was conservatively estimated at 240 m^3. To stockpile the additional 800,000 m^3 of processed surfacing needed each year would require 12 such plants, with their auxiliary equipment. The acquisition cost for the crushers alone, without the necessary tractors, loaders and other units, would be on the order of E$4,800,000.

Plants rated at 225 tons per hour were estimated to have a daily capacity of 1,180 m^3 in processing select material. Such plants would have to be moved about 3 times annually, reducing working days from 274 to around 244. Three of these units would then be needed to stockpile the 800,000 m^3, at an estimated procurement cost of E$2,100,000 (plants only). In this case the investment would still be large, and the material cost would continue to be abnormally high for the maintenance of gravel roads, though considerably less than the unit prices from the smaller plants.

Section III-H of the report discusses a possible means of lowering gravel-road maintenance costs to more normal limits, by conducting an organized search for better natural materials. These would presumably be gravels, volcanic cinders or other deposits of acceptable gradation which would not require processing, or only non-mechanical treatment to remove oversize stone. It was considered reasonable to expect that such a search should be successful in discovering granular materials to take care of some 65 percent of the total length of Type 3 and 4 roads. If this expectation were realized, the annual requirement for processed select material would be reduced to 350,000 m^3. Deducting the 200,000 m^3 which could be supplied by the 4 existing 50-ton plants would leave a 150,000 m^3 processing requirement. This quantity would be less than the capacity of a single 225-ton plant, but more than could be produced by two 75-ton crushers. The Consultants concluded, in these circumstances, that the most logical course of action would be to proceed immediately with the acquisition of one 225 ton per hour plant, with its auxiliary equipment, and to simultaneously start a program of materials exploration and research along the principal gravel roads.

The discovery of suitable natural gravels for 65 percent of the Type 3 and 4 roads would then require the extraction of about 650,000 m^3 annually of pit-run materials. It was assumed that this exploitation (stockpiling) would usually be done with crawler tractors, as at present. At an assumed daily production of 130 m^3 for 5-1/2 hours, which would again make some allowance for down time, 5,000 dozer-days per year would be needed. Using 274 working days per year, 18 tractors would be required for this purpose alone.

The acquisition of these dozers is not recommended at this time. In the first place, if the materials search is not successful, or to the extent that it is not successful, the IHA will have no choice but to acquire more crushers, if good gradation material is to be provided for the roads. Secondly, the nature of materials discovered might dictate the use of heavy front-end loaders, or crawler or truck-mounted shovels in place of tractors for the extraction of natural gravels. A decision on types and numbers of equipment should therefore be deferred until the exploration program is completed.

Regardless of the solution finally adopted for the principal gravel roads, there is the separate need for about 300,000 m^3 of lower-quality (pit-run) material to maintain the Type 5 and 6 roads and asphalt-highway shoulders (in the year 1973/74). This indicates the need for 8 or 9 crawler tractors, and the immediate provision of 8 is recommended for this program.

New equipment acquisitions in general are discussed later in this section, but it should be clear from the foregoing that the majority of machine requirements for materials production cannot be quantified at this time. A supplemental procurement will have to be defined at a later date.

B. Scheduling of Rehabilitations

Because of the urgency of this work, it is recommended that the program be started in July, 1973, in all four of the districts involved, and be prosecuted continuously until its completion in about April of 1976. Compliance with this timing will depend on the provision of funds,

the arrival of equipment, and the efficient marshalling of all resources, but the need to begin is compelling.

1. Work Programs

The locations, types and quantities of rehabilitation work have been described previously, with estimates of cost and examinations of the economic viability of the projects. Exhibits XII-1 through XII-4 offer a tentative scheduling of the necessary operations, with the force account and contract phases identified separately. It is evident that work should begin immediately on the preparation of such simple plans and standard specifications as would be necessary for the contract portions.

2. Materials

It was indicated in Sections VI and XI that large volumes of granular materials would be employed in the force account phases of the rehabilitation projects, as follows:

Crushed aggregate base	261,400 m^3
Processed select material for surfacing	661,300 m^3
Pit-run select material for subbase, base and surfacing	428,600 m^3

Plainly, it will not be possible for the IHA to produce these quantities with its own facilities, and if new equipment units were acquired for the purpose there is no assurance that they would subsequently be of the right types and numbers for use in regular maintenance. Further, it would hardly be practical for the Maintenance Branch to assemble the machines and trained personnel for this production capacity simultaneously with a materials program of similar magnitude for routine operations. The Consultants recommend that the furnishing of these rehabilitation materials be advertised for bid, to be stockpiled at suitable locations. Preparations for these contract purchases should begin at once.

ALEMGENA DISTRICT

WORKING ITEMS	WORKING DAYS	METHOD
ROUTE NO. 5 ADDIS ABABA – AGREHIWOT		
REMOVE BASE FAILURES SCARIFY ROADBED AND SHOULDERS PLACE CRUSHED AGGREGATE BASE	95	IHA
LEVELING COURSE TACK COAT PLACE LEVELING COURSE	135	CONTRACT
PLACE SEAL COAT	35	CONTRACT
PLACE DOUBLE SURFACE TREATMENT	85	CONTRACT
ROUTE NO. 7 ADDIS ABABA – WELKITE		
REMOVE BASE FAILURES SCARIFY ROADBED AND SHOULDERS PLACE SELECT EMBANKMENT MATERIAL PLACE CRUSHED AGGREGATE BASE	75	IHA
LEVELING COURSE TACK COAT PLACE LEVELING COURSE	20	CONTRACT
PLACE SEAL COAT	30	CONTRACT
PLACE DOUBLE SURFACE TREATMENT	75	CONTRACT
ROUTE NO. 1 ADDIS ABABA – DEBRE BERHAN		
REMOVE BASE FAILURES SCARIFY ROADBED AND SHOULDERS PLACE CRUSHED AGGREGATE BASE	165	IHA
LEVELING COURSE TACK COAT PLACE LEVELING COURSE	70	CONTRACT
PLACE SEAL COAT	20	CONTRACT
PLACE DOUBLE SURFACE TREATMENT	120	CONTRACT

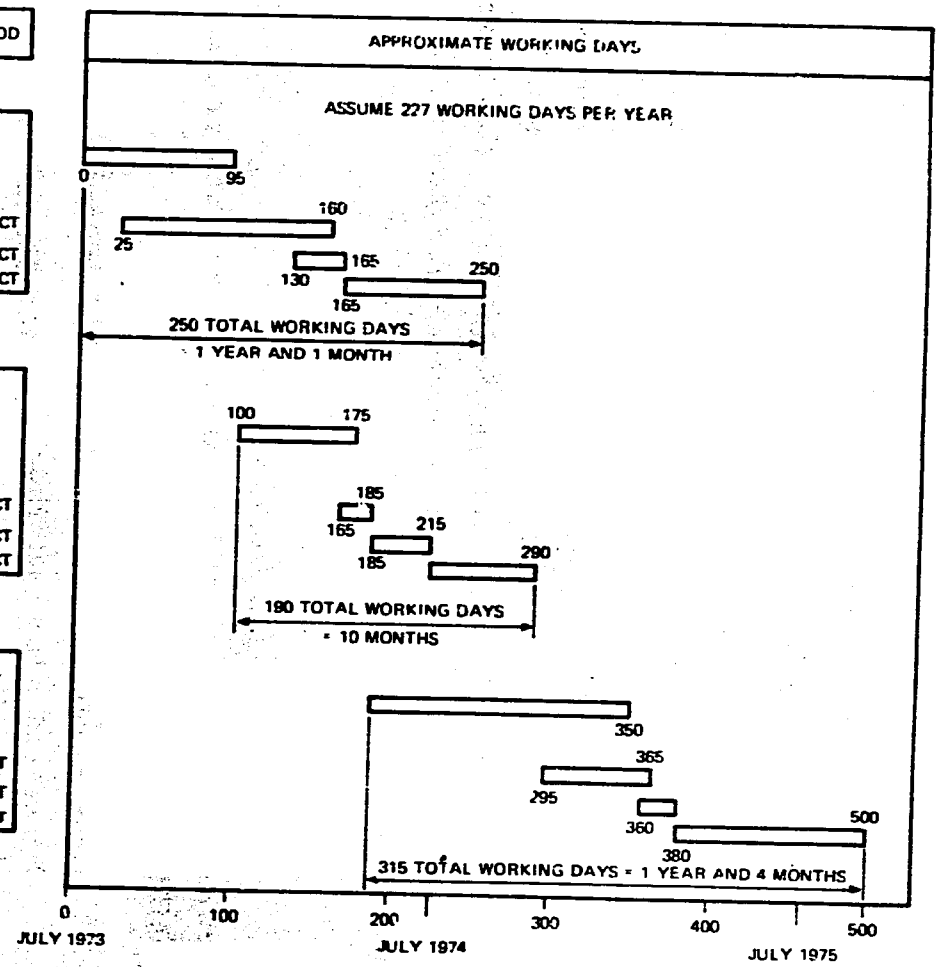

EXHIBIT XII-1 TENTATIVE SCHEDULE OF REHABILITATION PROJECTS

COMBOLCIA DISTRICT

WORK ITEMS	WORKING DAYS	METHOD
ROUTE NO. 2, TENDAHO – ASSEB		
REMOVE BASE FAILURES PLACE CRUSHED AGGREGATE	130	IHA
LEVELING COURSE TACK COAT PLACE LEVELING COURSE	155	CONTRACT
PLACE SEAL COAT	65	CONTRACT
ROUTE NO. 1, TARMABER – WOLDIA		
SCARIFY ROADBED AND SHOULDERS	240	IHA
PLACE PIT-RUN SELECT BASE	210	IHA
PLACE PROCESSED SELECT SURFACE	250	IHA

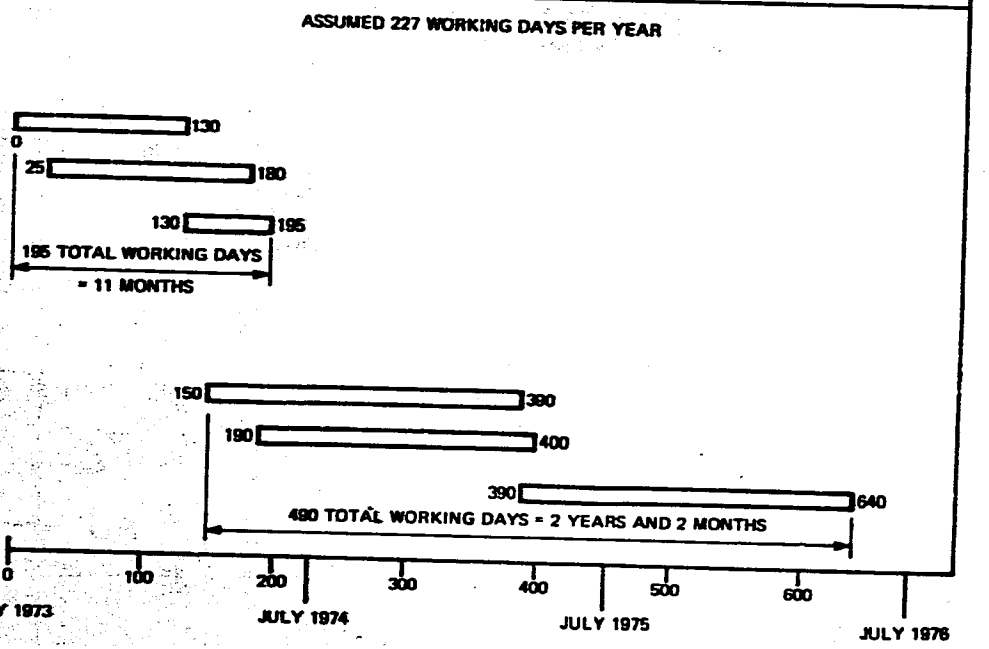

EXHIBIT XII-2 TENTATIVE SCHEDULE OF REHABILITATION PROJECTS, COMBOLCIA DISTRICT

SHASHAMANE DISTRICT

WORK ITEMS	WORKING DAYS	METHOD
ROUTE NO. 41, SHASHAMANE – SODD		
SCARIFY ROADBED AND SHOULDERS	120	I.H.A.
PLACE PIT-RUN SELECT BASE	60	I.H.A.
PLACE PROCESSED SELECT SURFACE	120	I.H.A.
ROUTE NO. 40, SHASHAMANE – KOFOLE		
SCARIFY ROADBED AND SHOULDERS	75	I.H.A.
PLACE PIT-RUN SELECT BASE	150	I.H.A.
PLACE SELECT MATERIAL SURFACE	30	I.H.A.
ROUTE NO. 44, WONDO – KEBREMEGIST		
SCARIFY ROADBED AND SHOULDERS	95	I.H.A.
PLACE PIT-RUN SELECT BASE	60	I.H.A.
PLACE PROCESSED SELECT SURFACE	160	I.H.A.

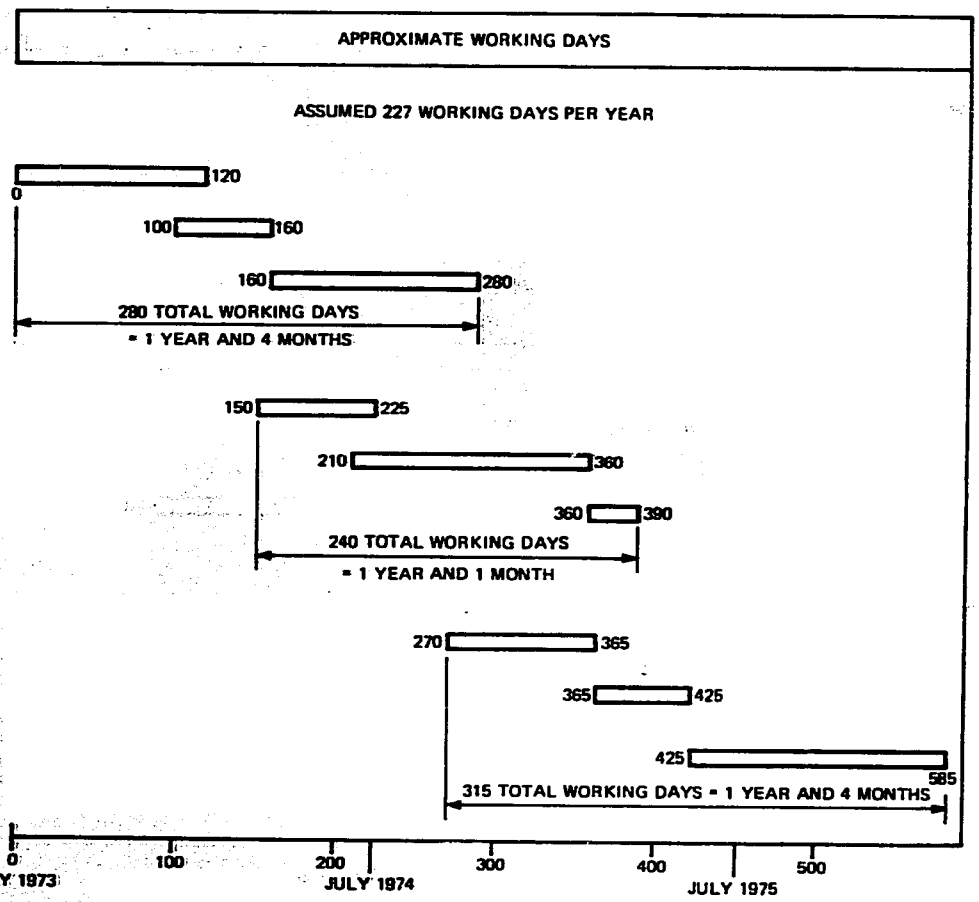

EXHIBIT XII-3 TENTATIVE SCHEDULE OF REHABILITATION PROJECTS, SHASHAMANE DISTRICT

JIMMA DISTRICT

ROUTE NO. 7 JIMMA – BONGA JUNCTION

WORK ITEMS	WORKING DAYS	METHOD
SCARIFY ROADBED AND SHOULDERS	75	IHA
PLACE PIT-RUN SELECT BASE	150	IHA
PLACE PROCESSED SELECT SURFACE	150	IHA

ASSUMED 227 WORKING DAYS PER YEAR

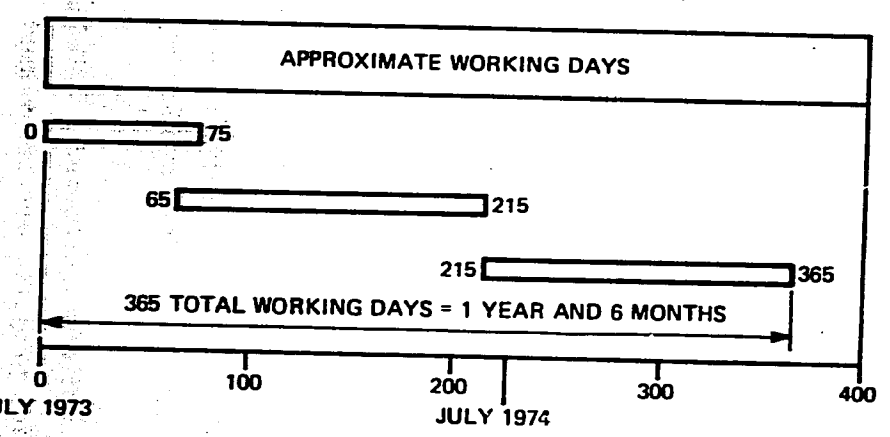

EXHIBIT XII-4 TENTATIVE SCHEDULE OF REHABILITATION PROJECTS, JIMMA DISTRICT

C. Comparisons of Existing and Required Resources

Possible revisions in maintenance staffing and the scheduling of capital expenditures for new equipment would be indicated by comparing the quantified needs with existing resources in these two categories. This was done by assembling the necessary data in tables which would permit evaluations, and offer a guide to action.

1. Personnel

Exhibit XII-5 presents figures on the labor force required in the first program year, 1973/74, to the extent that these needs are defined by the study procedures. The numbers of personnel are given separately for regular maintenance, rehabilitations, and materials production, and then in a combined total. Also shown are the numbers officially authorized (Maintenance Branch only) and those actually employed in the corresponding classifications for the current year, 1972/73.

Obviously, the total initial requirements will be somewhat reduced as the rehabilitation projects are completed. The regular maintenance forces, however, will have to increase gradually as the system grows. The latter changes can be seen on Exhibit XI-10.

Considering the positions individually, requirements compared with present staff, there will be an immediate shortage of 13 Construction Foremen. These are required primarily for the direction of asphalt seal coating and periodic gravel resurfacing by sizable crews, and failure to fill these posts would have serious effects. Eight new Construction Foremen for maintenance should be trained or recruited by whatever means are available. The five needed for the rehabilitation projects might be "borrowed" from other branches or divisions of the IHA, or consulting services might be substituted in that program.

An initial excess of Labor Foremen is indicated, but this will disappear by 1975 as maintenance needs rise.

There is a small deficiency in Mason Foremen (3), which might be ignored if present operations are satisfactory. Otherwise, the correction of this should not present difficulty.

An excess shows in the Mason II category, but a deficiency in the Mason I. Obviously, the higher grades can substitute for the lower, at some increase in program costs. Additional Mason I's should be hired.

Large excess numbers are indicated in all 3 labor titles, and future expansion of the road system will do little to correct this. Two factors offer partial explanations for these differences. First, 6 laborer II's and 81 laborer I's are assigned to general, non-operational work in the District Headquarters and warehouses, and are therefore covered by overheads. Second, labor forces have necessarily been increased in recent years to make up, in part, for shortages of equipment. The condition of the roads indicates that this has not been a satisfactory alternative, but probably there was little choice. This situation will continue until equipment needs are fully met, but it appears that the labor complement should be gradually reduced.

Exhibit XII-5 shows a number of excess crusher operators, and 2 extra quarry foremen. There is a deficiency in quarry supervisors and in the Helper I and Driller I classifications. All are related to the materials program which cannot be fully defined, so no firm conclusions can be drawn.

Initially, there are 5 more grader operators than necessary. By mid-1976 this number would be absorbed by maintenance needs, but the completion of rehabilitations will have released 16. Some of these should be shifted to other equipment types.

The Helper II title was used by the Consultants to identify grader operators assistants and the levermen for asphalt distributors and relay trucks. These are substantially in excess now as a class, and will become more so in 1975/76. Some of these employees should also be re-trained for other positions.

Truck drivers were divided into three classes in the study; those for dump trucks, water trucks, and for flat-beds (or older, small-size

EXHIBIT XII-5

COMPARISON, TOTAL IHA MANPOWER REQUIREMENTS FOR 1973/73 WITH EXISTING PERSONNEL, 1972/73

Position	Requirement				Authorized Force	Deficiency or (Excess)	Present Staff	Deficiency or (Excess)
	Regular Maintenance	Rehabilitation	Materials Program	Total				
Construction Foreman	17	5	0	22	4	18	9	13
Labor Foreman	108	10	15	133	197	(64)	145	(12)
Mason Foreman	8	0	0	8	9	(1)	5	3
Mason II	23	0	0	23	71	(48)	43	(20)
Mason I	40	0	0	40	--	40	--	40
Laborer II	63	12	0	75	629	(554)	540	(465)
Laborer I	285	0	28	313	1,533	(1,220)	1,358	(1,045)
Contract Laborer	618	64	66	748	--*	--	1,885**	(1,137)
Crusher Operator	0	0	12	12	48	(36)	36	(24)
Grader Operator	74	16	0	90	102	(12)	95	(5)
Dump Truck Driver	162	66	-20	248	362	(114)	261	(13)
Truck Driver	20	0	0	20	9	11	6	14
Water Truck Driver	19	12	0	31	12	19	9	22
Roller Operator	42	24	0	66	62	4	26	40
Asphalt Distributor Operator	6	0	0	6	6	--	6	--
Asphalt Relay Truck Operator	6	0	0	6	7	(1)	6	--
Dozer Operator	6	8	22	36	19	17	19	17
Loader Operator	48	14	18	80	52	28	24	56
Quarry Supervisor	0	0	7	7	0	7	0	7
Quarry Foreman	0	0	11	11	17	(6)	13	(2)
Driller I	0	0	8	8	17	(9)	6	2
Powder Man	0	0	7	7	44	(37)	7	--
Helper I	0	0	5	5	--	5	--	5
Helper II	62	16	8	86	120	(34)	110	(24)

*Authorized "as needed"
**Average during year

dump trucks) used to transport small work crews and their materials. For the 3 groups, there is a net deficiency of 23 drivers in the first year. Maintenance growth would increase this to a shortage of 40 by the beginning of 1976/77, except that 66 will have been freed from the force account rehabilitations, resulting in an overage of 26. A partial solution to the early shortage is discussed later under equipment procurement.

If the recommended programs are put into effect there will be an immediate and critical shortage of operators for loaders, rollers and, to a lesser extent, dozers. While it is true that large numbers of all 3 classifications will be released after the rehabilitations, much of the resulting excess could be absorbed by regular maintenance and, especially, a fully developed materials program. Steps should be taken at once to train these operators.

The numbers of drivers required, authorized and now employed for the operation of asphalt distributors and relay trucks are all in good agreement.

2. Equipment

Exhibit XII-6 is a compilation of all relevant data on equipment, as viewed by the Consultants. The requirements by types are presented, separately for the different programs and for each of the five years 1973/74 through 1977/78. Following this, the existing fleet is shown, then the deficiency or excess of units, and finally the recommended procurement. The recommended purchase figures are intended to mean for delivery at the beginning of the fiscal year in which they are shown, to the extent that initial time and funding limitations will permit. For the years after 1973/74, the existing fleet is shown in two components, old and new. The "old" equipment is that shown in the appropriate-year columns of Exhibit VIII-20; that is, presently-owned units (1972/73) expected to remain in service. The "new" equipment figures assume that the recommended acquisitions of prior years have been made. If any recommended procurement cannot be made, or the units are not delivered, the "existing fleet" of the following year will be decreased by

EXHIBIT XII-6

COMBINED EQUIPMENT REQUIREMENTS
MAINTENANCE REHABILITATION AND MATERIALS PROGRAMS
Fiscal Years 1973/74 Through 1977/78

	Motor Grader	Dump Truck	Loader	2-1/2 Ton Truck	Roller	Water Truck	Crawler Tractor	Asphalt Heater	Asphalt Distributor
1973/74									
Requirements									
Maintenance	99	212	60	23	53	22	8	17	9
Rehabilitations	16	66	14	0	24	12	8	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/0	227/0	25/0	0/0	17/0	0/0	14/0	67/0	8/0
Deficiency or (Excess)	41	71	67	23	60	34	17	(50)	1
Recommended Purchase	40	70	65	15	60	30	15	0	1
1974/75									
Requirements									
Maintenance	103	225	64	27	61	29	8	20	10
Rehabilitations	12	66	14	0	24	12	6	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	183/70	25/65	0/15	17/60	0/30	14/15	61/0	8/1
Deficiency or (Excess)	1	58	6	12	8	11	0	(41)	1
Recommended Purchase	0	40	6	10	0	0	0	0	1
1975/76									
Requirements									
Maintenance	106	232	70	28	65	25	8	21	10
Rehabilitations	9	40	14	0	10	8	2	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/110	19/71	0/25	17/60	0/30	13/15	55/0	8/2
Deficiency or (Excess)	1	43	12	3	(2)	3	(3)	(34)	0
Recommended Purchase	0	10	12	0	0	0	0	0	0
1976/77									
Requirements									
Maintenance	105	236	79	29	68	24	8	21	10
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/120	13/83	0/25	17/60	0/30	11/15	49/0	8/2
Deficiency or (Excess)	(9)	(3)	1	4	(9)	(6)	(3)	(28)	0
Recommended Purchase	0	0	0	0	0	0	0	0	0
1977/78									
Requirements									
Maintenance	104	241	80	29	72	24	8	23	12
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/120	13/83	0/25	17/60	0/30	10/15	49/0	8/2
Deficiency or (Excess)	(10)	2	2	4	(5)	(6)	(2)	(26)	2
Recommended Purchase	0	0	2	0	0	0	0	0	2

EXHIBIT XII-6
(Continued)

	Asphalt Relay Truck	Aggregate Spreader	Conveyor	Compressor 600 C.F.M.	Wagon Drill	Crushing 225 T.P.H.	Screening Plants 50 T.P.H.	Truck Tractor and Trailer
1973/74								
Requirements								
Maintenance	9	9	0	0	0	1	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/0	8/0	0/0	21/0	6/0	0/0	10/0	7/0
Deficiency or (Excess)	7	1	4	(9	6	1	0	0
Recommended Purchase	7	2	4	0	6	1	0	5
1974/75								
Requirements								
Maintenance	10	9	0	0	0	0	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/7	8/2	0/4	17/0	6/6	0/1	10/0	5/5
Deficiency or (Excess)	1	(1	0	(5	0	0	0	0
Recommended Purchase	1	0	0	0	0	0	0	5
1975/76								
Requirements								
Maintenance	10	9	0	0	0	0	10	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/8	8/2	0/4	14/0	5/6	0/1	10/0	3/10
Deficiency or (Excess)	0	(1	0	(2	1	0	0	0
Recommended Purchase	0	0	0	0	1	0	0	0
1976/77								
Requirements								
Maintenance	10	9	0	0	0	0	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/8	8/2	0/4	11/0	5/7	0/1	10/0	3/10
Deficiency or (Excess)	0	(1	0	1	0	0	0	0
Recommended Purchase	0	0	0	1	0	0	0	0
1977/78								
Requirements								
Maintenance	12	11	0	0	0	0	0	--
Rehabilitations	0	0	0	0	0	0	0	0
Materials	0	0	4	12	12	1	10	0
Existing Fleet; Old/New	2/8	8/2	0/4	11/1	5/7	0/1	10/0	3/10
Deficiency or (Excess)	2	1	0	0	0	0	0	0
Recommended Purchase	2	1	0	0	0	0	0	0

the numbers of units not acquired or delivered, and the deficiency or excess will change accordingly.

Exhibit XII-6 shows that 115 motor graders are needed in each of the first three program years (with varying proportions between maintenance and rehabilitation), decreasing to 104 units in the fifth year. Seventy-four are expected to be available from the existing fleet in 1973/74, leaving a shortage of 41. In order to carry out the programmed work, 40 new graders should be delivered by July 8, 1973. The Consultants felt that the continuing shortage of one machine should be accepted through 1975/76 because, as the exhibit shows, there will be an excess of graders in the final two years.

The total number of dump trucks required is 298 in 1973/74, with 227 existing units still serviceable if adequate parts and repair facilities are provided. The required number increases to 311 in 1974/75, then declines for two years (to 292 and 256), and finally increases again as maintenance needs continue to rise. It is recommended that 70 be acquired at the beginning of 1973/74, and another 40 for the start of Fiscal 1974/75. This procurement would still leave a deficiency of 18 units in the second year. It is the opinion of the Consultants that this deficiency should be met by contract hauling, preferably on the rehabilitation projects. This course would serve the double purpose of avoiding a large excess of dump trucks in the last two program years, and of alleviating the temporary shortage of truck drivers which was indicated in Section XII-C-1. Contract hauling should be increased to the equivalent of 33 trucks in 1975/76, to complete the rehabilitations, but 10 new dump trucks should also be purchased for delivery at the beginning of that year.

Exhibit XII-6 indicates a heavy and persistent demand for front-end loaders (of intermediate size), with a critical deficit in the first year. The needs quantified for the rehabilitation and interim materials programs are stable through their 3- and 5-year periods, respectively, but those for maintenance increase. Twelve units presently in use will go out of service by 1976/77. The Consultants recommend that 65 loaders be bought for 1973/74, another 6 for the succeeding year, 12

for 1975/76 and 2 more for delivery at the start of 1977/78. This acquisition schedule would meet all requirements except for a shortage of 2 in the first year, and is considered to be justified because of the importance of this tool to most other operations. Furthermore, it is probable that the resolution of the materials production program will add to the need for loaders, and there is little possibility of an excess.

In reviewing current maintenance practices in Ethiopia, the conclusion was reached that the use of smaller trucks should be introduced for the specific purpose of transporting work crews, hand tools and materials. In prior years, when 3 and 4 cubic-yard dump trucks were the common size, there was good reason to use these for general purposes and not buy special vehicles for transport. Now, however, the standardization on units of about 6 m^3 capacity makes it uneconomical to continue this dual usage, and the volume of masonry work, hand ditch cleaning and similar labor-crew activities justifies the acquisition of some units better fitted for this function. Exhibit XII-6 shows a need for from 23 to 29 such trucks, depending on the year. There are none in the existing fleet, but the recommended procurement is limited to 15 for 1973/74 and another 10 for the following year. Since this is relatively light duty, it was assumed that some older dump trucks of the present fleet might be used to make up the deficit.

There is a large shortage of rollers in the 5 to 8 ton and heavier sizes, and the Consultants felt that 60 should be acquired for the initial program year. Eight more would be needed in the second year, but their purchase would result in rather large excess numbers after the rehabilitation projects were done. It was considered preferable to fill this short term need by rental, if feasible, or by temporary transfer of units from the Direct Labour Branch or other agencies.

The few water trucks now owned by the IHA are used exclusively for hauling domestic water to camps and other locations, but the proper compaction of material in extensive base and surface work demands that water trucks be available for moisture control. Thirty-four are needed in 1973/74, and a minimum of 30 should be purchased. This will still

leave a deficiency of eleven units in 1974/75 and 3 in the succeeding year, but no procurement beyond the 30 is recommended because the requirement declines and an excess of 6 trucks appears in the last 2 years.

Most of the need for new crawler tractors can be met by the recommended purchase of 15 for the first program year. A shortage of 2 would still exist in that year, but this would disappear in 1974/75, and become an excess of 2 to 3 units during the rest of the program period.

Exhibit XII-6 shows that the existing number of asphalt heaters will meet all requirements throughout the five years, without new purchases. One additional asphalt distributor truck should be acquired for 1973/74, another for 1974/75, and a final 2 units for the last program year. The deficiency in asphalt relay trucks is greater, according to data supplied to the Consultants, with 7 new units to be provided for 1973/74, one more for 1974/75, and 2 for 1977/78. The quantification process showed that one additional aggregate spreader would fill the requirements during the first four years, but the purchase of two is recommended to provide at least one with each distributor truck. A third new chip spreader should be on hand at the start of 1977/78.

Various capital acquisitions are recommended for the interim materials program, the main item being one large plant for aggregate production. For the purpose of estimating an approximate cost, this was assumed to consist of a jaw-type primary crusher and a separate, gyratory secondary, each semi-portable with an integral power source. The rated capacity of about 225 tons per hour would be fixed by the secondary crusher, with the primary adequate in size to feed that unit under the most adverse conditions which might logically be expected with regard to the size and hardness of material to be handled. The estimated total plant cost included the necessary attachments and conveyors, but not auxiliary units such as dozers, loaders and so on.

It is recommended that 4 small, self-powered belt conveyors be purchased for use in 1973/74, in conjunction with the existing 50 ton

per hour crushers which would be assigned to processing select material.

The presently owned IHA air compressors are mostly of smaller capacity that the 600 C.F.M. unit that was used as a standard. Their total rated capacities were converted to equivalent 600 C.F.M. units by simple arithmetic. This provided a basis for comparing needs with existing resources, and indicated that no new purchases would be necessary until 1976/77. However, the smaller existing units may not actually be efficient or satisfactory for quarry operations, and many of them are no doubt used for slide clean-up, minor betterments and other work not quantified in the study. The compressor requirements should be reviewed in more detail by the Supply and Equipment Division.

Exhibit XII-6 indicates that 6 wagon drills should be acquired for use in 1973/74, and another for 1975/76.

Repeating the information conveyed in Section XI, the resource needs described for materials production would supply all aggregates needed for the regular maintenance of asphalt roads, but only about 35 percent of the controlled-gradation surfacing which must be supplied for Type 3 and 4 gravel roads. The capital outlay indicated above will have to be increased substantially as soon as the best course can be determined.

Finally, the last column of Exhibit XII-6 gives the Consultants' views on the needs for truck-tractors and lowboy trailers, considered as combined units. Those of the existing fleet are generally old and in poor condition. The recommendation is that 5 new combinations be acquired for 1973/74 and 5 more for the succeeding year.

3. Recommended Acquisitions

All of the foregoing recommended purchases are shown in Exhibit XII-7, by years, with the estimated unit prices and total procurement costs. An additional 15 percent is added for spare parts in each year's total. Exhibit XII-8 gives a summary for the five years.

EXHIBIT XII-7

RECOMMENDED EQUIPMENT PROCUREMENT UNITS
ESTIMATED PRICES AND TOTAL COST
(1972 E$)

Description	Total Units	Unit Price E$	Total Cost E$
1973/74			
Motor Grader	40	75,600	3,024,000
Dump Truck	70	60,000	4,200,000
Front End Loader	65	75,000	4,875,000
2.5 Ton Truck	15	27,000	405,000
Roller	60	51,500	3,090,000
Water Truck	30	75,000	2,250,000
Crawler Tractor	15	110,100	1,651,500
Asphalt Distributor	1	76,500	76,500
Asphalt Relay Truck	7	56,500	395,500
Aggregate Spreader	2	15,900	31,800
Conveyors	4	18,000	720,000
Wagon Drill	6	30,000	180,000
225 T.P.H. Crushing and Screening Plant	1	700,000	700,000
Truck-Tractor and Trailer	5	180,000	900,000
Subtotal			E$22,499,300
Spare Parts @15%			3,374,895
Total			E$25,874,195
1974/75			
Dump Truck	40	60,000	2,400,000
Front End Loader	6	75,000	450,000
2.5 Ton Truck	10	27,000	270,000
Asphalt Distributor	1	76,500	76,500
Asphalt Relay Truck	1	56,500	56,500
Truck Tractor and Trailer	5	180,000	900,000
Subtotal			E$ 4,153,000
Spare Parts @15%			622,950
Total			E$ 4,775,950

EXHIBIT XII-7
(Continued)

Description	Total Units	Unit Price E$	Total Cost E$
1975/76			
Dump Truck	10	60,000	600,000
Front End Loader	12	75,000	900,000
Wagon Drill	1	30,000	30,000
Subtotal			E$1,530,000
Spare Parts @15%			229,500
Total			E$1,759,500
1976/77			
Compressor, 600 C.F.M.	1	65,000	65,000
Subtotal			E$ 65,000
Spare Parts @15%			9,750
Total			E$ 74,750
1977/78			
Front End Loader	2	75,000	150,000
Asphalt Distributor	2	76,500	153,000
Asphalt Relay Truck	2	56,500	113,000
Aggregate Spreader	1	15,900	15,900
Subtotal			E$ 431,900
Spare Parts @15%			64,785
Total			E$ 496,685

EXHIBIT XII-8

SUMMARY
RECOMMENDED EQUIPMENT PROCUREMENT
Total Cost by Years in 1972 Ethiopian Dollars

Fiscal Year	Amount
1973/74	E$25,874,195
1974/75	4,775,950
1975/76	1,759,500
1976/77	74,750
1977/78	496,685
Combined Total Cost	E$32,981,080

D. Emergency Procurement

All of the equipment needs defined above would seem to fit the definition of "Urgent", but in view of the large capital cost for the initial year there may be a need to establish relative priorities.

1. Equipment

The existing IHA-maintained highway system (1972/73) is generally in a deteriorated state, as established by the condition ratings of the individual segments. Those sections with the poorest ratings were, by definition, taken to be the ones most urgently in need of attention, and were evaluated for rehabilitation. It follows, therefore, that the equipment needed to carry out the force account portions of the rehabilitation program should have the higher priority in the procurement scheduling. As indicated by Exhibit XII-6, the numbers of units for this work are at their maximum in the first year. The first priority purchases should therefore, be as follows:

Description	Units Needed	Unit Price	Total Cost (1972 E$)
Motor grader	16	75,600	1,209,600
Dump truck	66	60,000	3,960,000
Loader	14	75,000	1,050,000
Roller	24	51,500	1,236,000
Water truck	12	75,000	900,000
Crawler tractor	8	110,100	880,800
Subtotal			9,236,400
Spare parts @15%			1,385,500
Total			10,621,900

2. Spare Parts

The estimates of units remaining service of the existing equipment fleet were based on the assumption that adequate spare parts

would be supplied. The Consultants were given to understand the large parts orders were being received in the second half of 1972, for the reconditioning of repairable equipment currently out of service. The evaluations of deadlines units were influenced by this information. No specific needs for large additional parts orders beyond normal purchases were identified.

E. Budgets

Exhibit XII-9 presents the combined recommended budgets by years resulting from the findings of this study. These annual budgets are separated into line items, derived in the manner discussed in the paragraphs below.

1. Normal Maintenance Program

a. Personal Services

These figures were obtained by taking all labor hours for regular maintenance and applying the hourly rates given in Section III for the various classifications, including fringe benefits and desert allowance where applicable. The total hours computed provide for the production of all necessary aggregates and surfacing materials by the means used as a basis for estimating in the original costing procedures of Section III.

b. Equipment Rentals

This line item was computed by multipying all machine hours required for maintenance and materials production times the hourly rental rates for the various equipment types, as established in Section III. The annual amounts are therefore intended to include depreciation, fuels and lubricants, repairs and servicing, and all other costs of equipment usage excepting operator's wages.

c. Materials

The budget amount for this time covers the purchase of materials, especially bitumens, from outside sources, by contract or other means.

EXHIBIT XII-9

RECOMMENDED BUDGETS, IHA MAINTENANCE BRANCH
BY PROGRAMS AND FISCAL YEARS
(1972 E$)

Program and Item	1973/74	1974/75	1975/76	1976/77	1977/78	Total 5 Years
A. Ordinary Budget Request						
Normal Maintenance						
Personal Services	2,448,608	2,591,714	2,712,357	2,775,124	2,836,320	13,364,123
Equipment Rentals	18,091,408	18,604,893	19,136,095	19,182,553	18,883,124	93,898,073
Materials	2,097,502	2,351,892	2,553,684	2,686,203	2,902,138	12,591,419
Others*	4,776,516	4,968,733	5,148,851	5,199,859	5,195,154	25,289,113
	27,414,034	28,517,232	29,550,987	28,843,739	29,816,736	145,142,728
Emergency Rehabilitation						
Personal Services	400,032	417,343	106,615	--	--	923,990
Equipment Rentals	3,003,594	3,158,151	811,304	--	--	6,973,049
Materials	5,481,523	6,253,328	1,950,368	--	--	13,685,219
Contractual Services	4,495,749	2,216,168	287,429	--	--	6,999,346
Others*	1,861,902	1,880,794	524,752	--	--	4,267,448
	15,242,800	13,925,784	3,680,468	--	--	32,849,052
Subtotal, Ordinary Budget	42,656,834	42,443,016	33,231,455	29,843,739	29,816,736	177,991,780
B. Capital Expenditure Budget Request						
Equipment Acquisition	25,874,195	4,775,950	1,759,500	74,750	496,685	32,981,080
Total Budget Request for Maintenance Branch	E$68,531,029	E$47,218,966	E$34,990,955	E$29,918,489	E$30,313,421	E$210,972,860

*Overhead and undistributed incidental expenses.

d. Others

This figure represents District-level overheads and other undistributed incidental costs, as defined in Section III, at 21.1 percent of the preceding categories.

e. Discrepancies in Totals

It will be noted that the annual budget totals for normal maintenance in Exhibit XII-9 are slightly different from the figures previously used in discussing funding requirements by years (Sections VIII and XI). This results from the differences in procedures for the two distinct presentations. Previously, the annual amounts have been an accumulation of engineering-based crew costs. Here, they are accounting-oriented budgetary costs by fiscal categories.

2. Emergency Rehabilitation

The annual amounts for the line items of this program were derived in a manner similar to that for normal maintenance, except that Contractual Services were added to cover work by contract, engineering supervision, and other engineering assistance from outside the Maintenance Branch. In this program, some small arbitrary adjustments were made in the undistributed incidental expenses to make the totals by years agree with the figures given in earlier report sections.

3. Capital Expenditures

This budget category represents only the recommended annual procurements of equipment (plus spare parts), and the figures are taken directly from Exhibit XII-7.

4. Applicability of Budgets

It must be noted that the yearly amounts for normal maintenance in Exhibit XII-9 are founded entirely on the data and assumptions described in Sections III-F and III-G of this study, and on the recommended road systems. Any change in these bases would result in altered budgets. The figures in the exhibit do not provide for small betterments,

assistance to other agencies, or any activities not defined and quantified in the report. A successful materials exploration program, as recommended in Section XI, could reduce budgetary costs considerably, with no loss of benefits. Failure in making the indicated equipment acquisitions might also permit a reduction in operating budgets, but only at the expense of the road users, in abnormal vehicle operating costs. Other possible revisions would have their specific monetary effects. The final IHA maintenance budget for any year must be based on the programs which are actually adopted, with the real numbers of personnel employed, the equipment units to be operated, related materials, and the authorized capital expenditures.

Section XIII

BENEFITS OF IMPROVED MAINTENANCE

Although the analysis used in Section V to establish priorities for maintenance was a hypothetical exercise, genuine economic benefits would accrue to the road users, and indirectly to the nation as a whole, by applying the maintenance standards described in this report to the recommended highway system. User savings would be realized because the quality of the travelway surfaces would be improved on most of the highways, and vehicle operating costs would be reduced.

A lowering of VOC would not occur on all road segments, because some are now in their "best", or normal, condition, and operating costs are at the standard level for the surface type. However, most segments were found to be in a sub-normal condition, by varying degrees.

In Section V, relationships were established between road condition ratings and VOC. The levels of maintenance effort established in the study were designed specifically to preserve each road type in some "best" or standard state. The total potential user savings for the system are represented by the difference in total VOC between the existing (1972/73) condition and the condition to which the roads would be returned by adequate maintenance.

It was shown in Section VIII that the costs of recommended maintenance would be higher than past and current expenditures for the present road system. This differential is the cost of obtaining the benefits. The only year in which it is possible to make a direct comparison of costs and benefits is the current year, with the roads in their observed condition. However, in order to derive a stream of net benefits by years, in the normal manner for economic analysis, it is logical to establish a comparative base by projecting current expenditures per kilometer for the pertinent road system, and assume that this will continue to cause equivalent sub-normal conditions on the roads. Sets of annual savings and costs can then be quantified, and the net differences converted to present worth.

A. Determination of User Savings

The benefits which can be derived from the implementation of the Consultants' recommended maintenance program are expressed terms of reduced vehicle operating cost. As described in Section IV, each segment of road was rated as to condition. Paved roads were rated from Condition 1 (normal) to 4 (worst), and gravel roads from Condition 1 to 7. Vehicle operating costs for each surface type and condition were derived in Section V. Adoption of the recommended maintenance practices would result in all paved roads and all Type 3 and 4 gravel roads being returned to Condition 1, or being preserved in that state. Type 5 gravel roads would be returned to or kept at Condition 2, and Type 6 gravel roads would be in Condition 3. Consequently, the vehicle operating costs for any segment in sub-normal condition would also be reduced by some range of values. The net system reduction in VOC represents the benefits of the recommended maintenance program. These benefits are calculated annually for the years 1972/73 through 1977/78. For each year, the additional roads, changes in surface type and increasing traffic are taken into account. A stream of benefits is thus generated.

1. Quantification Procedure for Benefits

The following steps are performed in determining the reduced vehicle operating costs resulting from the recommended maintenance program.

a. Identify each segment of road and its condition (excluding those of the rehabilitation projects).

b. Determine the standard incremental increase in VOC from normal to any other condition, for each vehicle type, surface type, and topographic class. See Exhibit XIII-1.

c. For each individual segment, multiply the incremental VOC for each vehicle type from the observed road condition to the final condition, by length of segment, vehicle volumes, traffic growth factor, and 365 (days per year), for each of the program years.

EXHIBIT XIII-1

STANDARD ECONOMIC VOC INCREASE FROM CONDITION 1 TO ANOTHER CONDITION BY VEHICLE TYPE (E$/KM)

Terrain	Condition	Car	Bus	Truck	Truck/ Trailer
		PAVED SURFACES			
Flat	2	.01	.03	.02	.05
Flat	3	.02	.07	.05	.10
Flat	4	.03	.10	.08	.16
Rolling	2	.01	.04	.03	.08
Rolling	3	.02	.08	.06	.15
Rolling	4	.03	.11	.10	.23
Mountain	2	.01	.05	.04	.11
Mountain	3	.02	.10	.08	.22
Mountain	4	.03	.14	.13	.33
		GRAVEL SURFACES			
Flat	2	.01	.05	.05	.11
Flat	3	.02	.11	.10	.23
Flat	4	.04	.17	.14	.34
Flat	5	.05	.22	.19	.46
Flat	6	.06	.27	.24	.57
Rolling	2	.01	.06	.06	.16
Rolling	3	.02	.13	.11	.32
Rolling	4	.04	.19	.16	.48
Rolling	5	.05	.25	.22	.65
Rolling	6	.06	.31	.28	.81
Mountain	2	.01	.08	.07	.23
Mountain	3	.03	.16	.15	.46
Mountain	4	.04	.25	.22	.69
Mountain	5	.05	.32	.30	.92
Mountain	6	.07	.40	.37	1.15

d. Sum the segmental delta VOC for all vehicle types. This gives the reduced VOC, or benefits per segment per year.

e. Sum all the segment benefits to obtain a system total.

f. To determine the benefits for the next year:

(i) Delete all new paved roads of the revised system, and all paved segments which were gravel-surfaced in the preceding year. These are assumed to be in Condition 1, with no potential reduction in VOC.

(ii) Add all new gravel segments. The assumption is made that without adequate maintenance the new gravel surfaces will not remain in the best condition possible, but will deteriorate by one step in the condition rating. This deterioration is accompanied by the respective increase in operating costs.

g. Repeat steps "a" through "e" above.

The foregoing process gives the total annual reduction in VOC for the entire system. No benefits are taken for segments within the rehabilitation projects because, while real savings result from the improved surfaces, the savings are derived from expenditures other than those for regular maintenance. Paved sections are returned to Condition 1 by the rehabilitation but the benefits are considered to defray the special costs involved, over the payout life. Three of the gravel rehabilitations would, at present levels of maintenance, deteriorate again by one step in the condition ratings in the final two program years of this study (3 years in one case), after their completion. The recommended maintenance practices would produce savings on these roads in the appropriate future years, but such benefits were not included in the calculations.

B. Benefits from the Recommended Maintenance

The condition rating of each segment in the present system is described in the Engineering Appendix. Traffic forecasts on each segment are provided in the Economics Appendix. The computer program to generate VOC savings by segment and for the total system is also

listed in the Economics Appendix, with the annual system totals presented in Exhibit XIII-2. The results are shown at zero traffic growth and at the forecast traffic growth. The former is considered a "worst case" situation where traffic remains static. The predicted growth is about 6 percent annually, on a system basis. The exhibit includes the benefits which would occur if the recommended maintenance program were applied to the 1972/73 road system. This calculation is required as a point of reference for comparison and forecasting purposes. Ideally, some immediate benefits could be gained through the better utilization of existing equipment. On the other hand, delays in the receipt of needed equipment will prevent the full benefits from occurring until at least 1973/74.

Examination of the exhibit shows that the benefits decline annually, especially under zero traffic growth conditions. This is due to the fact that the new paved sections (new routes and former gravel), do not produce any benefits from improved maintenance, being always rated in Condition 1. Realistically, the new pavements would deteriorate to some extent without the recommended maintenance and the total benefits would be slightly higher than those shown. Therefore, the total reduction in VOC as given is considered to be conservative. The total savings do include the incremental VOC for new gravel roads because, as previously mentioned, the present maintenance practices will not keep these roads in Condition 1. However, traffic volumes on the majority of these new gravel roads are low, and the total effect of such routes on the incremental VOC is minimal.

Exhibit XIII-3 shows, for the revisions of the system, the new paved segments which do not generate benefits. Those segments which were previously gravel are generally part of high-traffic routes on which the effects of the recommended maintenance program were quite pronounced so long as they were unpaved. Exhibit XIII-4 lists those new gravel road segments on which the condition rating was taken to be one step worse, given the continuation of present maintenance practices. The best achievable condition is considered to be one for Type 3 and 4 gravel roads, Condition 2 for Type 5, and Condition 3 for Type 6.

EXHIBIT XIII-2

ECONOMIC BENEFITS
FROM IMPROVED MAINTENANCE TOTAL
AND DISCOUNTED AT 10 PERCENT
(Thousands of 1972 E$)

Fiscal Year	Vehicle Operating Cost Savings			
	Zero Traffic Increase		Positive Traffic Growth	
	Total	Discounted	Total	Discounted
1972/73	18,817	18,817	18,817	18,817
1973/74	17,751	16,136	18,816	17,104
1974/75	16,438	13,578	18,460	15,248
1975/76	15,269	11,467	18,181	13,654
1976/77	13,187	9,007	16,642	11,366
1977/78	11,206	6,959	14,994	9,311
		75,964		85,500
Less 1972/73		18,817		18,817
Benefits, 1973/74-1977/78		57,147		66,683

EXHIBIT XIII-3

NEW PAVED SEGMENTS WITH CONDITION RATING OF ONE

Segment	Year Paved or Added and Length (km)				
	1973/74	1974/75	1975/76	1976/77	1977/78
01010	24				
01011		25			
01012			8		
04006			(5)*		
04401		6			
04501			6		
04601			27		
05004-05006				100	
05007-05008					108
05009-05010		53			
05011-05013			78		
07006-07009			68		
08002-08006		60			
18007-18011		48			
04033					30
18001-18002	150				
18003-18006		97			
06006-06008					94
06009-06015		106			
06016-06019			101		
06020-06024			100		
06025-06029				107	
07010-07012				64	
07013-07015					85
43003-43005		50			
43006-43009			50		
43010-43016	101				
43017		16			
Increase in Paved Length	275	461	433	271	317

*Length reduction from relocation.

EXHIBIT XIII-4

SCHEDULED SYSTEM ADDITIONS
GRAVEL SURFACE

Segment	Year Added and Length (km)				
	1973/74	1974/75	1975/76	1976/77	1977/78
05014		70			
09002	70				
13001-13009		133			
17006		40			
25001-25003				132	
21001	60				
21002-21005		140			
23002			46		
23003				50	
04071					140
30002-30005	190				
30006-30009					295
35008-35009				42	
08007		54			
08008-08011			66		
08029-08030	60				
08031-08032			40		
08033-08034				40	
90003			107		
09101-09102		48			
36001-36002					110
07023-07026		36			
07027					43
37001	60				
43101				48	
Total Increase in Gravel Length	440	521	259	312	588

C. Cost and Benefit Stream

The costs of obtaining the benefits shown in Exhibit XIII-2 are the annual differences between the Consultants' maintenance program costs and the projection of current IHA maintenance costs, assuming continuation of present operational conditions. The Consultants' costs are discussed fully in other sections of the report, and were summarized by years in Exhibit VIII-18. They are repeated in Exhibit XIII-5, together with a projection of IHA maintenance costs based on historical spending levels and the extent of the future system. It can be seen from the exhibit that the overall average cost of maintenance per kilometer under the recommended program is E$3,515 in 1972/73, compared with an IHA figure of E$2,770 per kilometer for the same year. It must be pointed out again that the present operations do not provide adequate maintenance, as evidenced by the deteriorating road system. The average cost per kilometer using recommended practices is reduced from E$3,515 in 1972/73 to about E$2,900 in 1977/78. This reduction is the result of an increasing proportion of paved surfaces in relation to high-type gravel roads, and the introduction into the system of more service-to-traffic and feeder roads. All of these classes have a lower maintenance cost per kilometer than the Type 3 and 4 roads.

The projected IHA maintenance costs in Exhibit XIII-5 are based on the system average annual cost increase during the years from 1967/68 to 1971/72. This forecast also shows a declining cost per kilometer, from E$2,770 in 1972/73 to about E$2,350 in 1977/78. This is a conservative estimate of future IHA maintenance costs. If maintenance costs per kilometer on the 1972/73 system of 7,355 kilometers were held (at the 1972/73 rate of E$2,770 per kilometer), and all new roads to be introduced were maintained at only one-half that cost, the resulting 1977/78 maintenance cost would be about E$24,450,000, which is still slightly higher than the annual system cost used to determine the cost stream associated with the recommended program.

EXHIBIT XIII-5

PROJECTED COST DIFFERENCE BETWEEN PRESENT AND RECOMMENDED MAINTENANCE PROGRAMS
(Financial Costs)

Year	Total kms of Road	Total Maintenance Costs (E$000) IHA*	Consultants	Difference
1967/68	6,826	16,020		
1968/69	6,836	16,780		
1969/70	6,848	16,983		
1970/71	7,024	18,866		
1971/72	7,257	19,054		
Forecast				
1972/73	7,355	20,373**	25,850	5,477
1973/74	8,046	21,086	27,243	6,157
1974/75	8,834	21,820	28,275	6,455
1975/76	9,289	22,573	29,303	6,730
1976/77	9,708	23,367	29,804	6,437
1977/78	10,296	24,183	29,844	5,661

*Includes Total Financial Costs for Equipment Use
**Source: IHA Cost Accounts Branch and Consultants' Analysis.

Exhibit XIII-5 also shows the annual differences in financial cost of implementing the recommended program. These differences are in the range of 5.5 to 6.7 million dollars per year.

Exhibit XIII-6 gives the annual cost and benefit stream for the years considered in the study, plus the present value of the net benefits to the IEG. Both the maintenance differential (costs) and the incremental VOC (benefits) are expressed in economic terms. As illustrated, the total present value of net benefits is E$53,200,000 for the period 1972/73 through 1977/78. These are the benefits which would be realized if the IHA could begin immediately to apply the recommended maintenance practices. This is an idealistic scenario. More likely, no significant improvement can be made during 1972/73. The total net benefits would therefore be reduced accordingly, to E$40.4 million for the five years 1973/74 through 1977/78, assuming that the program could be fully implemented in 1973/74.

D. Internal Rate of Return

The benefits of improved maintenance were expressed above as Present Value Net Benefits, at a 10 percent opportunity cost of capital. This appeared to be the most appropriate method for assessing the returns to be realized in a five-year time span taken from a continuing stream. The quantities compared were differential maintenance costs and incremental road user savings, both of which would be undergoing long-term changes apart from the normal variable of traffic growth.

The concept of internal rate of return, as called for in the contract, did not seem to the Consultants to be applicable to a situation in which there is no clearly defined initial investment from which the benefits flow. Obviously, there will have to be a large capital investment for equipment, plus other expenditures, and the estimated benefits cannot be obtained without these capital outlays. However, the assumed benefits will also be dependent on a more complete utilization of existing resources, including established management, present labor forces, fixed facilities of several kinds, and present equipment. The benefits

EXHIBIT XIII-6

NET BENEFITS OF
RECOMMENDED MAINTENANCE PROGRAM
(Thousands of 1972 E$)

Fiscal Year	Differential Maintenance Costs		Economic Benefits (A VOC)	Net Benefits	Present Value Net Benefits (@10%)
	Financial	Economic			
1972/73	5,477	6,025	18,817	12,792	12,792
1973/74	6,157	6,773	18,816	12,043	10,948
1974/75	6,455	7,100	18,460	11,360	9,388
1975/76	6,730	7,403	18,181	10,778	8,098
1976/77	6,437	7,081	16,642	9,561	6,530
1977/78	5,661	6,227	14,994	8,767	5,444
Total					53,200
Less 1972/73					12,792
Five-Year Net Benefits					40,408

*Financial to Economic Cost Factor = 1.1

will result, in part, from corollary investments now being made, such as the major program for new district shop buildings and tools. There did not appear to be any practical means of separating partial benefits which could be said to derive from identifiable investments with a determinate life.

Section XIV

ADMINISTRATIVE IMPLEMENTATION

No important changes in the basic IHA organization are necessary immediately to carry out the programs recommended in this study. Some additional staffing at critical points could contribute to more rapid and effective implementation. The filling of certain administrative posts might require recourse to expatriate advisors temporarily, but it is hoped that this can be avoided (a limited number of technical advisors are recommended later in Section XV).

The budgeting and accounting processes remain to be examined in this section, plus some aspects of program funding.

A. The Budget Process

1. Planning, Preparation and Approval

The IHA annual budget requests comprise estimates of:

a. Administrative expenditures

b. Road maintenance program needs, including rehabilitation

c. Capital expenditures for equipment, road construction and reconstruction

IHA budgetary records and controls were established pursuant to procedures manualized in June 1969. Capital expenditure items for construction or reconstruction flow from a plan of priorities set through long range planning processes of the IEG and IHA. A condensed sequence of input events to an approved annual budget is shown as Exhibit XIV-1 in the Administrative Appendix. Fund resources are classified in the approved budget as estimated revenues from specific sources, e.g., IEG General Funds, Foreign Loans and Grants, Private Contributions and Local Governments' share of local works. The application of fund resources to specific work program items is also shown in budget requests.

The maintenance budget, prepared by the District Engineers in the form required by the Budget Branch, expresses their needs for manpower, materials and supplies, equipment and other expense items in terms of "budget objects of expenditure". There are nine major object of expenditure classes, including personal services of IHA employees, contractual services, materials and supplies, machinery and equipment parts, fuel and lubricants and other. The budget in this form is a conversion by the District Engineer from his maintenance work programs set forth in narrative and quantitative terms in an attachment.

The attachment data include detail of maintenance activities programmed for completion during the budget year. Exhibit XIV-2 lists maintenance activity items and the corresponding units of measurement.

In broader terms, the district maintenance work program and budget includes a fairly constant level of routine maintenance operations and a plan of periodic maintenance, plus some rehabilitation work to be done by direct force account labor. The routine maintenance estimate is basically a program to support the district complement of maintenance personnel and equipment assigned to designated road sections. The program for periodic maintenance and rehabilitation is generated both by direction from the IHA Division of Operations and by the results of inventories of road sections made by district staff. There generally is interaction during the program development stage between the District Engineer and the Maintenance Engineer headquartered in the Operations Division. When an approved budget reduces funds available for maintenance from the amounts proposed, the reduction is applied to all districts in terms of budget objects of expenditure. The Maintenance Engineer may set the new order of priorities for periodic maintenance and rehabilitation force account work required by the reduction or, where considered appropriate, the decision may be made by the District Engineer.

2. Execution and Control

The approved budget is executed through "responsibility centers" established in the IHA organization plan at division, branch,

EXHIBIT XIV-2

MAINTENANCE ACTIVITY LIST

Item	Maintenance Activities	Unit
1	Clearing	m^2
2	Slide and shoulder maintenance	m^3
3	Slide removal	m^3
4	Sight distance improvement	m^3
5	Primary and secondary ditch cleaning	m^3
6	Primary and secondary ditching	km.
7	Culverts cleaned	No.
8	Inlet and outlet channel excavation	m^3
9	Culvert construction	No.
10	Culvert repair	No.
11	Fords cleaned	No.
12	Bridges constructed	No.
13	Bridge repair	No.
14	Mortar masonry placed	m^3
15	Dry masonry	m^3
16	Reinforced concrete	m^3
17	Mass concrete	m^3
18	Cement used	kgs.
19	Sand used	m^3
20	Crushed stone used	m^3
21	Blading surface	hrs.
22	Resurfacing, select material	m^3
23	Resurfacing, crushed material	m^3
24	Spot repair	m^3
25	Bituminous patching	m^2
26	New bituminous surface	m^2
27	Bituminous seal	m^2
28	Single surface treatment	m^2
29	Double surface treatment	m^2
30	Road mix surfacing	m^2
31	Asphalt used	tons
32	Kerosene used	lts.
33	Crushed stone produced	m^3
34	Quarry stone produced	m^3
35	Select material produced	m^3
36	Structural excavation and backfill	m^3
37	Road signs installed	No.
38	Guard posts installed	No.

section and project levels. District offices are considered to be a division level responsibility center for budget account purposes. Designated road sections for routine maintenance operations are considered a project responsibility center as is periodic maintenance and rehabilitation force account work between designated road section termini.

The control of the IHA budget is through a system of allotments to the division level of responsibility. The allotments constitute authority for entering into obligations and incurring expenditures pursuant to stated conditions. Additionally, the documents provide subtotals by objects of expenditure available for the operation of subordinate organizational units of each division, such as branches, sections and projects. Prior authorization for transfers of expenditure objects within the division organization is required by budget policy. Fiscal control is provided through a system of accounts designed to apply encumbrances and expenditures against budget allotments and to show the resulting appropriation fund balances.

3. Organizational and Personnel Factors

The IHA maintenance program is managed by the Chief of the Operations Division through delegation to the Chief Maintenance Engineer and the assignment of supervision of specific programs to the District Engineers. Budget policy is implemented through various records maintained within the Budget Branch, the Fiscal Services Division, the Operations Division and the several district offices. Budget - related and other fiscal records are kept and reports drawn therefrom by personnel classified and assigned as shown on Exhibit XIV-3. Classification standards of the IHA applicable to the identified positions are included in the manuals of the Personnel Division.

A condensed analysis of these positions is set forth as follows:

a. Clerical Aide - is a minimal level record-development assignment with corresponding minimal qualification standards.

b. Clerk II and III - represent supervisory assignments over general office operations, including budget and fiscal matters.

EXHIBIT XIV-3

RELATIVE ASSIGNMENT LEVEL OF SELECTED POSITIONS

Functions	Classification levels of clerical and fiscal positions authorized for office having budget and related fiscal record and report responsibilities		
	Budget Branch	General Accounts Branch	Cost Accounts Branch
Fiscal	Chief	Chief	Chief
	Budget Analyst I	Accountant I	Accountant I
		Accountant II	Accountant II
		Accounting Clerk I	Accounting Clerk I
		Accounting Clerk II	Accounting Clerk II
		Accounting Clerk III	Accounting Clerk III
Operations Division	Budget and Fiscal Unit		
	Clerk II		
	Account Clerk I		
	Each District Office		
Field	Clerk III		
	Clerk II		
	Account Clerk I		
	Section Crews		
	Clerical Aide		

They require a capability to apply general office management practices and procedures to their assignment. The qualification standards include graduation from high school and two to four years experience in general office work.

c. Account Clerk I, II and III - are assignments to the maintenance of specific accounting records under prescribed rules and professional supervision. Qualification standards include graduation from a commercial school for the lower level position, with three to five years experience in this type of work added to standards for the higher positions.

d. Accountant I and II - are professional accounting positions involving application of accounting principles to their assignments. Qualification standards include a degree in business administration from an accredited college or university, major in accounting. Differences in the grades result from added experience and increased responsibility levels at the higher grade position.

e. Budget Analyst I - is an entrance-level professional position responsible for examination, analysis and assembly of fiscal and statistical budget data. It requires a general understanding of public finance and general governmental accounting. Also, an ability to recognize organizational problems and to interpret or prepare financial type reports. Incumbent must be a graduate of college or university - or have an equivalent combination in training and experience.

B. The Accounting System

1. General Status

The present IHA plan of accounts and implementing procedures were manualized in June 1969 and put into operation July 1, 1970. It is the initial significant result of a gradual upgrading effort made over the preceding four to five years. At the start of this effort, the fiscal operation was failing in its basic responsibility to provide fiscal custody of IHA resources. There existed many variances between the accounting records and the inventoried value of assets and creditor accounts. In brief, the system with its inherent weaknesses and fundamentally unprofessional operation yielded at best a small measure of integrity in its fund balances.

The emphasis of corrective actions over the years has been to achieve an acceptable level of fiscal integrity in IHA budget controls, expenditure records and reports. Reports of fiscal systems and operations reviews made a year or more after installation indicate a general trend of improvement and greater reliability in results.

2. Expenditure Records and Reports

The present IHA fiscal systems are designed to control totals of quarterly ordinary budget allotments at the division level of responsibility and major object of expenditure. The status of allotments and fund balances are provided by recording of encumbrances, expenditures and interdepartmental charges against the allotment totals. Additionally, the system provides for recording allocations of portions of a division allotment to its subordinate units as well as charges against these allocations. Details of expenditures within the division are recorded for each district, for the construction and maintenance branches within each district, and for each of its programmed force account labor projects and maintenance sections. Additionally, provisions are made for recording costs of operational components of maintenance such as mobilization, general overhead, drainage, roadway and traffic services. These provisions have not been put into effect in the IHA accounting operations.

The development and processing of many source documents to the maintenance expenditure record is done at the district office in accordance with instructions found in the Accounting and other service function manuals.

A monthly statement of encumbrances and expenditures is prescribed by the Accounting Manual. Its purpose is to inform division managers of the status of allotments and fund balances.

3. Cost Accounting Records and Reports

The IHA cost accounts are intended to be subsidiary to the appropriation accounts. They are also to provide cumulative totals for projects on which work is authorized during two or more budget years. Their broad purpose is to record and report each responsibility center's cost of operations. Provisions of the Accounting Manual set the measure of "cost of operations" as including budget expenditures, non-budget cost items such as equipment depreciation, and an appropriate allocation of

overhead. It is required that annual totals of responsibility cost centers, excluding non-budget components, be reconciled to the annual expended appropriation totals.

The development and processing of source documents to the cost accounts takes place at the district offices pursuant to provisions of the Accounting Manual and other service function manuals.

A monthly statement of project costs is prescribed for release by the Cost Accounting Branch by the 15th of the succeeding month. The statement is designed to show cumulative cost totals and remaining balances of allocated (budget) funds.

C. Evaluation

The budget staff of IHA does not appear to be a participant in policy deliberations associated with budget development. Rather, it serves basically a mechanical role in the development and processing of budget documents and in the review of fiscal progress. In addition to this rather limited role, a broader service to maintenance management could bring about more meaningful budget requests and improved program operations. For example, because there is no authorization to budget for emergency maintenance, the funding of this work reduces funds budgeted and available for other maintenance purposes. A resolution of this problem through the initiative of the budget staff would give recognition to another responsibility inherent in the budget function, namely a substantive support role.

Procedures in the Budget and Accounting Manuals place emphasis on budget and expenditure controls that primarily serve to satisfy responsibilities of the fiscal services. At the same time, however, the detail of controls within the level of the budget allotment interfere with the efforts of maintenance program managers to put available funds to the most effective use.

In the matter of execution and control, the budget and fiscal systems are not yielding a prompt and accurate showing of fund balances and budget trends to program managers. One contributing cause is the procedures adopted for funding warehouse operations and charges for materials and supplies. These procedures result in charges having the undesirable features of being untimely and of questionable accuracy.

Improvements in the timing and accuracy of statements of fund balances could well result from resolution of this problem alone.

The fiscal system as a whole is not functioning at a desirable level, particularly in its inability to present timely and accurate fiscal reports. Nor can it reasonably be expected to do so without attention being given to definite problem areas. Such matters as communications and distance logistics within the districts and between the districts and the central headquarters definitely contribute to a failure to promptly and accurately prepare and transmit numerous reports to various headquarters offices. Staff capabilities or, more properly, limitations therein are likewise an inherent contributing cause for system failures. District office staff complements make no provision for assignments of personnel qualified to implement, even with extensive training, the complex provisions of various technical procedural manuals. The creating of systems through issue of various manuals of procedures has itself contributed to the problem in several ways. First, the procedures fail to recognize the impact that difficult communications and limited staff capabilities have on a successful system operation. Secondly, there has not been sufficient coordination of the offices concerned with preparation of the several manuals of procedures issued.

The cost accounting plan of IHA establishes records subsidiary to the expenditure accounts. They are designed as controls of funds allocated and a source of cost information relating to specified responsibility centers. As such, they form a part of a continuing effort to improve on the fiscal reliability of the total accounting system. Such a plan is essential to analysis of program execution within specific responsibility assignments and appropriate reporting thereon to IHA management. In terms of serving IHA road maintenance management, however, the cost accounting plan does not now meet basic needs in several respects. First, the records do not reflect a value of resources applied to designated classes of work accomplished and other elements that comprise a road maintenance program. Secondly, the plan does not yield a value of some resources consumed in maintenance work through clearly defined and monitored cost determination procedures.

D. Recommendations

Preface

The Consultants acknowledge the IHA decision to act on fiscally oriented recommendations and that same will be made in the environment and context of reality. Thus, it may well be justifiable for the IHA to defer decisions on proposals relating solely to modification of operations and procedures identified with the IHA fiscal systems. Such a position would not be inconsistent with a judgement by IHA management on the timing and general purpose of modifications it believes can be successfully introduced into its fiscal operations.

As to recommendations relating to maintenance program reporting, including a showing of what kinds of work were done and what the elements of cost were, the Consultants' studied judgement is that basic classification of maintenance work programs is vital to a sound maintenance management effort particularly as same becomes more complex. It follows that management of the projected five year maintenance plan will find it prudent to adopt either the Consultants or similar in purpose classification and reporting procedures at as early a date as is consistent with its ability to do so.

The consultants suggest the IHA decision in the matter of maintenance program reporting give full weight to the fact the Consultants proposal provides for its administration wholly within the Operations Division, i.e., it is not a fiscal procedure.

These comments apply equally to recommendations in the instant Chapter XIV - D and succeeding Chapter XV as such relate to reporting of data of accomplishments within the maintenance program.

1. Condensed Presentation

In the judgment of the Consultants there are several fiscally-oriented specific courses of action that the IHA could take to improve its

management of the road maintenance program. These actions concern modification of programming and budgeting procedures and measures to improve supporting services provided by the budget and accounting functions. A brief description of each recommendation is presented first, followed by more detailed discussions thereof:

a. Develop budget proposals and monitor progress on the basis of a maintenance program designed to yield costed quantities of maintenance functions completed.

b. Upgrade the budget function to assure positive response to planning responsibilities.

c. Seek IEG authorization for special funding of repairs to roads damaged by unusually severe flood or slide conditions.

d. Establish a capitalized working fund for the receipt, custody and issue of materials, supplies and parts.

e. Provide organizational recognition of the fiscal systems function within the Fiscal Services Division. Develop the function at a high level of experience and demonstrated competency.

f. Establish cost determination procedures to govern input of overhead costs and costs of production operations and service centers into the IHA cost accounts.

g. Design and institute a program analysis and reporting system within the Operations Division based on field input of resource utilization data and computer application of related pricing data.

h. Establish capability within the Operations Division to execute and monitor the program analysis operation.

2. Detailed Presentation of Recommendations

a. Budgetary consideration of this recommendation is dependent upon and requires correlation with action by the Operations Division to redefine its road maintenance program. In substance, the road maintenance program will comprise a number of functions and

subfunctions defined by engineering work classification standards; reference Section XV. Each standard establishes a basis for estimating resources required for recommended levels of the particular maintenance function defined. Quantification of the maintenance functions on the IHA system to be maintained should produce a budget related directly to the approved maintenance program. Monitoring of budget execution by maintenance management could then extend not only to object of expenditure controls but also to a test of the rate its resources are applied to maintenance program accomplishments. This analysis would also be of value in an assessment of the realism factors in engineering standards set by the IHA for its several maintenance functions.

b. The budget process should embrace two major elements, namely, planning and control. The planning element comprises the:

+ development of resource data
+ establishment of objectives
+ development of long range plans
+ development of short term plans
+ computation of expenditure budgets
+ establishment of performance standards
+ development of program budgets

The control element includes:

+ an appraisal and ultimate approval of the planning product
+ analysis of the budget process and action to improve future cycles
+ the monitoring of actual versus planned budget execution

In the Consultants' view, the IHA needs to interlock more directly the planning and control processes within its organization. It is also the Consultants' view that this will not be effectively accomplished as long as the budget function continues to be discharged through a second-level administrative organization, namely a budget branch in a division

having primarily administrative management responsibilities. Although budget responsibilities include both planning and fiscal assignments, it has been customary to place the budget function in an administrative organizational unit. In view of the key position of IHA planning in the development of IHA programs in conjunction with broad IEG planning, it is the Consultants' judgment that planning supervision of the budget function would be to IHA's advantage. It is accordingly recommended that the IHA consider assignment of the budget function to the Planning and Programming Division. Additional discussion of principles involved in this recommendation were previously set forth in Section II.

c. A good classification system operative over a period of years will yield an experience record of unusual emergency road repairs and related costs. Because of the uncertainty factor, this record would not provide a base for a definite annual projection of emergency situations and related fund and resource requirements. Although IHA has no such experience record, it is clear that unusual floods and slide conditions have occurred and resources budgeted for normal maintenance have been used for the necessary repairs. The use of normal maintenance budgets to fund work of an unusual and emergency character, simply because maintenance personnel are assigned to do the job, does not treat the problem directly nor equitably. It is therefore proposed that authority be sought and procedures established to provide funds solely for the emergency repair and rehabilitation of roads damaged by unusually severe natural events.

One approach to the problem is to establish a reserve for emergency road repair and rehabilitation through the usual budget processes. The Consultants reject this approach because of the aforesaid uncertainties and the secondary objection that reserves for contingencies serve to withhold available resources from other essential programs. An alternative which is the choice of the Consultants would be initiated by budget and legislative action to authorize the IHA to undertake emergency work on a reimbursable basis. This plan is briefly described as including:

+ The issuance of standards by IHA which define emergency work of repair and rehabilitation of roads damaged

by unsually severe natural events, including a definition of the term "unusually severe natural event."

+ The establishment by IHA of operational and fiscal procedures to control the work and record the cost of said emergency work.

+ The enactment of budget law or other legislative authority directing the IHA to perform said emergency work with any funds otherwise available to it and to present statements of accounts at prescribed intervals for reimbursement from general revenues of the IEG. Provision should also be made for the annual budget proposals of IHA to include reports of emergency work funds expended under these procedures.

+ A program limitation set by the budget law or legal authority to set IEG controls, subject to change only through further budget or legislative review and action.

d. Timely and accurate charges to maintenance programs are essential to meaningful analysis of progress as well as forecasts of costs. The present system of funding and charging for materials and supplies received, warehoused and issued to maintenance programs is producing neither timely nor accurate cost data. In the judgment of the Consultants, the IHA needs to act to improve on the management of this vital service function. The recommendation for a capitalized working fund could be implemented either:

+ By budget item request for advance of general funds to establish the working fund in IHA or,

+ By IHA reservation of budgeted funds for materials and supplies and an advance thereof for capitalization of an internally established working fund.

The Consultants recommend the choice of the first of these two alternatives, as it would assure IEG endorsement in the continuity of the operation as well as a desirable second level of governmental surveillance.

In substance, the capital working fund would be charged with conducting the business of supplying IHA with its inventory items at prices yielding a recovery of its costs without a material or continuing gain or loss result. Further, no change in the capital fund account should occur except through action of the IEG to increase or decrease the outstanding advance.

In more detail, the fund would:

+ receive and issue equipment*, materials, supplies and parts in response to requisition and purchase order specifications.

+ provide for custody and warehousing of its inventory between its receipt and issue.

+ provide fiscal custodianship of fund assets, including:

(i) The establishment and maintenance of books of account designed to show the financial condition of the fund.

(ii) Nominal accounts directed to disclose variances between fund costs and earnings.

(iii) The installation of procedures to assure recovery of costs incident to the stores operation and equitable charges to consumers.

(iv) Policy identification of cost components of the stores operation.

e. The IHA and its several programs comprise a large and complex system of interrelated management functions. The fiscal system, perhaps more than any other, can present the true face of IHA to other IEG levels. These systems should encompass:

+ The design and maintenance of a plan of accounts and set of records assuring, (1) fiscal custody of IHA assets and fund balances; (2) compliance with all legal and budgetary requirements, and; (3) a real and meaningful presentation of costs of the several elements of IHA operations.

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* Limited to classes designated by IHA policy.

+ The design of documents and the establishment of procedures assuring the proper recognition and treatment of all transactions having fiscal significance to IHA operations.

+ Provision for analysis, interpretation and reporting of fiscal data in the accounting records.

Management of the fiscal function must provide a capability to discharge these inherent responsibilities of system design just as adequately as it provides for system operation. Additionally, these capabilities are required on a continuing basis if the fiscal system is to properly recognize the constant effect of changes in the IEG and IHA manner of carrying out their responsibilities.

It is the Consultants' judgement that much of the cause of current fiscal problems is directly related to the limited fiscal system design capabilities in the IHA fiscal organization. The recommendation is directed to the IHA acquiring this capability through:

+ Establishment of a system design function within the responsibilities and organization of the Fiscal Services Division.

+ Appointment of a systems accountant qualified by education, experience and demonstrated capabilities to service the function.

f. In simple terms, the primary objective of an IHA cost accounting plan is the reporting of meaningful cost information to two broad management levels. One comprises those interests of executive direction and general administration that are concerned with broad organizational assignments and resource allocations.

The second comprises those interests of management or supervision of specific programs or parts thereof. Additionally, if the plan objective is to be reached, it must assure that all cost items are recognized, accurately measured and recorded. The IHA cost accounting plan is designed to accommodate the reporting of cost information relating to assignment to, and use of, resources by organizational units of the IHA. It provides no other cost information to program management

or supervision nor does it control, through cost determination procedures, the accuracy of cost information recorded in its accounts.

It is the Consultants' judgement that management of the road maintenance programs requires cost information on a more accurate, timely and meaningful basis than is now available. A part of this problem could be resolved through a simple decision to cost out IHA production and service center operations in accordance with generally accepted methods and cost determination procedures. These operations include those concerning equipment repair, materials and supplies, aggregate production and others. It is the Consultants' recommendation that early action be taken to effect this decision.

Exhibits XIV-4, 5 and 6 of the Administrative Appendix depict:

+ IHA general ledger control and distributions to responsibility (cost) centers under the cost accounting system installed in July, 1970.
+ IHA general ledger control and distributions to responsibility (cost) centers under system concept recommended by the Consultants.
+ The flow of budget expenditure objects through service center operations and their reclassified distribution to responsibility (cost) centers - under the system concept recommended by the Consultants.

Significantly, Exhibit XIV-6 provides for the allocation of only those overhead costs associated with the operation of the district offices and subordinate units and service centers where cost determinations and reclassification of expenditures is involved. It is the Consultants' judgement that allocation of other expenses of IHA as an overhead item to costs of its major programs should be discontinued. The results of this practice are misleading and distort the cost picture. This data are, of course, available through the IHA accounting system and can always be introduced into economic analysis through work sheet format. As to the development of capabilities to provide cost information of the road maintenance program, the Consultants recommend no early formal cost accounting action. The implementation of recommendation "e"

above, along with scope and priorities of assignments will basically determine the timing of such action. Recommendation "g" below represents the Consultants' preference in this matter.

g. The timely availability of reasonably accurate information on work accomplished and resources consumed is essential to management and supervision of the road maintenance programs. Since it is not expected that the IHA cost accounting plan could provide this information at an early date, the Consultants recommend that the Operations Division design and undertake alternate procedures for program analysis and reporting purposes. Because these procedures would be keyed directly to the maintenance program and its several components defined by work classifications, it is logical for them to be developed within the maintenance organization. Reference is again made to Section XV and proposals for maintenance function and work classification standards.

Briefly, the procedures would:

+ Produce field data identifying where, when and what maintenance work has been accomplished, along with quantitative data on resources applied.
+ Indicate the "cost" of each major resource item required for road maintenance work and a factor to "cost" minor resource items.
+ Calculate overhead and indirect "cost" data.
+ Correlate "cost" calculations with fiscal, warehousing and equipment staff.
+ Provide for controlled transmittal and receipt of field data.
+ Provide for controlled introduction of field data to the computer and its application to stored "cost" data.
+ Prescribe computer interpretations required for program analysis and reporting purposes. The field report form should logically be designed for precoding of all but that information that is directly related to field

crew production, such as the maintenance function involved and data relating to units of resources applied. Provision should be made for precoding of the maintenance functions whenever consistent with local conditions.

h. The Operations Division has responsibility for management of the many components of the road maintenance program. The lack of meaningful program analysis data severely handicaps the Division in its efforts to meet this responsibility. The Consultants therefore recommend that the division strengthen its support staff capabilities to assure the design of records and reports essential for the control of its programs. Implementation of recommendation "g" is an important assignment to this staff, but even so is only one of many that would evolve from establishment of a complete program record in the division. One of the most significant aspects of this assignment would be in reversing the trend of asking for more and more reports from the District Engineers. Quite to the contrary, this staff would be expected to provide mostly for raw data submission and for interpretive reporting thereon to the District Engineers.

E. Equipment Fund

Equipment resources available for the IHA road maintenance program have been purchased through annual budget authorizations for capital equipment and construction projects. There is no IEG provision for recovery of this equipment investment except as its depreciation may be reflected in costs of IHA programs. The acquisition of additional or replacement equipment is through annual budget requests that compete with ongoing programs for funds made available to the IHA and through periodic IEG loans approved for that purpose.

These funding procedures have not brought about replacement of equipment items on expiration of useful service life. The resultant overage inventory of equipment available for road maintenance has contributed to a condition of deferred and high-cost maintenance operations. Accordingly, it is appropriate for the IEG and IHA to consider the feasibility of other funding procedures supporting a more orderly equipment acquisition program.

Alternate procedures that could provide for equipment replacement include those associated with a capital working fund operation. A capital working fund would require that it be capitalized and given custodianship of fund assets. A discussion of a Capitalized Equipment Working Fund for the IHA is presented in the Administrative Appendix.

The Consultants do not recommend the creation of an IHA equipment working fund. It is the Consultants' judgement that:

(1) The impact of capitalization funding on the IEG could constitute an undue strain on cash reserves.

(2) The highly complex nature of a capitalized working fund would require such substantial changes in IHA organization and procedures as would offset foreseeable benefits.

The Consultants' previous recommendations concerning improved procedures for shops and warehousing operations (Section XIV-D-2-d) should provide an initial base for internal improvement in fiscal elements of the IHA equipment management program. Implementation of these procedures will not, of course, satisfy the objective of the IHA to fund equipment replacements upon expiration of useful service life. Other alternatives need therefore to be considered.

One such alternative would be a modification of the capitalized equipment working fund previously discussed. The Consultants have considered a "Capital Equipment Fund (IEG)" which procedurally, has the potential of providing funds for future replacements of IHA equipment. The Consultants recommend that the IHA and the IEG consider the creation of an IEG fund having the characteristics and procedural possibilities of such a capital equipment fund, as described below. It is the Consultants' judgement that the adoption of recommendations on internal improvement of the IHA equipment program along with creation of an IEG capital equipment fund would provide a reasonable and timely means of assuring future funding of IHA equipment acquisitions.

1. Capital Equipment Fund (IEG)

A Capital Equipment Fund (CEF) created and operated by IEG for the funding of IHA equipment acquisitions would differ considerably

from an equipment working fund as discussed in the Administrative Appendix. Its role would be confined to that of a Financial Agent of the IEG authorized to advance funds to the IHA for limited purposes, and in accordance with appropriate specifications. The IHA would in turn, retain full responsibility for management of its operational equipment program. A number of actions relating to the creation and operation of a CEF by the IEG are detailed below. These actions are intended to stimulate and not in any way limit the development of implementing procedures.

a. Approval of enabling law to include provisos such as:

(i) Authority for the IEG to establish the CEF, including internal organization and administrative matters.

(ii) Authority and responsibility of the CEF and the IHA in the execution of the program.

(iii) Establishment of a limitation in CEF capital, including actions concerning future adjustments.

b. Approval of CEF administrative and operating procedures governing:

(i) Organization plan and administrative program.

(ii) Records and controls relating to management of CEF balances, including reserves.

(iii) The form and incidental provisions of agreements to be executed between the CEF and the IHA relating to the financing of specific IHA equipment acquisitions.

(iv) Coordination with the IHA in scheduling of cash flow, to reflect needs of authorized IHA equipment acquisitions and IHA repayment of CEF advances.

c. Approval of IHA procedures governing such matters as:

(i) A program and annual budget for capital equipment acquisitions.

(ii) Annual budget and implementing fiscal procedures governing the payment of equipment depreciation expenses to the CEF.

It is assumed that the capital limitation of the CEF established by the enabling law would be developed by the IHA in cooperation with appropriate officials of the IEG. It is also assumed that IHA equipment acquisitions would be limited to those financed through the CEF operations.

F. Equipment Procurement and Debt Service Implications

Exhibit XIV-7 shows the IEG outstanding indebtedness as of June 30, 1971. If the total equipment procurement necessary to implement the programs recommended in this report were to be funded from external loans this would increase the total outstanding debt by 6.40 percent. The outstanding debt, as is shown in Exhibit XIV-8, has been rising constantly, at 11% to 12% per year for the past seven years. This annual increase has declined but slightly since 1964. Exhibit XIV-9 provides an indication of Ethiopia's ability to repay external debt, and shows that debt service has been a rising percentage of export earnings and of domestic revenue. These figures suggest that the IEG's position concerning resources available to repay external debts is worsening. This, coupled with the fact that the trade balance has been negative in every year since 1960 and progressively more so, could lead to debt service problems. Coffee exports have not met the projected goals in 1970/71 or 1971/72. As coffee is the primary source of foreign exchange, this shortfall has a significant impact on the ability of the IEG to repay external debt.

G. Dedicated Funds

The dedication by law of certain classes of revenues to specific, circumscribed programs has been debated by many governments and resolved in various ways. The objective is usually to assure the funding of some sector which is recognized as important and continuing. The justification is usually that the revenues are derived from a closely defined group of taxpayers of particular purchases and related activities, and that these taxpayers should be the primary beneficiaries.

The equity and efficacy of "earmarking" funds are questions more in the realm of governmental science and broad economics than that of

EXHIBIT XIV-7

IEG OUTSTANDING INDEBTEDNESS AS OF JUNE 30, 1971 (EFY 1963)

Direct and Indirect Indebtedness by Domicile of Lenders,
in Thousands of Ethiopian Dollars

	Outstanding Indebtedness	% of Sub-Total	% of Grand-Total
Multilateral			
IBRD	128,979	67.6%	25.0%
IDA	61,930	32.4	12.0
Subtotal	190,909	100.0%	
Bilateral			
United States	172,602	53.2%	33.5%
Soviet Union	30,827	9.5	6.0
Czechoslovakia	9,839	3.0	1.9
Yugoslavia	7,835	2.4	1.5
Federal Republic of Germany	17,845	5.5	3.5
Belgium	704	.2	--
Italy	63,528	19.6	12.3
Japan	768	.2	.1
Netherlands	8,798	2.7	1.7
Spain	9	--	--
Sweden	9,706	2.9	1.9
Switzerland	885	.3	.2
United Kingdom	1,222	.4	.2
Subtotal	324,568	99.9%	
Grand Total	515,477		99.8%

Source: Imperial Ethiopian Government, External Debt, 30 June, 1971 (EFY 1963) Page 21.

EXHIBIT XIV-8

GROWTH OF IEG OUTSTANDING DEBT

Debt by Years in Millions of Ethiopian Dollars

Year	IEG Outstanding Debt			Annual Increase
	Direct	Indirect	Total	
1964	171.7	28.1	199.9	
				12.1
1965	179.9	61.4	241.3	
				12.3
1966	194.7	102.7	297.4	
				10.9
1967	211.2	112.7	323.9	
				11.8
1968	220.3	162.8	383.0	
				10.9
1969	256.9	163.4	420.3*	
				11.0
1970	269.4	195.0	464.4	

*Excludes Repayment of about E$85.0 Million on Loans fully re-paid in previous years (i.e. loans from Yugoslavia, U. K. and Italy)

Source: National Bank of Ethiopia, Quarterly Bulletin, No. 34 (92), June 1972 Page 64

EXHIBIT XIV-9

REPAYMENTS COMPARED TO EXPORT EARNINGS AND DOMESTIC REVENUES

Monetary Amounts in Millions of Ethiopian Dollars

Year (December)	Repayments			Earnings from Exports and Re-Exports	Repayments as Percent of Earnings	Domestic Revenues	Repayments as % of Domestic Revenues
	Direct	Indirect	Total				
1964	13.0	0.7	13.7	262.5	5.2	373.1	3.7
1965	13.7	2.4	16.1	289.8	5.5	417.4	3.9
1966	15.8	5.8	21.6	277.0	7.8	431.4	5.0
1967	16.2	10.1	26.3	252.7	10.4	429.1	6.1
1968	19.6	8.6	28.3	266.0	10.6	458.3	6.2
1969	23.1	9.3	32.4	298.1	10.9	490.1	6.6
1970	20.3	18.1	38.4	305.8*	12.6	Not applicable	

*Exports and Re-exports Figure for 1970 from Quarterly Bulletin, Page 46.

Sources: Repayments - National Bank of Ethiopia, Quarterly Bulletin, No. 34 (92), June 1972, Page 64.
Earnings - Statistical Abstract, 1970, Page 89.
Domestic Revenue - Statistical Abstract, 1970, Page 121.

highway engineering. Consultants from the United States are inclined to favor the dedication of highway user charges to road programs because that method of financing has been a key factor in the development of a highway system which is generally adequate, safe and efficient, and which has contributed enormously to the national development. The present controversy over justification and uses of the U.S. "Highway Trust Fund" and other user revenues was not heard during the years when there were still obvious, widespread deficiencies in the extent and standards of that system. Significantly, there is little opposition now to financing procedures which are often similar, and which are directed to the urgent improvement of airports, navigation and control facilities, and other improvements required for safe and efficient air travel in a time of exponential growth in demands.

It is recognized that programs of government other than those for highways are just as necessary to overall economic and social progress - education, agricultural development, communications. There is an unending list, and they all require funds; money which must usually be raised by imposing levies on the various sectors of the active economy.

Nevertheless, it is believed that there are special and persuasive arguments for insuring that highway agencies have known and predictable sources of funds, in any nation where it is generally agreed that the road network is not yet sufficient and must continue to grow, and where the existing system is to be maintained.

First, important highway projects require a very long time from the initial, tentative investigations to their completion. They must have continuous, reliable budget support through all the stages of preliminary route studies, feasibility studies, programming, location and design, materials investigations, right of way, contract preparation, scheduling, and the long process of construction. Major road sections will take a minimum of five years to go through this chain of events. It is sometimes substantially longer. If the financing is interrupted or long delayed at any stage, the prior investment may be partially or entirely lost. The financial requirements mount rapidly in the progressive stages, so that the possibility of interruption in the more distant future phases carries

the greatest risk of loss. Highway projects (in common with many others) need long-term planning, with assured funding.

Second, major road improvements are usually subject to demonstrations of economic feasibility. This is not intended to imply that programs of education and public health, for example, should have a less systematic financing because their benefits are more difficult to quantify. Further, the absence of a comparison base make it impossible to say that any proposed road, regardless of its net benefit picture, is the best investment that can be found. Nevertheless, to the extent that good feasibility can be shown, the state is assured that highway improvements will make positive contributions to national progress, and that they are not controversial experiments in the use of public funds.

Finally, roads have to be maintained, if the benefits assumed for their feasibility are to be realized, if the users (and the nation) are not to suffer a "hidden" tax in the form of higher operating costs, and if the investments are to be protected. Existing highways represent a standing obligation in maintenance costs which is not variable from year to year, except for a slow increase from the effects of age. Further, the moment a firm decision is made to construct a new road, an obligation to maintain it is entered on the hypothetical budget sheet of some future year, and for all the years thereafter. In an orderly management process, it should also be entered on some real "future book", and compared with the projected funds which will be available. Naturally, all physical facilities have to be maintained, whatever their nature. The distinguishing characteristics of roads in this regard is that they are very long and almost insignificantly narrow ribbons, imposed on nature and, to a large extent, in conflict with natural forces. This conflict is much greater than that for, say, a buried pipeline or an electrical transmission line. The environments for dams, buildings and airports can be chosen and controlled with much better success, as they are for highway bridges, on which unit maintenance costs are usually much less. The point of this is that the annual maintenance of large road systems is very costly, and if the necessary funds are not forthcoming, when needed and without

arbitrary debate, the consequences are certain, and they are normally unfavorable to the general economy.

The fundamental matters of revenue dedications, and national policy on budget approvals and fund allocations, are beyond the scope of this report. However, the Consultants feel that the overall national interest might be well served if the IEG were to give serious consideration to the following views:

1. Highway user revenues should, by law or at least by fixed policy, be devoted and reserved primarily for the support of highway programs.

2. The total amounts of such revenues, actual or projected, should not be considered as fixing the maximum or the minimum of highway expenditures in any year. Funds in excess of those required for clearly justified programs should be put to other uses. Additional monies need in exceptional circumstances, as for the rehabilitation projects of this study, should be made available from other sources.

3. The maintenance of the road system should have a first and automatic claim on available user revenues, subject only to the determination of maintenance budget requests by a rational process. In this manner, the adjustment of final budget amounts should be based on questions of fact and interpretation of technical variables where these exist. The success of this procedure would obviously depend on the IHA making effective use of the funds provided and faithfully performing the programmed maintenance.

4. From the user taxes not utilized for maintenance, the obligations for projects under construction or previously committed should be met next. The reasons for this need no explanation. If the user revenue balances are not adequate, supplementary allocations should be made.

5. Remaining funds of this category should be devoted to highway projects of demonstrated feasibility or to support other programs of development requiring highway access, such as new agricultural schemes.

6. Highway expenditures, including maintenance, should be estimated and tentatively programmed for five-year periods beyond the current year, and compared with projections of user revenues, as a guide to planning and budgeting.

Section XV

ENGINEERING IMPLEMENTATION

Throughout the foregoing sections of this report, a number of engineering-related recommendations have been stated or implied, many of which will require positive action on the part of the IHA or others to put the defined programs into effect. Some of these measures are necessary to the regular maintenance and road rehabilitations as described, in order to achieve the improved highway conditions and the corresponding benefits which would follow. Other steps and alternative actions offer the potential for reductions in costs to levels even lower than those estimated, so that net benefits could be further augmented and capital expenditures decreased to some extent. Some improvements in procedures would be less subject to quantification in monetary terms, but could result in more efficient management and operations in maintenance, and a better appreciation of the costs and effects associated with the program.

A. Maintenance of the Highways

1. Administration and Control

Ethiopia is a large country, and its road system is necessarily extensive. As presently constructed and planned the system has, to a remarkable degree, a tentacular form. It consists of routes radiating outward from Addis Ababa to other centers of population and development, and then further radiating from those regional centers to lesser areas of some economic activity. There is an almost total absence of connections between the tentacles, which would serve to form a grid, or web, of highways. The road distances to the regional centers are great, and often cross formidable natural barriers. Travel is slow. Voice communication is imperfect. Exchanges by mail take time. Telegraphic messages are necessarily brief and of limited information content.

In these circumstances the direction of an orderly maintenance program is difficult. Heavy reliance must be placed on the District Engineers; on their professional capacities, their personal initiative, and their willingness to make and carry out decisions. The present maintenance operations are functioning surprisingly well in view of these obstacles and the demands on all the individuals involved, but there is also an obvious need to strengthen and unify the program. Clear direction has to be given to the District Engineers, uniform practices and standards should be established, the operational headquarters must be informed of what is happening, and the District Engineers then have to know whether they are doing the right thing.

Since the distances cannot be shortened (instead they are constantly increasing, as the system is expanded outward) and other communications will only improve gradually, better maintenance administration will have to come through the best possible instruction, more effective information exchange and, above all, increased personal contact between headquarters and the districts, and among the District Engineers.

a. Headquarters Staffing

As of June, 1972, the authorized administrative staff for the IHA Maintenance Branch consisted of the following positions:

- Chief Maintenance Engineer
- Three Area Engineers
- One Secretary
- One Driver

Only one of the Area Engineer posts was filled at that time, with the incumbent stationed in Asmara. The other two positions had been vacant for about four years.

In addition to the authorized staff, one Engineer-in-training was assigned to assist the Chief of Maintenance, on a temporary basis, in the Addis Ababa Office. This engineer had then been on "temporary" assignment for approximately 1-1/2 years. Under the usual personnel

procedures, permanent assignment is made after six months of satisfactory performance, and thereafter the employee accrues time in-grade under the Classification and Salary Plans.

In substance, then, the headquarters direction of the IHA maintenance program in 1972/73 was being carried on by the Maintenance Engineer, one assistant without official status, and a secretary. Regardless of whether this is considered to be a line or a staff function, the Consultants had to regard this staffing as being totally inadequate to the needs of the program. The assignment of the Chief Maintenance Engineer as the principal IHA Counterpart in this study placed further demands on his time, and it was observed over a period of months that his position is charged with a burden of responsibility and sheer volume of work which cannot possibly be met adequately by this small force. The fact that a cohesive maintenance program was nevertheless being carried on with reasonable success must be credited, in the opinion of the Consultants, to the abilities of the incumbent Maintenance Engineer and the respect and spirit of cooperation which he has earned from his subordinates.

Section II-F of this report recommends the establishment of an "Operations Planning Engineer" position within the Planning and Programming Division. One of the two basic responsibilities of this post would be Maintenance Program Planning, founded on rational methods similar, perhaps, to those employed in this study. The adoption of this measure would relieve, to some extent, the workload which now falls on the Maintenance Engineer. Nevertheless, the preliminary preparation of budget requests could only be done logically by having the submissions of the District Engineers reviewed and correlated first by the operational supervisor of field programs, the Chief Maintenance Engineer. In addition to this major task, there would remain the primary responsibility of directing, coordinating, scheduling and monitoring the operational activities of field maintenance.

It is recommended that a full time authorized position be established to provide the Maintenance Engineer with an office engineer assistant who would deal with the large volume of reports, correspondence,

data assembly, and work program preparation necessary to maintenance administration. At least one clerical aide should also be authorized.

The protracted vacancies in the two unfilled positions of Area Engineer suggests that this omission has not been felt too strongly. Further, it has been the experience of the Consultants that such an insertion of an intermediate level of supervision away from headquarters is not especially effective unless communications are very good and the area engineers are in frequent contact with the main office. These conditions are not within practical reach in Ethiopia.

If the Area Engineer now stationed in Asmara fills an important role in the supervisory chain for maintenance, then this position should not be disturbed. It is recommended, however, that in addition to this individual, or in lieu of the Area Engineer scheme, the Chief Maintenance Engineer be provided with an assistant engineer for field operations. The role of this assistant would be to travel widely, inspect road conditions and maintenance activities, monitor the progress and problems of the districts, assist in organizing special projects like rehabilitations, coordinate activities which cross district boundaries (e.g. materials production and temporary equipment transfers), and represent the authority of the central office in establishing standardized and adequate maintenance practices. The existence of such an assistant would permit the Maintenance Engineer himself to travel the system on occasion, a crucial necessity.

It is recognized that the IHA is sparsely staffed in many of its branches, and exercises a commendable economy in limiting its administrative forces. Nevertheless, the maintenance function is a vital one. It needs stronger direction and coordination that can be supplied by the small group now charged with the accomplishment of its programs. The above recommendations are believed to be a minimum for successful administration.

b. Field Staffing

It has previously been pointed out that it would be desirable to have professionals in all District Engineer positions and to

fill the subordinate administrative level posts in the districts when this becomes possible (Section II). Also discussed were the minimum staffing for the various maintenance activities and the needs and scheduling for technical training (Section XI).

2. Information Flow

The districts need to be advised with unmistakable clarity what programs they are to accomplish and what resources they will be given to do the job. This should include instruction on what operations and activities are not authorized, where any doubt exists. The District Engineers, in turn, must have channels and means for presenting questions regarding their programs and for making their problems known. Finally, progress and expenditures must be reported regularly to headquarters, for work control, fiscal accounting, and to assist in planning future operations.

The initial outflow from the central office is simplified and made most effective through well-planned and clearly stated annual programs and by the use of written, formalized policies defining authority and covering the utilization of resources and the separation of maintenance, betterment and construction. Interpretations and questions are best handled, whenever possible, by personal contact and through meetings, because they are often complex and related to special circumstances difficult to present in letter form. Decisions of general import should be formalized in writing.

At present the third element, program reporting, requires from the districts an excessive volume of data and paperwork in various forms, in both regular and special reports. Often, this must be prepared under the direction of the District Engineers and supervisors, taking time from their primary functions, or done by subordinates with less understanding of what is required and less reliable results. The problem is believed to arise, in part, from some uncertainty about what form and detail is really essential for program control, and what use should be made of the data.

a. Progress and Cost Reports

This matter is extremely complicated, and has been a problem for all maintenance administrations through the years, however stable and well-developed. It continues to be a problem. Progress and cost reporting for any particular system is properly a subject for extensive, separate study, but it is hoped that discussion of the fundamentals and some general guide-lines can be of assistance at this time. Three principles apply:

- The reporting of physical work and the costs of the work are really separate matters, but they can and should be combined at the field level so that they will be related and duplicate reporting will be avoided.
- Fiscal accounting and cost accounting are distinct efforts. The first tells how much of a particular budget allocation has been spent (supported by payroll records, purchase receipts, etc.) and how much remains in the allocation. Cost accounting answers the question of how much it costs to accomplish some objective, whether it is the seal coating of one kilometer of asphalt or the full maintenance of a specified type or section of road.
- Report information must be structured in a manner which will show first, what kinds of work were done and, second, what the elements of cost were. There is then a third choice regarding to what extent the records should show where the work was done.

In substance, the management of a road maintenance program requires the classification of its several functional activities within basic descriptions of the types of work associated with each activity. The resulting detail is essential to programming, budgeting, determination of program accomplishments, and as an essential foundation to any future plan for managing through performance standards. Under ideal conditions, programming, budgeting and an assessment of program

accomplishments would be supported by cost accounting. These accounts would record and report the costs of road maintenance for each functional activity and for each class of expenditure applicable to the associated types of work.

In the present IHA maintenance accounting, there is no cost reporting of program accomplishments except in terms of budget expenditure classifications applicable to specific road sections or projects. Statistical reports are, however, supplied by the District Engineers, correlating data on maintenance work accomplished with work programs authorized on specific maintenance sections. This data is not keyed within the system to cost information. Further, the reliability of the data must be considered debatable because the units of measure, in a number of instances, require engineering calculations, a capability that is not assured at the source of the data, namely the field maintenance crews.

In the Consultants' judgment there are alternative cost procedures that could provide the IHA with more meaningful and reliable reports on road maintenance programs. Briefly, these procedures should develop standard costs of personal services, identified major items of materials, equipment use, and appropriate indirect and overhead expenses. The costs so reported should, in turn, be related directly to maintenance district and section, road class, surface type and major and subclassifications of functional activities. Both the principal and subordinate classifications of maintenance activities would be defined, in terms of the types of work to be done. Exhibit XV-1 of the Engineering Appendix presents the Consultants' views of basic program reporting requirements consistent with the IHA's potential to implement within a reasonable period of time. Recommendations 2-a and 2-g of Section XIV-D are suggested as administrative actions essential to the development and operation of procedures for reporting road maintenance programs classified in principle with those indicated in Exhibit XV-1.

It is also the Consultants' opinion that development of a more detailed analysis of program costs and accomplishments should proceed on a selected study approach. This not to deny a management need for

information on a wide variety of additional operational and work type characteristics. It is to affirm, however, that management should avoid demands for repetitive reporting of more than is basic in form and content and reasonably assured in terms of timeliness and reliability.

3. Maintenance Practices

In general, it appeared to the Consultants that maintenance methods in Ethiopia are based on sound, established practice. There were instances, however, where it was observed that some activity was being neglected or work quality was poor, and although the overall impression gained was one of diligent effort and productive use of the available resources, much remains to be done to increase the effectiveness of maintenance.

Apart from the ordinary requirements for surfaces and drainage, there were three very common conditions noted in the course of travel which adversely affect the safe use and the preservation of the roads:

a. The shoulders along paved routes are usually inadequate in dimensions and conditions. Naturally, this is partly due to original construction standards, but it is also true that the shoulders have often been worn and eroded away without the lost material being replaced. This is especially true where there is heavy use of the shoulders by pedestrians and domestic animals.

b. In many areas of rolling and mountain terrain, the primary ditch maintenance is not sufficient for the full protection of the roads. The initial construction of limited ditch sections coupled with the equipment shortages of recent years have frequently reduced the ditches to small sinuous channels of inadequate cross-section, dug and cleaned by hand through detritus and around fallen boulders. Those which are too small in capacity, and too high in grade to de-water the roadway base layers, are not performing their intended function. Even after the arrival of more loaders and graders it will still not be possible to reshape all of this ditch length by machine; steps should be taken now to improve the engineering control and general standards for this work by labor forces.

c. The pit-run materials now used for surfacing gravel roads commonly have, as reported previously, large quantities of oversized stone. After this has been hauled and placed on the road it immediately constitutes a disposal problem. Often, it has simply been bladed into a windrow of coarse rocks and left on one shoulder of the road. There it reduces the effective width of the roadway, impedes surface drainage, and represents a considerable hazard for vehicles.

Hopefully, under the recommendations of this study the problem would be alleviated by the discovery of new materials sources and the processing of gravels for some roads. For low-type roads and for circumstances where crusher use is not warranted, it would seem to be preferable to treat the problem at the pit site and not on the road. To provide final surfacing, loading chutes and gravity-cleared grizzlies could usually be provided at reasonable cost.

For those road sections where a serious existing problem has resulted from a combination of windrowed stone and narrow width, it is believed that a special corrective effort would be justified. Obviously, just blading the oversize into the ditches will not offer an acceptable solution. Where it can be bladed off the road on to fill slopes without blocking drainage channels this should be done. In some cases it may be possible for labor crews to throw the oversize beyond the ditches without causing some additional, future problem with cultivated lands or surface drainage. In other circumstances it may be necessary to pick up the windrows with loaders or labor crews and dispose of the oversize at the nearest suitable locations.

4. Advisory Services and Training

With respect to general maintenance supervision and methods, the Consultants did not identify any areas where specific technical assistance was required. However, it appeared that it might be extremely useful to organize some "pilot programs" covering overall regular maintenance, with professional guidance by consultants. One such program might be set up for asphalt maintenance, including patching, shoulder rehabilitation and seal coating, and a second for gravel roads to include

surface grading, ditch maintenance and organized regraveling under controlled conditions. In such pilot operations, key personnel could be brought from two or three contiguous districts to see demonstrations of scheduling the work, collecting the required forces and materials, the most efficient use of equipment, and the control and reporting of results. Direct participation by IHA supervisors and crews would be an essential ingredient, on projects chosen from the regular maintenance programs. Selected IHA operators could demonstrate the equipment use and other procedures, with the outside assistance limited to perhaps one team leader and two specialists. No further detail is offered at this time because it would appear impractical to set up such pilot operations until a reasonably adequate equipment fleet is on hand.

5. Maintenance of Low-Type Roads and Trails

Branching from the main road system of Ethiopia, and extending beyond its outer limits, there are many kilometers of old trails, vehicular tracks, partially constructed roads, and penetration or access-type routes of varying standards. There is, further, a wide-spread feeling among agencies concerned with rural development that many more roads of this class are needed. The questions which arise are: Who should build or improve roads of this type? What standards should they have? How should they be funded? What king of maintenance is justified? Who should be responsible for them?

The problem is common to most developing countries. Where local government is not organized to provide general public services, with the requisite taxing authority plus administrative and technical proficiency, there is a universal tendency to turn to the state for money, engineering advice, and direct help in the form of equipment use and materials. The local forces of the highway agency are highly visible on the main roads, they are known to the provincial officials, and they have knowledge, machines and other resources which could solve the local problems.

In different countries, the reaction of the state has varied from total rejection to total acceptance of this area of responsibility, but usually it has been something in between. The highway agencies themselves have almost always resisted participation in such programs, and are almost always criticized for their attitude.

In the experience of the Consultants, this nearly universal reluctance on the part of highway administrators is founded on several very real concerns, not easily articulated, about the effects and the effectiveness of extending their efforts beyond the main roads.

The General Road Study inventory of Ethiopia covered some 16,000 km, indicating the existence in 1969 of almost 10,000 km outside the maintained system. Which of these routes should be taken over by the IHA? New accesses are being built or opened all the time. Do the new ones have any better claim to state upkeep than the old ones? What are the criteria for decision?

During the past few decades highway engineering has expanded beyond the techniques of location and construction and beyond the calculations of engineering economy. The concepts of feasibility, and of comparative feasibility, are now a firm part of the discipline. So long as traffic volumes, existing or predicted, are large enough to furnish a rational guide to the relative importance of roads, the engineer and the transportation economist can assess the worth of their projects. When traffic drops below a basic threshold and no longer seems to justify a road in terms of vehicular usage, the engineer finds himself subjected to claims of social, economic and political justification which are unfamiliar and not quantifiable in terms he knows. If these claims were convergent and mutually-reinforcing they might offer a substitute guide to action. They are not.

The body of law of any state must normally include provisions limiting the ways and places in which public resources can be used. For highway agencies, this usually takes the form of a defined system of roads on which the entity is authorized to expend funds, and beyond which it may not. If the system is formally extended to include low-standard roads the highway administrator has, at least, the reassurance of legality,

a security which is not by any means universally provided to such administrators. Even so, if the traffic is minimal the question of how much expenditure is justified may remain as nebulous as before, but it is almost always considered to be a technical matter for the highway administrator's decision.

In addition to these questions of propriety and justification, the engineer is often disturbed about the effectiveness of applying engineering to very primitive facilities. Frequently, at the lowest level of usage, it is not a road which is needed, but simply access. Nevertheless, in these cases, it is not the easy part which the engineer is called on to build or keep up. Enterprising truckers and local groups will open their own trails over dry plains and rolling hills. It is at the mountain crossing or the unfordable river where the engineer is needed, and the effort required to complete the simple access may cost just as much per unit of work as on a primary highway. Five-ton capacity bridges will not do even on a trail if it is possible that a 15-ton truck will attempt to use them. Engineering design on very low-standard mountain roads is more difficult and expensive than it is on primary highways in the same terrain.

Finally, there is a serious problem of logistics involved in using the facilities of national highway agencies on local roads. Usually, not much machine-time or other effort is called for, especially to do occasional simple maintenance, but it is usually needed at the end of the logistic chain. Few of the access roads are around the district offices, where a few equipment units might be spared without too serious effect; such roads are more likely to be beyond the last section camp, the organizational unit least able to assist. Either that camp must be given excess resources for the purpose, or it must partially neglect its primary responsibility, or resources must be transported out from locations where they are in better supply. None of these choices is efficient or economical.

This study is not required to seek a general solution or recommend a policy for local roads in Ethiopia, but it is the opinion of the Consultants', based on observation of the programs adopted in other countries,

that local roads should be left fundamentally to local authority and initiative. If consistent with national policy and law, the provincial governments should be provided with some source of revenue for this purpose. Limited technical assistance should perhaps be provided by the IHA, about at the present level. Care should be taken to have program decisions and the organization of such assistance made at the central office level, and to protect field forces, especially the District Engineers, from the necessity of resisting local pressures or diverting resources from their assigned responsibilities. In the building and upkeep of minimum-standard roads by local initiative, under the most difficult of circumstances, the long experience and broadly successful results of Bolivia may be of interest to the IHA and, particularly, the IEG.

The Consultants did find it pertinent to consider what kind of maintenance effort might be appropriate for very low-standard roads if it became necessary. Obviously, the requirements would vary through an extreme range, involving anything from tracks across gravelly deserts to the most difficult of mountain trails. Two general types of work were described previously (see Section III-C-3-i) and Estimate Sheets are included in the Engineering Appendix for these assumed operations. The Estimate Sheets are identified as being for the "Intermittent Maintenance of Earth Roads", special work items for road types "X" and "Y". The type designations are arbitrary and have no particular significance.

Basically, the assumed crews and minimum equipment are intended for temporary assignment in opening roads which have been closed during a rainy season, or have otherwise become difficult or very costly for vehicular travel. The Consultants have observed this kind of maintenance and restoration of service on seasonal roads in various countries, although the forces and methods employed may differ considerably from place to place.

There is little more to be said about such minimal maintenance. Unless a specific set of conditions is posed there is no basis for estimating justified frequency of repetition, cost per kilometer, cost per unit

of traffic, or any other meaningful index. The objectives of such efforts are normally to clear obstacles and improve the quality of the travelway surface to a minimum standard. The most common problems are those associated with water damage; washouts, saturation of the travelway and deposits of mud or other substances. Aside from clearing and reforming the travelway, the work usually consists of draining and stabilizing the road, which sometimes requires raising it above or moving it away from unstable ground, or adding material which is stable even when wet.

B. Equipment Use and Repair

1. Training

It is believed that the productivity of equipment could be somewhat increased and various problems avoided by making some revisions and additions to the operator training programs of the IHA. There seems to be a need for more orientation toward field problems and conditions, and toward care of the machines and recognition of incipient failures or malfunctions. Any equipment training instructors who have not had extensive experience on actual maintenance operations should be given that experience.

In addition, it would definitely be very useful to foremen and other field supervisors who were not previously operators, or who had only limited experience as operators, to gain a better knowledge of machine use, capabilities, and problems. Special or short combined courses should be devised for this purpose.

2. Servicing and Inspection

The necessity of improving these programs is well known at all operational levels, and no extensive comment is needed here. A more effective care and checking of the units on a systematic basis can pay big dividends in equipment utilization. Too much dependence should not be placed on the District Shops for this service. Instead, the system should be organized to have a maximum amount of the servicing done at the work locations, even for very mobile equipment. It is certainly imperative for tractors, rollers and similar units.

3. Equipment Repair Program

a. Personnel and Management

It is expected that improvement will continue progressively in the reduction equipment down-time and in returning units to service if sufficient personnel are made available and the supervisors are supported in all the other factors necessary to this program.

b. Shops and Facilities

Completion of the new District Shops and the installation of tools and shop equipment should give a substantial boost to this effort. Attention should turn next to providing some limited facilities and shop personnel at strategic locations other than the district headquarters. Teseney now represents a site which cannot possibly be served economically from the District Shop. Some specialized services will probably be needed in the future on the Awash-Tendaho-Asseb Route. Lekempty is now distant from effective support and, of course, inaccessible from its district headquarters. In the more distant future, some minimum facilities should be provided south of Shashamane, perhaps at Yabelo, and at other locations such as Degehbur or Kebre Dehar.

c. Spare Parts and Supplies

It will obviously be of crucial importance to improve the availability and flow of repair parts and the supplies of filters and other materials for equipment servicing. There is no doubt that weaknesses in this field have, during recent years, been the cause of great losses of machine time and considerable loss of equipment investment.

Ethiopia is not in a favorable position for obtaining parts and related materials. No important items are manufactured locally or in neighboring countries, the distances to European and U.S. supplies are great, and surface transportation is slow. The total equipment fleet of the nation, government and private, is not large enough to support big stocks of parts by commercial dealers. As stated previously in Section VIII-C, for the machine makes now owned by the IHA in significant numbers, there are only two representatives who offer parts for

direct purchases; Mercedes and Caterpillar. One other dealer, Fiat, has good supplies and service, but the IHA fleet includes very few Fiat machines. Two representatives for U.S.-made trucks have established facilities, but almost no parts stocks. For great numbers of trucks, tractors, loaders, rollers, and other units there are no parts on the market.

It is certainly to be hoped that this situation can be improved in the coming years, by encouraging existing dealers through increased parts purchases and by requiring that bidders for the supply of new equipment (in reasonably large numbers) provide in-country service. It is understood that, until recently, this was a stipulation for bidders. The Consultants recommend that this be reinstated as an obligation for successful bidders, with adequate bonding or other measures to insure compliance. Until there is significant improvement in the local parts supply, the IHA will have to continue relying on its own bulk purchases and warehousing, which is both complex and expensive if all costs are figured.

The IHA procedures on parts cannot be termed satisfactory at present. As stated in Section VIII, the parts stocks themselves, the warehouse control, and the issue process are all showing serious deficiencies. Various recommendations could be offered to better this internal situation, but the nature and gravity of the problem have been recognized, and the Consultants were informed that another expatriate advisor will be added to the HERF group in November, 1972, to assist the Supply and Equipment Division. His specific function will be to help improve parts supply and warehouse management. It is expected that this step will help remedy the most persistent problems in this critical function.

d. Equipment Availability Factors

If the equipment repair program continues to have energetic management and the measures discussed above are realized - adequate personnel, improved routine servicing, new shops, better parts supply - the availability of equipment should be raised significantly. It is

impossible to assess the total effects in absolute terms, but it seems reasonable to expect that the factors for normal mechanical units (trucks, graders, loaders, etc.) might be increased from the present estimated 65% to a future 70% to 80%, with a middle range of 75%. The potential benefits of this improvement are described in Section XVI.

C. Equipment Standardization

It is apparent that some of the operational difficulties and costs of equipment usage could be reduced by simplifying the makeup of the fleet. Having a great variety of machine makes, models, sizes and modes of operation complicates servicing and operator training, decreases work efficiency and raises failure rates to some degree and, above all, multiplies geometrically the requirements for parts stocks, service supplies, operation and repair manuals, parts catalogs, and parts identification and control. These are serious and costly drawbacks in an operational program already beset by problems of funding, operator and mechanic training, and management of complex logistics support. The situation is a familiar one in public agencies, and produces a strong desire to reduce the welter of machine types and move toward greater uniformity.

In the private sector, contractors who are in a position to do so will often accept higher purchase costs and sacrifice some advantages in machine alternatives in order to standardize their equipment fleets. However, this option is not freely available to public entities, and there are sometimes real disadvantages in over-standardization. Too much dependence on a few parts suppliers has its dangers, and an established policy of standardization may result in somewhat higher bids from the favored companies for the furnishing of new units. The difference in costs may be more than the economies gained, the true cost comparisons are extremely hard to compute, and even approximations may not be known until months or years have passed. Furthermore, no company offers all the equipment types needed by a maintenance force, and desirable machine features are frequently obtained only by mixing fleets. As one example, all-wheel-drive and -steer graders have been found to be very useful by some agencies for work on narrow mountain roads, but they

are offered by only a few manufacturers with a limited range of other machines. Also, too much reliance on adopted makes will sometimes cause an agency to forego a very useful development by another company.

Along with reducing fleet variety, it is equally important for public entities to avoid new purchases of low-bid equipment which has given unsatisfactory service in the past. Some of the obstacles to this goal are similar to those which stand in the way of standardization. First among them is the fundamentally logical need to protect the public interest by making acquisitions through open, competitive bidding, with award to the lowest responsible bidder. This is usually a requirement of law, in some form. A second restraint on the free choice of purchasers applies when external aid funds or barter arrangements are involved. Selections may be limited to the products of a single foreign power or, in the case of multi-lateral agencies, it may be necessary to give all member nations an opportunity to have their manufacturers present bids, under policies which strongly favor award to the lowest bidder.

There are, however, means of moving toward fleet uniformity and avoiding unsatisfactory equipment without prejudice to the public interest or violation of law and policy. The first is the judicious use of specifications. The equipment descriptions used in advertising must, in any case, be written with care to insure that the units procured will meet the needs of the agency. It is not improper to have the specifications also exclude machinery with undesirable qualities or characteristics. As a second measure, recent years have seen the appearance of "total cost bidding", a process which attempts to take into account not merely the first cost of equipment, but also its upkeep during a specified life and, in some cases, its resale value at the end of that time.

The Consultants believe that the IHA could benefit somewhat from a reduction in equipment varieties, but that the potential savings are limited. A review of Exhibit VIII-19 shows that, of the present equipment expected to remain in service, there are only five makes of dump trucks, and one make (Fiat) made up only 7 units of the 275 total. The crawler tractors are from two manufacturers, as are the motor graders. Front-end loaders are from only three sources. There is more variety in the types of rollers, but it is still not extreme, and even greater

variation exists in the makes of air compressors, which is of minor significance. The asphalt distributor and relay trucks are all of one make, and standardization of the remaining equipment is of little importance.

It is not overly inefficient for an organization the size of the IHA Maintenance Branch to have four different brands of dump trucks, and the other major items offer few opportunities for simplification. Certainly, it would be highly desirable not to further increase the mix of dump trucks, loaders, or rollers with the recommended new acquisitions. It is strongly urged that, in these categories, the procurement should be from manufacturers already represented in the fleet if at all possible. Different makes would be of less critical concern in the new crawler tractors, graders and asphalt trucks, though it should certainly be avoided if the cost penalty for standardization would not be more than, arbitrarily, 4 or 5%.

No means was found for quantifying potential benefits from standardization, since the present dispersion of makes is not excessive and there is no way of knowing what would be the differential acquisition cost for avoiding further variety in the future. This differential will depend on the bids received, and the higher cost, if any, necessary to preserve fleet uniformity will have to be weighed against the alternative increased costs for operator and mechanic training, increased parts stocks, and other factors.

D. Rehabilitation Program

The estimates of cost for carrying out the contract portions of the rehabilitation projects included a figure of 8% for engineering supervision. The personnel necessary for this supervision were not quantified with the IHA labor forces, and implementation of the program will require that engineers and technicians be provided to control the work. This would include overall supervision by resident and chief field engineers, control surveys, inspection and measurement of the work, and laboratory testing. It was estimated that the cost using IHA forces, if they can be supplied, would be on the order of E$520,300. As an alternative, an estimate was prepared for supervision by outside consultants at a cost of US$136,200

plus E$193,600 in local costs, or an equivalent total of approximately E$508,800. Vehicles and drivers for local transportation were excluded in both cases.

E. Materials Search and Production

1. Exploration Program

One of the most urgent actions necessary to implement the recommended maintenance program is an organized search for suitable materials to be used as surfacing on the high-type gravel roads. In broad outline, this would consist of a study of available aerial photography in a band along the subject roads, by a geologist trained in photo-interpretation for materials discovery. This would be followed by field verification and more detailed exploration, with auger borings, visual classification of the materials, and laboratory testing of samples. Maps of the site locations would be prepared, along with reports of the results.

Unless the IHA organization includes personnel with professional experience in this work, it is recommended that the study be done by consultants. It was estimated that the program would require the following team:

Position	Number	Man-Months
Geologist	1	9
Soils Engineer	1	6
Laboratory Engineer	1	5
Office Engineer	1	9
Soils Technician	1	6
Laboratory Technician	1	5
Draftsman	2	12

The estimated cost for the study would be about US$55,000 plus E$85,000 in local expenses, or a total equivalent cost of approximately E$211,500. The estimate does not include vehicles and drivers for local transportation, nor the cost of some test pits and trenching by

dozer which might be required. If the available photography is not satisfactory for interpretation, or if coverage is not complete, this would represent an additional cost.

Whether done by local forces or by consultants, the study report should include recommendations for the exploitation of the material types encountered, and a definition of the new equipment acquisitions to carry out the materials program.

2. Crushing and Screening Plant Operation

It was observed in the course of the Maintenance Study that the existing materials production facilities of the IHA are usually operating at very low efficiencies. This often presents a serious handicap to maintenance activities and prevents the completion of scheduled work. The problem has been recognized, and expatriate advisors of the present HERF group have been pressed into service to assist in organizing quarry procedures and crushing/screening plant operations, and in training IHA personnel. This has produced notable improvement in production rates at a limited number of plant locations, but it was understood to be, in some respects, outside the originally-defined scope of the HERF Project. It is the opinion of the Consultants that this technical assistance should be formalized and considerably expanded. It would be highly useful to have the demonstration of methods and the training of quarry and plant operators extended to all highway districts, and to have the effort cover select-material pit operations as well.

Section XVI

ESTIMATED ADDITIONAL BENEFITS

A. Postponement of Maintenance

The contract for this study requires an evaluation of what benefits would result from postponing maintenance expenditures on the roads. The discussions in previous sections regarding the benefits of following the recommended maintenance practices and the ranking of the road systems demonstrate that there is adequate justification for the maintenance as described, and that the incremental cost of maintaining the entire proposed system is minimal. In any given year the economic benefits outweigh the costs. There is a sufficient excess of "road user tax" revenues over the IHA expenditures to justify the added program costs. Given these considerations, it does not appear reasonable to contemplate the postponement of maintenance on a system-wide basis.

Postponement of maintenance seems to have been the practice in Ethiopia. This is evidenced by the present condition of the roads and the number of rehabilitation projects that are required to bring the system back up to normal standards.

Attempts to investigate the effects of deferred maintenance on individual segments proved infeasible for several reasons. First, maintenance cost in Ethiopia is more a function of climate and terrain than it is of traffic, as suggested by the calculations in Section III for the development of estimated costs. Traffic on most paved sections is relatively low and causes negligible damage to these roads if adequate maintenance procedures are followed. Weather alone has pronounced effects on gravel roads. It becomes obvious that attempting to use low VOC savings to justify the postponement of maintenance may give quite unfavorable results. Roads with low traffic would be the prime candidates for maintenance deferral. If located in medium or high rainfall areas these roads would soon be washed out. If located in dry areas the maintenance costs would already be low and savings would be minimal.

Another consideration is the fact that paved roads rated in condition one make the least contribution to VOC savings due to maintenance. Paved roads have relatively longer lives and the annual incremental increase in VOC from deferred maintenance is small in the early years. However, it is these roads that carry a large percentage of the total traffic, especially export and import commodities. Deferral of part or all maintenance on these roads would create shifting traffic patterns and increased tariffs. These effects are not quantifiable within the scope of this study.

A third consideration in the postponement of maintenance is the effect on the established maintenance organization. It would be extremely difficult to reduce or abandon maintenance on selected segments when the equipment, labor, shops and communications are all established by districts. Overall maintenance in a district would have to be reduced, and the analysis demonstrated that there are positive benefits for maintenance on a system-wide basis. The Consultants could not envisage any practical revision of operations that would permit reduced maintenance on intermittent segments. A prime consideration of this study has been the establishment of minimum maintenance procedures to preserve the roads in normal condition. Incremental reductions in the quality of maintenance would result in unquantifiable increases in VOC, with the possibility of loss of some road segments and indeterminate effects on traffic. Reductions in the cost of performing some of the operations are possible, and these potential savings are investigated in other paragraphs of this section.

B. Postponement of Rehabilitations

The recommended rehabilitation projects are shown in Section X. A cursory analysis was made of the possible changes in rehabilitation costs if the work were further deferred. Generally, these costs can be expected to rise at a rate of about 25 percent per year. These increases are due primarily to the greater volumes of materials needed, and the increasing labor and material costs.

Postponement of rehabilitation would result in increased annual maintenance costs to hold a road in its present condition, a reflection of the additional manpower and equipment needs. The paradox is that if these additional resources had been available originally the rehabilitation would perhaps not be required.

It is quite obvious that the postponement of rehabilitation would result in rising costs both for maintenance and for rehabilitation. If a road section becomes impassable then traffic diversions or complete stoppage will take place. The economic ranking of the rehabilitation projects indicated that all but two had less than a 10-year breakeven period; the minimum period was 2 years and the maximum was 6 years. As the loss of the surface or the entire road is possible on some segments of each of the sections recommended for rehabilitation, it is not considered responsible for the Consultants, from an engineering standpoint, to recommend postponement. From an economic viewpoint, if rehabilitations are postponed the breakeven periods would become longer, indicating a lower return to the IEG.

Rehabilitation, therefore, should not be deferred. The effects of postponement would either be reflected in a greater annual VOC to the country, or in longer breakeven periods for rehabilitations to pay for themselves.

C. Effects of Training and Advisory Services

It can be expected that the development of better skills and management in all sectors of the IHA will continue to take place, and that this will produce additional benefits in maintenance, reflected in generally lower unit and total costs for all programs. To quantify such benefits it would be necessary to identify specific changes in skills and efficiencies and to follow these through the chain of events in which they would produce effects, which could then be measured or estimated.

It will be noted that this report offers few detailed recommendations for revised courses of training or completely new advisory services. Within those given, alternative solutions are sometimes presented. Reviewing the recommendations, it was felt that the overall effects on

program costs would be relatively modest and subject to considerable variation depending on the course adopted. No estimation was made of potential additional benefits from training and advisory services.

D. Effects of Increased Equipment Availability

As indicated in Section XI-A-2 and others, the factor used to determine in-service equipment units needed to provide the quantified program equipment-days was 65%. If, as suggested under "Engineering Implementation" above, the availability factor for mechanical units could be raised from 65% to 75%, by improved machine servicing, parts supply, and so on, this would naturally reduce the necessary size of the maintenance fleet. It is not realistic to expect that this change could occur in the remaining months of the current year, and the equipment required to be on hand at the beginning of 1973/74 would therefore continue unchanged. Unfortunately, the acquisition for that initial program year is far greater than that for any later period, and is more than 78% of the total for the 5-year span. In consequence, only limited reductions in capital expenditures would result from this desirable increase in fleet efficiency. Furthermore, the inescapable requirements for the early stages would cause a greater excess of equipment units to appear as the character of the road system is changed. Adjustments (economies) in the purchases for 1974/75 and later can avoid this to some extent, but not entirely. The disposition of this excess equipment, if a surplus can be achieved, would present a separate question.

Exhibit XVI-1 shows a revised equipment scheduling in which the 65% factor is used in 1973/74 and the higher (75%) availability for the succeeding years. This table can be compared with the earlier Exhibit XII-6, for the most common equipment types (non-mechanical units, truck-trailer/lowboy combinations and most materials-production machines are omitted since they are not generally affected by the factor variation).

With the quantities remaining unchanged for 1973/74, the tables display significant differences for the years 1974/75 through 1977/78:

EXHIBIT XVI-1

REVISED PARTIAL EQUIPMENT REQUIREMENTS FOR MAINTENANCE REHABILITATION AND MATERIALS PROGRAMS BASED ON 65% AVAILABILITY FACTOR FOR 1973/74 AND 75% FOR SUBSEQUENT YEARS

Description	Motor Grader	Dump Truck	Leader	2-1/2 Ton Truck	Roller	Water Truck	Crawler Tractor	Asphalt Distributor	Asphalt Relay Truck
1973/74									
Requirements:									
Maintenance	99	212	60	23	53	22	8	9	9
Rehabilitations	16	66	14	0	24	12	8	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/0	227/0	25/0	0/0	17/0	0/0	14/0	8/0	2/0
Deficiency or (Excess)	41	71	67	23	60	34	17	1	7
Recommended Purchase	40	70	65	15	60	30	15	1	7
1974/75									
Requirements:									
Maintenance	86	193	56	20	50	19	5	6	6
Rehabilitations	12	66	14	0	24	12	6	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	183/70	25/65	0/15	17/60	0/30	14/15	8/1	2/7
Deficiency or (Excess)	(16)	26	(2)	5	(3)	1	(3)	(3)	(3)
Recommended Purchase	0	26	0	5	0	0	0	0	0
1975/76									
Requirements:									
Maintenance	88	198	61	21	54	20	5	6	6
Rehabilitations	9	40	14	0	10	8	2	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/96	19/65	0/20	17/60	0/30	13/15	8/1	2/7
Deficiency or (Excess)	(17)	23	9	1	(13)	(2)	(6)	(3)	(3)
Recommended Purchase	0	0	5	1	0	0	0	0	0
1976/77									
Requirements:									
Maintenance	89	202	63	22	55	19	5	7	7
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/96	13/70	0/21	17/60	0/30	11/15	8/1	2/7
Deficiency or (Excess)	(25)	(13)	2	1	(22)	(11)	(6)	(2)	(2)
Recommended Purchase	0	0	0	1	0	0	0	0	0
1977/78									
Requirements:									
Maintenance	87	206	65	22	58	18	5	8	8
Rehabilitations	0	0	0	0	0	0	0	0	0
Materials	0	20	18	0	0	0	15	0	0
Existing Fleet; Old/New	74/40	139/96	13/70	0/22	17/60	0/30	10/15	8/1	2/7
Deficiency or (Excess)	(27)	(9)	0	0	(19)	(12)	(5)	(1)	(1)
Recommended Purchase	0	0	0	0	0	0	0	0	0

1. The number of graders required drops from 103 to 86 in 1974/75, and changes little after that. Formerly, a deficiency of 1 was accepted in the second and third program years, after which there was an excess of 9 or 10. With a better availability, an immediate surplus of 16 units appears and this is added to the excess of years four and five. Since no grader purchases were recommended after 1973/74, the future excess could only be avoided by immediately raising the availability factor for these units, and decreasing the initial procurement. This was not considered to be a practical measure because a large majority of the existing fleet consists of units already more than five years old.

2. The fleet requirement and deficiency for dump trucks would decrease by 32 units in 1974/74, so that purchase of 26 trucks would meet the full needs. A shortage of 23 appears again the next year, but should be solved by contract hauling due to the surplus which shows up in the final two years, even without further purchases for 1975/76. The principal effects of the 75% availability here would be to reduce dump truck acquisitions by a total of 24 units and to eliminate about half the total truck rental/contract hauling in the second and third program years.

3. The recommended provision of 65 new front-end loaders for 1973/74 would give a surplus of 2 the next year, instead of a shortage of 6. Thereafter, the fleet would be short 9 in 1975/76, and if 5 of these were provided a minor deficiency of 2 would exist the next year. The requirements would balance in 1977/78, and fifteen loaders would be cut from the total five-year procurement list.

4. Exhibit XII-6 called for 25 cargo trucks (2 1/2-ton) to be procured for the five years, and this left continuing shortages in all years. A 75% availability would permit all needs to be met (after 1973/74) by the purchase of only 22 units.

5. Provision of sufficient rollers in the first year again results in excesses through the final 3 years, and in greater numbers. No good solution was found for this problem and it appeared necessary to the

Consultants to make the initial acquisition in order to get the work done, and accept the later surplus if the 75% factor is achieved.

6. A similar situation exists for water trucks, with no reduction possible in capital costs and large excess numbers resulting from better equipment maintenance over the years. A limited market may exist for used water trucks (and rollers as well) in the private contracting industry.

7. The proposed acquisition of crawler tractors is unchanged, but the 75% factor would cause excess numbers to occur one year earlier and continue in somewhat greater numbers than those shown in Section XII.

8. Improved availability of the asphalt distributor trucks and relay trucks would allow these acquisitions to be decreased by 3 units each, according to the tables. The feasibility of this full reduction was open to some question, considering the age and condition of the existing distributors and the practicality of shuttling them long distances for work scheduling. However, since the initial procurement for 1973/74 would actually indicate surpluses in all following years at 75% availability, the decrease was assumed to be possible.

Utilizing the foregoing comparison, the achievement of a 75% availability factor through better equipment repair and servicing would permit the elimination of capital equipment purchases as shown below:

Description	Units Eliminated	Unit Cost	Total Cost Reduction (1972 E$)
Dump Truck	24	60,000	1,440,000
Loader	15	75,000	1,125,000
2 1/2-ton Truck	3	27,000	81,000
Asphalt Distributor	3	76,500	229,500
Asphalt Relay Truck	3	56,500	169,500
TOTAL			3,045,000

E. Benefits from Reduced Material Costs

A successful search for better natural materials would substantially lower the maintenance costs for type 3 and 4 roads, which are an important part of the total system. The costs for other road types would not be significantly affected. It was indicated in Section III-H-7 that if natural gravels costing around E$3.00 per m^3 (stockpiled) could be substituted for 65% of the annual requirement of processed select material, on which the program costs were based, then the composite cost for surfacing on the subject roads would decrease to about E$5.33 per m^3, as compared with E$9.67 in the estimates.

However, if the materials program recommended in Section XII-A-2 is adopted, and the described results are achieved, the remaining 35% of the rounded annual total of 1,000,000 m^3 of controlled-gradation material would be produced by two methods; 150,000 m^3 by the 225-TPH plant recommended for purchase, at an estimated unit cost of E$4.40 at the pit, and 200,000 m^3 by four of the existing 50-TPH plants, at a somewhat higher cost than the basic estimate from 75-TPH crushers. If the 200,000 m^3 is taken to cost E$11.00 per m^3, an intermediate figure compared to crushed stone, then the composite unit cost for the entire annual quantity would be approximately E$4.80 per m^3.

Both the E$9.67 of the basic maintenance estimates and the E$4.80 are calculated to include overheads at the time of production and would not be subject to further overhead costs on utilization, so the difference of E$4.87 can be used directly in computing potential savings.

Exhibit XI-21 previously showed the annual quantities of processed select material required, and these amounts reflect the changes in kilometers of type 3 and 4 road, year by year. Therefore, the system-wide cost savings by years are easily derived, as follows:

Year	Quantity (m^3)	Savings (E$000)
1972/73	850,367	4,141
1973/74	863,494	4,205
1974/75	835,839	4,070
1975/76	815,908	3,973
1976/77	779,093	3,794
1977/78	680,284	3,313

Since the above are financial cost reductions, they must be converted to economic cost differences by again applying the factor of 1.1, as in the benefit analysis of Section XIII. The resulting figures represent the added annual maintenance benefits from the proposed materials program. These, and the corresponding present values, are given in Exhibit XVI-2. Once more, the benefits shown for 1972/73 cannot be realized, and they are deducted from the total. It is not likely that the full savings of 1973/74 could be achieved either, and the 5-year net amount would therefore be reduced by some additional indeterminate quantity.

It must be noted that the benefits indicated in the exhibit can only be obtained by expenditures which have not been taken into account, both for the exploration and for the acquisition of further equipment. However, the depreciation of all equipment units, existing and new, is included in the estimated production costs, and the approximate expense of the materials search, E$211,500, represents only about E$0.053 per m^3 when prorated to the total material quantity for the five program years. The program expenditure in the first two years would have a larger effect on net benefits than is suggested by that increment in material cost, but the benefits would also continue to accrue for a much longer period than the five years shown.

The unadjusted benefits as shown in Exhibit XVI-2 indicate a potential increase of more than 40% over the basic benefits of the recommended maintenance program (previous Exhibit XIII-6) and represent the kind and scale of savings which are sometimes possible through the continuing use of engineering technology, and the unending quest for greater engineering efficiencies.

Exhibit XVI-2

ADDITIONAL NET BENEFITS OF PROPOSED
MATERIALS PROGRAM
(Thousands of 1972 E$)

Year	Financial Savings	Economic Benefits*	Present Value of Benefits at 10%
1972/73	4,141	4,555	4,555
1973/74	4,205	4,626	4,205
1974/75	4,070	4,477	3,700
1975/76	3,973	4,370	3,283
1976/77	3,794	4,173	2,850
1977/78	3,313	3,644	2,263
TOTAL			20,856
Less 1972/73			4,555
Five-Year Net			16,301

* Financial Savings times 1.1

ADDENDUM

ADDENDUM

The IHA comments following submission of the draft report indicated that after that draft had been compiled some 73 units of equipment were evaluated and recommended for salvage by the Supply and Equipment Division. The Consultants were advised that this recommendation, prepared after the departure of study personnel, was later approved by the Property Survey Committee. According to data supplied by letter the 73 units consisted of 44 dump trucks, 16 motor graders, 4 asphalt distributors, 1 roller, 4 front-end loaders, and 4 air compressors (210 c.f.m.).

The replacement of these pieces of equipment would entail an added capital outlay estimated as follows:

Description	Number of Units	Unit Cost	Total Cost (1972 E$)
Dump Truck	44	60,000	2,640,000
Motor Grader	16	75,600	1,209,600
Asphalt Distributor	4	76,500	306,000
Roller	1	51,500	51,500
Front End Loader	4	75,000	300,000
Air Compressor	4	35,000	140,000
Total			4,647,100

On the basis that the 73 equipment units have been retired from service by formal action of the Ethiopian Government, the Consultants recommended that capital expenditures for the program year 1973/74 be increased by the amount of E$4,647,100 to cover the acquisition of replacement units as listed above.