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9. ABSTRACT

This study presents a framework for evaluation of transport projects and selection of investment policies. The selection of transport investments and policies is dependent upon their influence on other activities in the modern and traditional sectors in the Sahel-Sudan region.

The region encompasses six nations of francophone west Africa, including Chad, Mali, Mauritania, Niger, Senegal and Upper Volta. The economies of these countries, although slightly different from one country to another, are largely agricultural-based and a majority of the population reside in the rural areas. A recent prolonged dought spell has aggravated the development problems facing these nations.

In seeking to develop the analytical framework, this study has proceeded along two lines. First, a review of the transport conditions in the region was conducted to develop a data base for use in cost simulation models for the transportation system. Second, the transport costs generated by these models were utilized to examine more generally the role of the transport system in the economic activities in the region, especially those in the rural areas.

This study has focused primarily on road transportation, because of the extent of the region and the predominantly agricultural nature of the economy. However, other modes of transport have also been addressed whenever their role became relevant to the overall transport picture.

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A FRAMEWORK FOR EVALUATING LONG-TERM STRATEGIES FOR THE DEVELOPMENT OF THE SAHEL-SUDAN REGION

Annex 7

THE ROLE OF TRANSPORTATION

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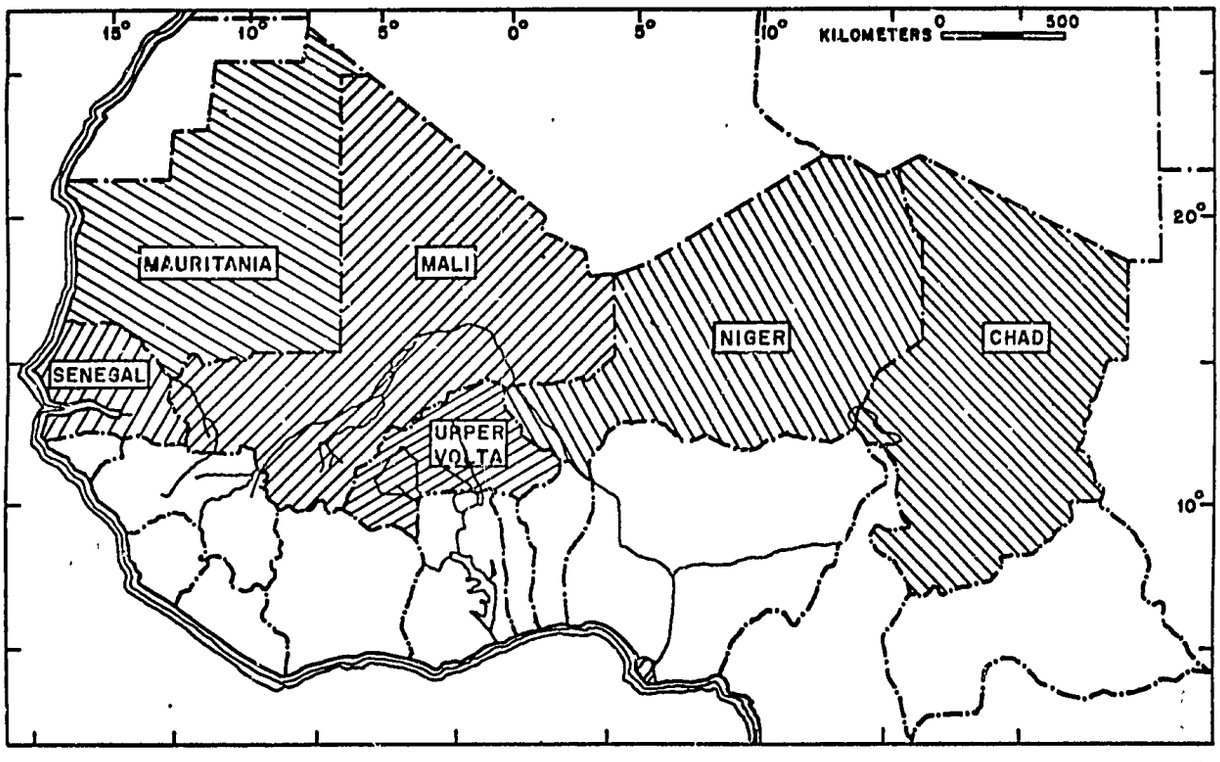
15. Abstract



Volume 1. Summary Report: Project Objectives, Methodologies and Major Findings

Volume 2. ISYALAPS, A Framework for Agricultural Development Planning

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The contents of this report reflect the views of the Sahel-Sudan Project at the Massachusetts Institute of Technology and do not necessarily reflect the official views or policy of the Agency for International Development.

FOREWORD

This report results from a one-year effort by a multidisciplinary team of analysts to establish a framework for evaluating long-term development strategies for the African Sahel-Sudan area.

By June 1973 it had become evident that the suffering caused by the drought was the most severe the area had experienced in the last half century. A meeting of donor organizations and U.N. agencies, called by the U.N., was held in Geneva to discuss the problem. It was clear that, while the area required immediate assistance to meet the problems of drought relief, there was also need for long-range assistance if the region were to become self-sustaining and begin an era of positive economic development and widespread improvement in the quality of life of its people. The U.S. delegation offered to undertake the first steps necessary to "identify the methodology, the data requirements and the possible alternative lines of inquiry from physical, economic, social and cultural points of view" on which to base "a comprehensive examination of technical problems and the major alternative development possibilities" for the region.* The United States Agency for International Development (A.I.D.) offered to take responsibility for this task and determined that it should enlist the assistance of the academic community in carrying out the work. A.I.D. then approached M.I.T., and a study effort was formally initiated with the signing of a contract covering the period September 1, 1973, through August 31, 1974. This contract was subsequently extended to January 1, 1975.

The goal of the U.S. effort is to develop a methodology for evaluating long-term development strategies for the Sahel-Sudan region. The

* Final Report on the Meeting of the Sudano-Sahelian Mid- and Long-Term Programme 28-29 June, 1973, Geneva. Special Sahelian Office, United Nations, New York. Statement by Donald S. Brown.

specific focus of the M.I.T. study has been on the development of an effective framework within which to appraise specific projects and programs. The term framework, in this context, refers to the accumulation, development, organization, integration, and analytical evaluation of information on the natural resources, economic resources, and human resources, including the social and political institutions, of the region. The framework is constructed in such a way that alternative strategies for the region can be identified and evaluated, in terms of both their requirements and their impacts, intended and unintended. The M.I.T. study has not been oriented toward detailed sector studies, prefeasibility studies, or project studies. Nevertheless, in the process of developing a methodology we have examined many kinds of information and a number of specific projects and have identified areas requiring further research to fill information gaps that impede long-range planning and evaluation of specific development proposals.

It is hoped that this framework will assist decision-makers in the Sahel-Sudan countries and in donor organizations in arriving at informed judgments concerning strategies for the long-term (20 to 25 years) social and economic development of the region.

The study was conducted under the direction of the M.I.T. Center for Policy Alternatives and was carried out by a multidisciplinary group. The Summary Report and the volume on agricultural development planning have drawn upon a number of working studies on specialized aspects of the problem prepared by the staff, i.e. (1) Economic Considerations for Long-Term Development, (2) Health, Nutrition, and Population, (3) Industrial and Urban Development, (4) Socio-Political Factors in Ecological Reconstruction, (5) A Systems Analysis of Pastoralism in the West African Sahel, (6) Technology, Education, and Institutional Development, (7) The Role of Transportation, (8) An Approach to Water Resource Planning, (9) Energy and Mineral Resources, and (10) Listing of Project Library Hold-

ings and Organizations Contacted. The basic elements of these studies have been drawn together in the two volumes of the final report.

In addition to M.I.T. personnel, individuals from a number of other organizations participated in the effort. Participants from the University of Arizona, in particular, made major contributions; they had primary responsibility for developing the analysis of the agricultural sector strategy. Professor John Paden of Northwestern University was a major contributor to the work on socio-political factors. Members of the Société d'Etudes pour le Développement Economique et Social (S.E.D.E.S.) in Paris provided valuable insights into various aspects of the Sahel-Sudan area. Several members of the Centre de Recherches en Développement Economique (C.R.D.E.) in Montreal developed sections on monetary policy, urbanization, and relationships between Niger and Nigeria. A list of individuals who participated in the study is included in Volume 1 of this report.

Numerous other individuals acted as consultants to the project, provided advice as the study progressed, and reviewed draft material for the reports. Help and advice were given by officials of the governments of the Sahel-Sudan countries, the Comité Permanent Inter-Etats de Lutte Contre la Sechèresse dans le Sahel (C.I.L.S.S.), members of United Nation organizations, members of the International Bank for Reconstruction and Dévelopment, and, especially, officials of the Secretariat d'Etat and various socio-economic and technical study groups in France. Finally, representatives of A.I.D. arranged meetings in Africa and reviewed the the progress of the study. All this assistance is gratefully acknowledged.

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ABSTRACT

The analysis of the national transport sector requires an understanding of the complex interrelations between transport and other sectors of the economy. Thus, the design of transport policies must be derived from the overall goals of social, economic, and political development. This study presents a framework for evaluation of transport projects and selection of investment policies. The selection of transport investments and policies is dependent upon their influence on other activities in the modern and traditional sectors in the Sahel-Sudan region.

The region encompasses six nations of francophone west Africa, including Chad, Mali, Mauritania, Niger, Senegal, and Upper Volta. The economies of these countries, although slightly different from one country to another, are largely agricultural-based and a majority of the population reside in the rural areas. A recent prolonged dought spell has aggravated the development problems facing these nations.

In seeking to develop the analytical framework, this study has proceeded along two lines. First, a review of the transport conditions in the region was conducted to develop a data base for use in cost simulation models for the transportation system. Second, the transport costs generated by these models were utilized to examine more generally the role of the transport system in the economic activities in the region, especially those in the rural areas.

This study has focused primarily on road transportation, because of the extent of the region and the predominantly agricultural nature of the economy. However, other modes of transport have also been addressed whenever their role became relevant to the overall transport picture.

The analysis of road transport costs rests upon the utilization of cost simulation models, which take as their inputs, economic factor

prices as well as the physical characteristics of the road transport elements. The outcome of these models is expressed in a breakdown of the costs associated with construction, maintenance, and vehicle operations, as well as information relevant to foreign exchange expenditures, fuel requirements, and a host of other factors related to road transportation. These models, which have been developed elsewhere by Moavenzadeh and co-wokers at M.I.T. and Robers and co-workers at Harvard University have been calibrated to the economic, social, and physical environments of the Sahel-Sudan region.

A trade-off analysis was performed to study the interrelationships among the costs of construction, maintenance, and vehicle operation for various construction standards and technology, maintenance policies including labor-substitution, and traffic patterns. By and large, construction and maintenance costs are government expenditures, while vehicle costs accrue to the private sector. The possible exception is the foreign exchange components of vehicle operating costs. Various raod surfaces were studied, including, earth, gravel, and paved types.

The output of these models was utilized in the study of the role of transport in economic activities of rural population. This is demonstrated in two example studies. One deals with the raising and marketing of cattle in Mali and Ivory Coast, and the effects of different transport alternatives on these activities. The second study in this context addresses the interrelationship between transport and agriculture. A mathematical programming model is suggested for the optimization of investments in rural roads. Various levels of agricultural technology, production potentials, human and animal resources, as well as market structures were taken into account to determine the optimal transport configuration (infrastructure and means of transport). Both examples are only intended for the illustration of the philosophy of approach used in this framework.

A final part of the study addresses the problems of transport in the region including maintenance, transport policies, and exploration of means of dealing with these problems including possible new technologies.

AUTHORS' NOTE

This study of the transport system in the Sahel-Sudan region was undertaken as a part of a larger study involving long-term development alternatives for the region. The region consists of six countries: Chad, Mali, Mauritania, Niger, Senegal, and Upper Volta. The first stage of this study involved a review of the literature on the existing transport system and its relationship to the social and economic activities of production, consumption, and patterns of movements of people, animals, and goods. An inventory of the transport network and facilities was complied as a part of this stage and is presented in the appendix.

As the work progressed three basic points became clear and began to reinforce the intuitions which were held during the early stages of the study. The points are:

1. Transport cannot be studied apart from other production activities. For that reason, long-term development plans, including transport investments, must simultaneously be associated with improvements and growth in the other sectors, particularly agriculture and mining.

2. Four of these countries are landlocked, and any study of transport must include consideration of transshipments across the borders of neighboring countries with access to ocean shipping. Among these considerations are: (a) traffic conditions at the ports, (b) the state of infrastructure and performance of surface transportation from the port into the countries involved, (c) the institutional constraints on movements of goods, and (d) tariffs and taxation policies in the transit countries.

3. A set of basic tools to predict and analyze cost and performance characteristics of transport in the region are needed to provide aid in decision-making. These tools will permit the examination of how and when to maintain, improve or expand transport links.

Furthermore, it became evident that the task of studying all these issues for all modes of transport is one of major proportion, and could not be

handled within the limited time and resources available.

As a result, an attempt was made to narrow the scope of the work to a manageable size. Since road transport is important not only because it is the backbone of the agricultural activities in the region, but also because it includes the principal commodities moved in the generation of foreign exchange, the bulk of the study was focused on roads. This is neither a narrow nor an easy task. Indeed, a significant portion of this effort has focused on examining methodologies for addressing transport problems within the context of particular economic activities.

The objective of this approach is twofold. First, to bring into focus the complex interactions between the transport and agricultural production activities which make up the bulk of the economic system in the region. Second, to provide the tools which enable analysts and decision-makers to predict road transport costs and study the trade-offs which exist among its components. Eventually, an informed judgement can be made on the selection of suitable design standards, maintenance requirements, and costs to various sectors of the economy resulting from any particular decision.

To satisfy the above objective, a set of methodologies was employed to determine construction, maintenance, and vehical operating costs under various design and maintenance standards, and traffic demands. An emphasis was placed on dirt roads, since these constitute a major portion of the road network in the region, especially in the remote rural areas. Then, a series of example investigations were undertaken to exemplify the role of transport in cattle movements and the interaction between agriculture and transport, and to provide a mechanism for selecting the optimum transport technology for various activities and at various levels of production.

The transport costs involved are examined from the viewpoints of the public sector (i.e, the government), the shipper (i.e., the supplier),

and the carrier. In each, the costs to the economy were accounted for by spelling out the foreign exchange components incurred and by allowing the specification of labor intensity in the construction and maintenance efforts.

A final part of this study involving observations and conclusions dealt with three specific issues. The first treated transport conditions, tariff and transit agreements across national boundaries. In this, we sought to identify trade policies, bottlenecks, and important elements which affect traffic to and from the landlocked countries. The north-south relationships, transit taxes, port conditions, storage facilities, and inland transport (roads and railroads) in the neighboring countries with major commercial ports were among the most important considerations in this category.

Another aspect treated briefly in this section involved the examination of the possibility of new transport technology. In view of the extent of the region, the lack of rapid means of transport, and low traffic volumes with little economic justification to extend the transport infrastructure presently in the region, aircraft seemed to offer some promise and both conventional and lighter-than-air craft were looked at. Alternative means of transport, suitable to terrestial operation and responsive to the existing infrastructure in the region were also investigated in the form of air-cushion vehicles.

The last issue was concerned with problems of transport logistics and equipment operations. The lack of maintenance due to both manpower and management problems is discussed. Furthermore, the available information on storage facilities in the region are rather limited. However, the sketchy information of bottlenecks in the distribution of drought relief supplies clearly indicates a severe lack of such facilities.

This report is presented in five parts. Chapter One deals with the role of transport in the economic development of the region and the

trade-offs involved in the joint production-transport activities. In Chapter Two this discussion is exemplified by providing tools for prediction of the cost performance relationships in road transport operations and showing how these can be used in determining optimal transport conditions in a given medium of production. An example study of the role of transport in cattle movement is presented in Chapter 3, while Chapter 4 presents a mathematical programming model for joint agricultural-transport activities. Chapter Five presents the conclusions.

The Authors

ANNEX 7

THE ROLE OF TRANSPORTATION

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1. TRANSPORTATION FOR THE SAHEL-SUDAN REGION

1.1 Introduction

The role of transport in development is one that has been debated intensively over the last few years. The answer that seems to be emerging is almost a trivial one; that is, where transport is the constraining element, it is crucially important. Where other elements, such as water, land, labor, or capital are the missing elements, no amount of transport will produce the desired result.

This role of transport is illustrated in Figure 1.1 – 1. On the left, is a local population grouping with local production and consumption. In the underdeveloped state this would be subsistence agriculture or a nomadic existence. In this society transport plays a relatively small role in the production and consumption process because the products are both produced and consumed locally.

1.2 Present Level of Economic Activity

The real need for transportation comes with development when the production of the local population is sold to more remote world markets. The transport process begins to play a larger and more crucial role. The sale of cash crops then produces the income to expend on imported goods, which in turn require more transport.

In order for this system to work, it must be economically viable. For all goods sold in the market, the cost of production, plus the cost of transport must be less than the market price of the goods in the marketplace.

Where the product being produced and transported to remote markets is not perishable, the transport requirements are not very demanding. However, where the crop is perishable -- as many agricultural products

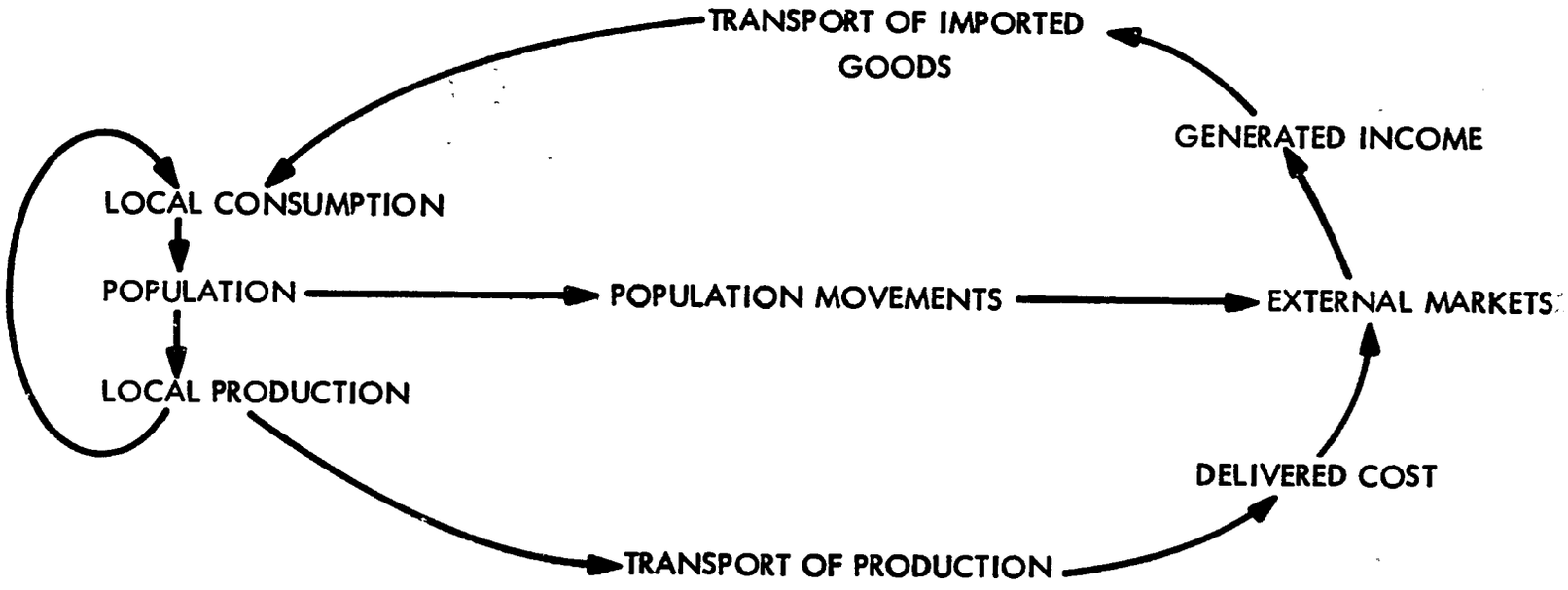

FIGURE 1.1 – 1: The Role of Transport in Development

are -- the transport requirements become more important to the success or failure of the production system. The transport requirements for many cash crops, particularly those that are perishable are very explicit. Without the proper transport there is no product to sell in the market, and therefore no production.

It is clear from this discussion that transport cannot be considered apart from its role as one, but only one, constraint in the overall production system.

1.3 The Limiting Effect of Transport

Transport does not play an important role in a subsistence economy. It only makes sense to emphasize transport if the real objective is development. The major issue then is the determination of the kind of development which makes the most sense in any particular environment. Is the best route to development the sale on the world market of a local product? the development of some natural resource with exceptionally low cost? or the exportation of the skills of the local population? Once this development objective has been determined, the next question to be answered is what transport is required to support this development?

In the case of the Sahel-Sudan region, there are a number of barriers to development. Some of these are probably more important than transport. The lack of adequate water, the largely untrained population, the lack of accessibility to major markets, all pose major barriers to the development of this region. The first and perhaps most important task is to identify these barriers and to understand the development options that are open to the region. This has been initiated in this project and the transport group had an active role in helping to define alternatives.

Once the overall development possibilities of the region are out-

lined, and the transport requirements to facilitate this development are defined, the next question is one of implementation. Sectors other than transportation must be considered, but for the transport sector the question is one of how to go about getting the transport institutions to work effectively in conjunction with the other sectors. How can costs be lowered to the point that they are competitive. Finally, what is the government role in accomplishing the overall transport development? The problems may be those of capital investment, selection of projects, or alternatively the reorganization and/or regulation of an existing transport mode.

Alternatives in this situation refer to the overall development alternatives rather than to the more detailed transport sector plans. A variety of possibilities seem to be attractive for the Sahel-Sudan region. The area appears to have the ability to produce a number of crops of interregional importance including the production of grains, such as millet or rice; cash crops, such as cotton or peanuts; and the production of cattle and other livestock. Mineral resources are another possibility that may be exploited.

If one thinks aggressively, one may consider the possibility of producing modern cash crops for exportation to the developed countries. These could include fresh fruits and vegetables for consumption in the winter markets of Europe or the Mediterranean, the production of beef using feedlot technology, or the growth of flowers for shipment by air freight to Europe or the United States. The transport requirements for these more modern undertakings are commensurately more demanding than for the simpler production of rice, cotton or peanuts.

1.4 Economies of Scale in Transport

Perhaps the most dramatic feature of transportation is the extent to which it involves economies of scale. For freight transportation,

these are even more dramatic than for passengers. For example, the move from normal oil tankers to super tankers, from the 707 to the 747, from single tractor trailer combinations to double bottom rigs in trucking, all demonstrate the trends in economies of scale. Costs have been demonstrably lower in each case. In order to gain a perspective on the types of economies of scale that are achievable in moving various volumes of goods, the reader is referred to Figure 1.4 – 1 which shows the typical costs per tone mile of transport for various quantities of movement.

Of course, economies of scale cannot be realized without similar economies in either production or consumption or both. Increasingly, however, industrial and agri-business groups in advanced countries have learned to develop these economies of scale in both production and usage. For collection and distribution within the developing countries, however, it is difficult to use the large equipment required to achieve economies of scale. The local levels of production are not sufficently high to support the cost. Therefore, one must typically go through one or more consolidation or deconsolidation phases to build the volume required to obtain these economies.

It is important to note, however, that the more economical line haul modes can only be available if the overall annual volume can be developed to keep them economically viable. For long distance travel, economies of scale in the line haul modes are reasonably easily attained.

1.5 Consolidation and Deconsolidation Processes

In order to consolidate to achieve economies of scale it may be necessary to go through several hierarchies of consolidation. Transport on the farm by human power, animal power, or by tractor is consolidated for transport by single unit trucks. These truckloads are then consolidated once more into over-the-road, line-haul operations.

VEHICLE MODE	SHIPMENT SIZE	DOLLARS PER TON MILE
Pickup Truck	500 lbs	1.80
Single Unit Truck	5,000 lbs	.20
Tractor Trailer	25,000 lbs	.06
Tractor Trailer	50,000 lbs	.03
40' Sea Container Transocean	25,000 lbs	.02
Rail car	50,000 lbs	.02
Rail Car	100,000 lbs	.015
Unit Train	1,000,000 lbs	.008
Neobulk Ship	10,000,000 lbs	.007
Full Ship Load	100,000,000 lbs	.003

FIGURE 1.4 – 1: Typical Cost Per Ton Mile of Line Haul Transport as a Function of Shipment Size

If overseas travel is involved, another consolidation into containerships may be required. In the developed world there are two to three consolidations in many transport systems; in these developing countries a larger number of consolidations may be necessary.

On the developed end of the transport of cash crops from the producing countries to more developed markets, the deconsolidation portion of the trip is easily accounted for by the infrastructure and organization available in the developed countries. The problem comes in the creation of the appropriate hierarchies of consolidation for cash crop movement in the developing country itself. Working from the traditional agricultural sector, the levels of production may be low and widely spread. Obviously, consolidation and deconsolidation are required to achieve the flows which will qualify for the low cost transport in Figure 1.4 – 1. Even then, the indirectness of the flow and the extra length that must be travelled means that a penalty must be paid. If it is impossible to perform these consolidations or if the level, even after consolidation, comes up to a very low volume because of the lack of density of production, then it may be uneconomical to perform economic activities of any kind.

1.6 Seasonality and Directionality

The economies of scale that are achieveable in transport are also fundamentally related to the directionality of movement and its seasonality. That is, if all of the goods are moving in one direction, or if they all move at the same season, then it is much more difficult to achieve low costs in the long run. For countries exporting cash crops it is extremely difficult to achieve the balance in transport flow that is needed. One direction or the other will typically be the forehaul with an empty or almost emply backhaul as the inevitable result.

Seasonality also is a factor which poses difficulties. Seasonality of production, particularly of agricultural products results in a peaking that aggravates the transport problem. If the commodity is perishable, then there is a high probability that some of it will be lost because of inadequate transport capacity during the highest part of the peak. Even when the commodity is non-perishable the peaking activity associated with the movement of this good will exacerbate the problems of flow of other goods in the system until this capacity peak has been worked off. Unfortunately, given the nature of agricultural production, peaking is the rule rather than the exception. This challenge faced by transport planners in these countries will be to develop commodity movements and production processes that will allow transport equipment to be used as continuously as possible throughout the year (see Figure 1.6 – 1).

1.7 Interrelationships of Transport with Production

Given the degree of understanding of the development problem in the Sahel-Sudan and the funds available, it is inappropriate for this study to adopt a planning approach oriented toward the identification of specific rail/road projects in specific corridors. Rather, it is appropriate to find out in general what the transport requirements are for each of the possible industries around which development may be focused. That is not to say that a single crop or industry will constitute the whole of the development strategy, but rather a mixture is the most likely possibility. The overall strategy by which we approach the problem is outlined below.

In the most general sense we must study the transport requirements for one product/industry at a time. Obviously, this cannot be done in detail, but we will take some prototypical products. Here we would like to know the nature of the raw product; its density as prepared for shipment; its value per pound; its perishability; the timing of its move-

	Full Both Ways	Full One Way 50% Full Backhaul	Full One Way Empty Return
10,000 miles/yr = 40 miles/day for 250 days or 100 miles/day for 100 days	.111	.148	CASE 1 .222
100,000 miles/yr = 400 miles/day for 250 days	.021	CASE 2 .028	.042
150,000 miles/yr = 500 miles/day for 300 days	.017	.023	CASE 3 .034

CASE 1) Typical of a truck used in the hauling of seasonal produce in a developing country.

CASE 2) The type of costs that are typically experienced in the U.S or Europe

CASE 3) The costs that might be achieved in a developing country where seasonality is not a problem, the roads are good, etc. Note that use of local wages could bring this cost down further.

Assumptions: Rig cost $50,000 for 40,000 lb payload, amortized over 5 years @ 15% CRF = .30 = $15,000/year

Repairs = 20 % of capital cost = $1,800/yr.

Registration, insurance and taxes = $3,200/yr.

Fuel = 5 mpg x $.30/gal = $.06/mile

Drivers wage = $8/hr = .16

variable costs = $.22/mile

Fixed Costs = $20,000/yr.

FIGURE 1.6 — 1: Line Haul Costs in Dollars per ton Mile for Trucking under Different Assumptions of Utilization and Backhaul

ment; its seasonality; the type of packaging and storing that is required; the necessity for special handling, refrigeration, etc.; the shelf-life and particular characteristics of the product that set the tolerable time limit between order and arrival of a shipment; and finally, the method of handling pick-up and delivery at the ends of the process.

For each product we must spend time understanding the production markets and institutional arrangements, because these interact with the transport requirements. Here, the essential element is to understand what role this particular product plays in the system of crops or products which are marketed, the method of production, the timing of production and consumption, the marketing elements and institutions including the market price, how the market is formed, who functions as the broker, etc. We would also like to know the inputs in the production of the crop -- such as seeds and fertilizers -- and possible by-products, such as seeds, hulls, oil which can be processed and used in a number of applications.

Understanding of the production process makes it possible to develop explicitly the transport requirements and the economies of movement. The attempt is first to understand the carrier's point of view. What are his costs? What type of equipment would he use? Is he interested in serving this market or is it unprofitable for him? Is he properly organized to be able to meet the time or equipment requirements?

Once this understanding of the product, its production and its transport requirements is completed for a number of products in typical areas, the results can be used to predict the future potential for an area under different assumed transport connections and services. The emphasis at this stage is place on a particular situation: What possibilities are already being exploited and what remain to be exploited? What changes in the transport system produce what changed in the production

of various goods. What amounts must flow to make the venture commercially viable? Once understanding has been advanced to this stage, there are a variety of analysis techniques that can be employed. Existing techniques of analysis can be used for feeder roads and their justification. Standard cost-benefit analysis of various highway alignment possibilities or rail-road operating procedures can be preformed and various network analysis techniques can be used to help develop the final answers regarding network staging and capital budgeting.

Using the approach that we have outlined, we do not have to be site-specific at the outset. As our understanding of the transport requirements for various kinds of production increases, and as our understanding of the mechanisms, constraints and economics of the various production develops to help understand the feasibility of alternate development schemes, our planning can get more specific and take the macroview. The lessons that we have learned in the microenvironment addressed in this study can then be applied to the place-specific macroenvironment.

2. COMPONENTS OF ROAD TRANSPORT COSTS AND PERFORMANCE

2.1 Introduction

The transport means available to subsistence agriculture in the Sahel-Sudan region is costly. Products can only be carried for a limited distance before transport costs become the overriding element in the market value of products and commodities. When considering the prospects of major improvements in agricultural production, transport costs of seeds, fertilizers, fuel and consumer goods to the agricultural population can also be prohibitive. Therefore, all major investments must be dealt with by considering both the level and timing of the growth in the production and the associated transport requirements. The agricultural study which is in a separate report (Volume 2) of this series has addressed the possibility and methodology by which a steady growth in production on a sustained yield basis can be achieved. The strategy for agricultural improvement in the region has centered on defining possible levels of production in the various ecological zones at various level of intervention. The strategy defines both the time-frame and infrastructural requirements associated with various levels of production. Coupled with agriculture are schemes for livestock and associated industries.

It is against this background that the transport picture is viewed. The methodology attempts to identify cost components associated with various technological levels of road transport. The analytical methods provided to determine these costs allow analysts and decision makers to examine the trade-offs among these costs and identify the best technology. The result is a balanced mix of cost elements which are suitable for meeting a wide range of goals and objectives.

The case for interactions between transport and agricultural pro-

duction is examined in the next section in order to show how such a tradeoff can be utilized. Allowing for choice among a number of alternative transport levels for feeder roads, this methodology attempts to place transport in perspective within the production system. Decisions on agricultural problems should be closely related to those on transport and vice versa.

The components of road-transport costs include: construction costs, maintenance costs, and vehicle operating costs. The first two constitute direct costs to the government, while the third component is incident on the private operators, vehicle owners, and shippers. In this section a brief description of the methods of obtaining these cost components is presented. Next, representative values of such cost components are shown. In these examples, various strategies, including various construction and maintenance policies, for road transport are presented. Further time-phased construction approaches are also examined to show how best to upgrade road surfaces with increasing traffic levels.

2.2 A Brief Description of Methodologies

2.2.1 Construction cost: This involves the estimation of all the costs associated with normal roadway construction. It includes estimates of the quantitites of materials, equipment, labor and transport resources needed for each of the primary construction operations. These operations include site preparation, earthwork, pavement or surfacing, drainage, overhead and supervision and miscellaneous. The costs of major structures such as bridges must be supplied independently (Moavenzadeh 1973).

The required inputs to the construction costs are:

- Soil and ground cover or vegetation data.
- Drainage and hydrology data.

- Site clearing width.
- Topographic description in terms of the terrain rise and fall.
- Roadway length and average degree of curvature.
- Profile geometry in terms of either a maximum grade if exact geometry is not known, or a series of elevations and stations along a specific vertical profile.
- Roadway description consisting of widths and cross-slopes for the roadway, shoulders and ditches; cut and fill side slopes.
- Pavement design consisting of a basic pavement type, the number, the thickness and type of each material layer in the roadway.
- Transport haul distances for the borrow material pavement quantities, and cross-drainage structures.
- Stage construction schedule consisting of the time each staging or upgrading is to occur and the type of construction strategy to be performed.
- Construction technology data for the major construction operations including productivities of labor/equipment packages, labor/hourly rates, equipment hourly rates, transport unit costs, and material acquisition costs.

Cost data are obtained for each construction period. The cost breakdown of materials, equipment labor and transport components as well as total costs are presented using discounted rates supplied by the analysts.

2.2.2 Maintenance costs: This item includes estimates of the costs and the resulting quality of road surface and drainage maintenance. The condition of the roadway surface, referred to as its serviceability is predicted by estimating how much the road has deteriorated from the condition of the previous year. Both of these tasks are

performed each year of the analysis horizon (Moavenzadeh 1973).

Maintenance costs are determined by first computing the quantities of labor, equipment, and materials that are expended for the various maintenance operations. These operations can be divided into four activities: surface maintenance, shoulder maintenance, drainage maintenance, and vegetation control. Surface maintenance and shoulder maintenance include all activities associated with both paved and unpaved surfaces, blading of unpaved surfaces, and regravelling of gravel roads. Drainage activities include the clearing of side ditches and the cleaning and repair of culverts. Vegetation control is the maintenance effort allocated for mowing.

The quantity of patching and sealing required for paved roads is estimated as a function of the Present Serviceability Index (PSI)* of the road, as determined by the model user. Productivity rates for this operation are applied to determine the time required to perform the maintenance. From unit cost cata, the total cost of this operation can be computed.

The amount or frequency of blading of unpaved roads is specified by the user. The frequency can be specified as a function of traffic -- for example, "5,000 vehicles per blading." Productivity rates are applied to determine the time required to blade, from which maintenance costs can be determined.

Once maintenance is applied, the deterioration of the road due to effects of environment, traffic, and age of the road are estimated for the next year, and so on.

The condition or serviceability of the road surface is important not only in determining maintenance cost, but it is also <u>used</u> to estimate user costs and the volume of traffic using the road, which in turn

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*PSI defined by A.A.S.H.O. as a measure of pavement surface criteria.

determines the deterioration of the road for each succeeding year.

The following is a summary of the information that is needed to estimate maintenance costs:

- Maintenance policies (for earth and gravel roads) including blading frequencies during both the wet and dry season and the amount of regravelling.
- Maintenance policies (for paved roads) including the percent of cracking that will be patched and sealed, fraction of rutting that will be filled and allowable mean rut depth.
- Drainage and mowing frequencies.
- Environmental consideration such as the amount of flooding.
- Maintenance technology data for maintenace operations including unit cost for labor and equipment packages, material acquisition cost for patching and cost of aggregate for regravelling.
- Labor or capital intensive techniques to be used.

Annual maintenance costs are determined both in present value and discounted forms.

2.2.3 Vehicle operating costs: The vehicle operating cost component includes the estimates of resources consumed by the vehicles using the road. The quantity of resources consumed in operating different vehicle types over different pavement surfaces and in different seasons are estimated. The calculation of operating costs is divided into the following categories: 1) the costs and quantities associated with the journey including such items as driver wages, and vehicle cost; 2) fuel and tire use and costs; and 3) quantities and costs of vehicle wear including maintenance and depreciation (Moavenzadeh 1973).

The roadway characteristics which influence the vehicle operating

cost are: verticle profile, horizontal alignment, and surface condition. Effects of traffic congestion on operating cost are not accounted for because the traffic volumes dealt with here are low enough to preclude a significant amount of vehicle interaction.

The steps which are followed in the basic production routine are the estimation of the time required to traverse the road segment, fuel requirement, tire wear, vehicle maintenance, and vehicle depreciation. The key element needed in these evaluating steps is the velocity of the various vehicles.

The estimation of this variable is relatively complex because there are a number of factors which influence average velocity. The factors which were considered to limit velocity include:

(1) The design speed of the vehicle itself, i.e., the top vehicle speed as given by its engine operating speed;

(2) The roughness of the roadway surface which is related to the condition or serviceability of the road;

(3) The horizonal alignment of the roadway as it is related to curvature;

(4) The horsepower available to overcome rolling resistance of the roadway surface; and

(5) The combined effects of available horsepower and momentum which determine average speed on hilly segments.

Each factor is considered as an independent constraint of maximum velocity. For example, the velocity is determined as a function of the condition or roughness of the road alone,then as a function of horsepower, and finally as a function of road curvature. These three velocities are compared with the design velocity of the vehicle and the limiting one is selected as the maximum velocity which is used in determining resource consumption and costs. These include fuel require-

ments (as a function of velocity, vehicle weight, the roadway profile and surface), vehicle maintenance, tire wear, and vehicle depreciation.

The following information is required to determine the vehicle operating cost:

- Vehicle characteristics including type, weight, horsepower, design speed, width, height, and fuel type;
- Initial vehicle cost;
- Unit costs for vehicle maintenance, driver, fuel, tires, and cargo;
- Traffic demand in terms of initial vehicles per day, market cost, demand, elasticity, and growth rate.

An alternative approach has also been used to determine the vehicle operating cost (Roberts 1972). This approach accounts for the congestion factor, in addition to the other factors, in determining the limiting vehicle velocity.

In this approach, performance on each link is determined by three sets of basic information:

1. The physical characteristics of the roadway.
   - length of the link;
   - surface type: paved, gravel or earth;
   - design speed;
   - rise and fall in feet per 100 feet;
   - width of a lane;
   - number of lanes.
2. The volume of goods being carried and the resultant number of vehicles. Five classes of vehicle type are considered: Bulk, general, special, common carrier passenger, and private passenger vehicles. Traffic conditions are determined by the number of vehicles by class type travelled over the link per day.

3. The characteristics of the vehicles.

For each class of vehicles the following characteristics and unit costs are presented:

- weight and payload of the vehicle
- horsepower and number of tires
- lifetime vehicle mileage on paved roads
- average vehicle mileage per year
- initial vehicle costs and tire costs
- fuel cost
- maintenance costs
- oil consumption

Information about the operation costs of each vehicle type are provided. These include the costs accrued to the transporter, shipper, and government. The operating costs computed first are those accruing to the shipper including, not only those costs passed on to him by the transporter, but also additional costs due to the delays and losses suffered in transit. Performance measures expressed in terms of waiting time, travel time, variability of time, and probability of loss are estimated; and, therefore, estimates of the total costs of transportation as viewed by the shipper can be obtained by making assumptions about the values to be associated with the unit costs of each of the above variables.

There are several variables of interest to the government including total transport costs, the amount of tax revenue that will be generated by a proposed transport link, the foreign exchange components. These are developed by this approach.

2.2.4 Methodology for staged construction: Staged construction of a low-volume road is a procedure whereby a road is initially built to a level sufficient to meet the immediate requirements of traffic

and, at a later date, is reconstructed or upgraded to meet the increased demands of traffic. In order to accommodate the increased traffic, staging strategies may include improvements in surface type (for example a road is initially constructed with an earth surface which later is upgraded to gravel, and finally to a paved surface), improvements in vertical and horizontal alignment, changes in roadway template, or a combination of these strategies.

2.3 Framework of the Analysis

The framework for analysis of road transport costs and trade-offs for choice using the above methodologies can now be described. The data base for the analysis has drawn upon a number of sources (Roberts et al. 1970; Nible 1973).

The operating costs are not uniform throughout the Sahel-Sudan countries, but they fall within the following ranges:

asphalt roads:	6-12 CFAF/ton - km;
gravel roads:	9-19 CFAF/ton - km;
earth roads:	15-20 CFAF/ton - km;

Using this data base, a number of different strategies are examined. The objective is to identify suitable strategies and to determine the drawbacks of the existing policies.

The results are presented both in tabular and graphical forms. First, different staged construction strategies according to traffic volumes are considered. The object was to determine the strategy that fits best the current and future traffic demand levels.

Second, we have examined for three different traffic volumes, the changes in the construction, maintenance and operating costs over a 20-year horizon. Two maintenance policies (low and high) were used for each road type. The purpose was to determine when and how changes in the roadway surface are desired.

Third, trade-offs among construction and maintenance costs on the one hand, and vehicle operating costs on the other are shown in order to establish trade-offs between government expenses and those incurred by vehicle operators.

Finally, the operating cost components and their sensitivity to changes in road construction and maintenance standards in the region are addressed.

2.3.1 Some basic assumptions: We considered a 100 km road link with a typical geographic layout in the Sahel-Sudan region and representative of average values of factor prices, productivities, and other economic and physical data.

The road consists of two lanes, each 3.65 meters wide. The overall cross-section of the road is 22.70 meters wide. The terrain is a rolling one, with a 2 percent average rate of rise and fall, and a 4 percent maximum grade. This means that the ground is predominantly flat.

Three types of roadways have been examined:

(1) earth road with one layer of 38 cm sandy gravel as a surface.
(2) gravel road with one layer of 38 cm sandy gravel, and a second layer of 15 cm crushed stone.
(3) asphalt road with a layer of 38 cm sandy gravel, a layer of 15 cm crushed stone and a layer of 7.5 cm bituminous macadam.

A discount rate of 10 percent per annum is used in determining the net present values of cost components.

2.3.2 The maintenance policies examined: (a) Low maintenance: For earth and gravel roads, the blading will be performed for every 10,000 vehicles during the dry season and every 8,000 vehicles during the wet season. For asphalt roads, the mean acceptable rut-depth

is 5 cm, with 30 percent of the rutting fraction filled, and 20 percent of the cracking fraction patched and 20 percent sealed.

(b) High Maintenance: For earth and gravel roads, the blading is performed every 2,500 vehicles during the dry season and every 1,500 vehicles during the wet season. For the asphalt road, the allowable mean rut depth is 1.5 cm, the rutting fraction filled is 100 percent, the cracking fraction patched is 80 percent, and cracking fraction sealed is 70 percent.

The minimum allowable Present Serviceability Index (PSI) of the road before the reconstruction of the upper layer will be performed is 1.5. The PSI is a measure of the quality of road surface derived in a way that reflects how the drivers react to the road condition. It was proposed by the Highway Research Board during the A.A.S.H.O road test (Highway Research Board 1962).

Labor costs are relatively low in the Sahel-Sudan area; therefore, we have considered values between 50-100 CFAF/hr. The equipment cost, on the other hand, is very high, depending on the sophistication of the equipment. Costs for all types of equipment used in road construction and maintenance have been assumed.

Four types of vehicles have been considered:

(1) private automobiles, at a cost of 1,060,000 CFAF each.

(2) small, 1-ton pick-up trucks with a cost of 1,060,000 CFAF each.

(3) 3.5-ton trucks at a cost of 4,300,000 CFAF each.

(4) 15-ton semi-trailers at a cost of 6,000,000 CFAF each.

These traffic levels and vehicle types have been used along with different construction strategies (changes in pavement type) and maintenance policies and are presented in the next section. We should point out that the maintenance policies examined are lacking in these countries, contributing considerably to the rapid road deterioration generally experienced

in the region.

2.4 Results

The results presented in this section come from the output of the computer programs whose underlying framework is discussed in section 2.2 above. This exercise is aimed at demonstrating the capabilities of these programs in providing information on road transport performance, cost elements, and the trade-offs among the various elements. The results themselves, therefore, are not intended to give accurate nor exhaustive assessment of road transport costs in the Sahel-Sudan region, but are merely suggestive of the type of consideration which must be given when decisions on investments are to be made.

This section is presented in three parts, each dealing with various aspects of road transport cost analysis. The first part deals with costs associated with dynamic staging and reconstruction of roads, while the second part is concerned with the sensitivity of transport costs to changes in traffic patterns including traffic levels and growth rates. Finally, the third part addresses the trade-offs which exist among the construction, maintenance, and vehicle operating costs for different maintenance policies and traffic. From such trade-offs, analysts and decision-makers can determine optimal design standards and maintenance policies which optimize public or private investments for a given set of traffic and operating conditions.

2.4.1 Construction staging analysis: This part of the study deals with the reconstruction strategies. A number of possible combinations of pavement changes have been examined. The upgrading sequence is done as follows: an earth road could be reconstructed to gravel, then finally upgraded to a high-grade asphalt road. Or an earth road could be upgraded to an asphalt road and so on.

Examples of various construction, maintenance, and vehicle operation resulting from different staged construction strategies are presented in Figures 2.4 – 1, through 2.4 – 3. The total costs are also shown on these figures for three different traffic levels. A large number of combinations of staged construction strategies can be examined with relative ease using these programs. After careful consideration of the traffic growth patterns and the trade-offs among the cost components, decisions on optimal strategies can be arrived at.

2.4.2 Sensitivity of transport costs to changes in traffic levels, and design and maintenance standards: Examination of the accumulated yearly costs associated with construction, maintenance, and vehicle operations for different traffic levels and maintenance policies on asphalt, gravel and earth roads are presented in this section.

Three different traffic levels have been considered: low (between 20 and 50 vehicles per day); medium (between 50 and 200 vehicles per day) and high (more than 200 vehicles per day). The composition of traffic is made up of the following proportions:

30 percent	one-ton pick-up trucks;
50 percent	3.5-ton trucks; and
20 percent	15-ton semi-trailers.

The accumulated annual construction, maintenance, and vehicle operation costs in various types of roads for a low level of traffic is given in Figure 2.4 – 4. Two different maintenance policies (high and low) were used for each type of road. In those, the construction costs, maintenance costs, and the foreign exchange component of the vehicle operating costs are government expenditures. It can be seen that from a total cost viewpoint that lightly maintained gravel and earth roads are most suitable for this low level traffic. In contrast, Figure 2.4 – 5 shows that for a medium traffic level, asphalt roads with light maintenance become more economical from a total cost standpoint. This trend

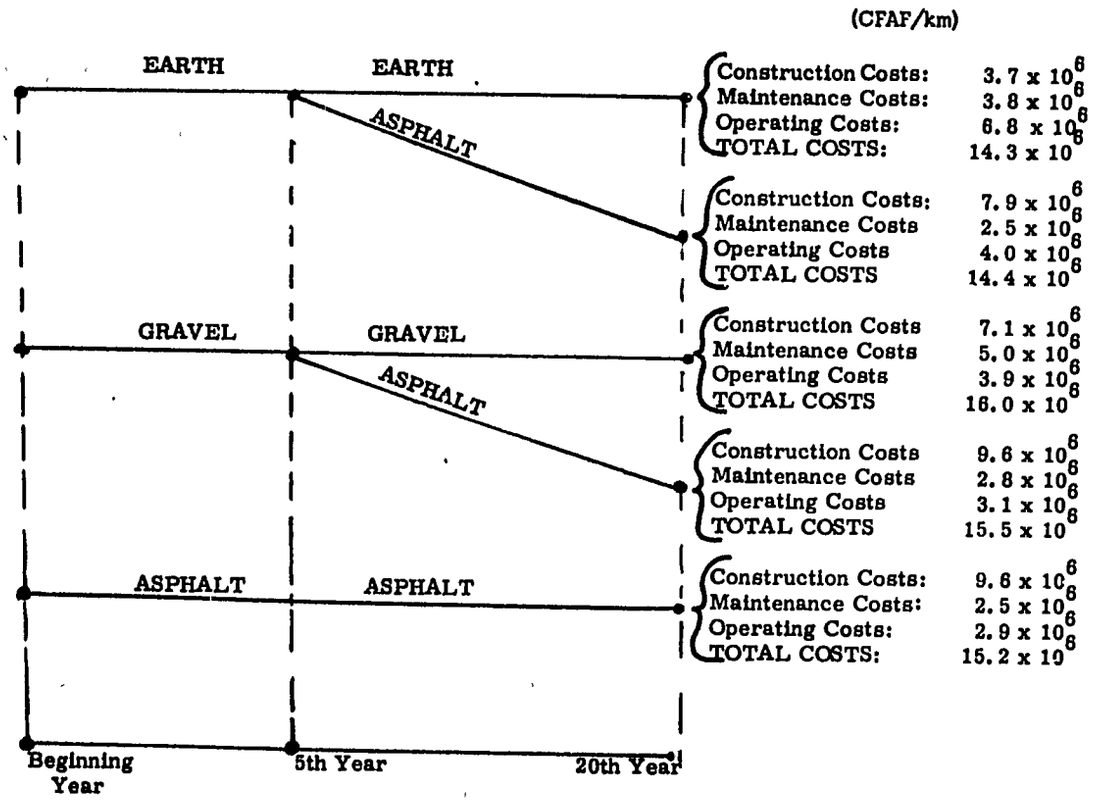


FIGURE 2.4 – 1: Discounted Value of Transport Costs Associated with Staged Construction Strategies for Low Traffic Volume (20-50 vehicles/day)

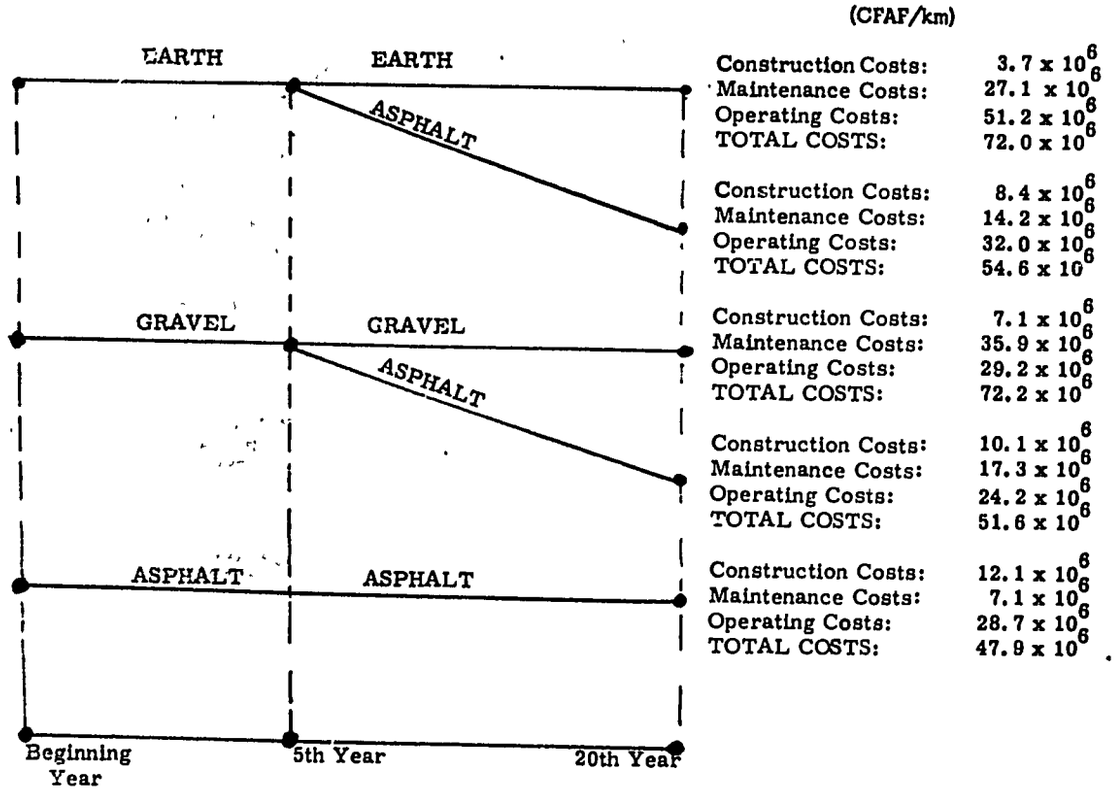


FIGURE 2.4 – 2: Discounted Values of Transport Costs Associated with Staged Construction Strategies for Medium Traffic Volume (50-200 vehicles/day)

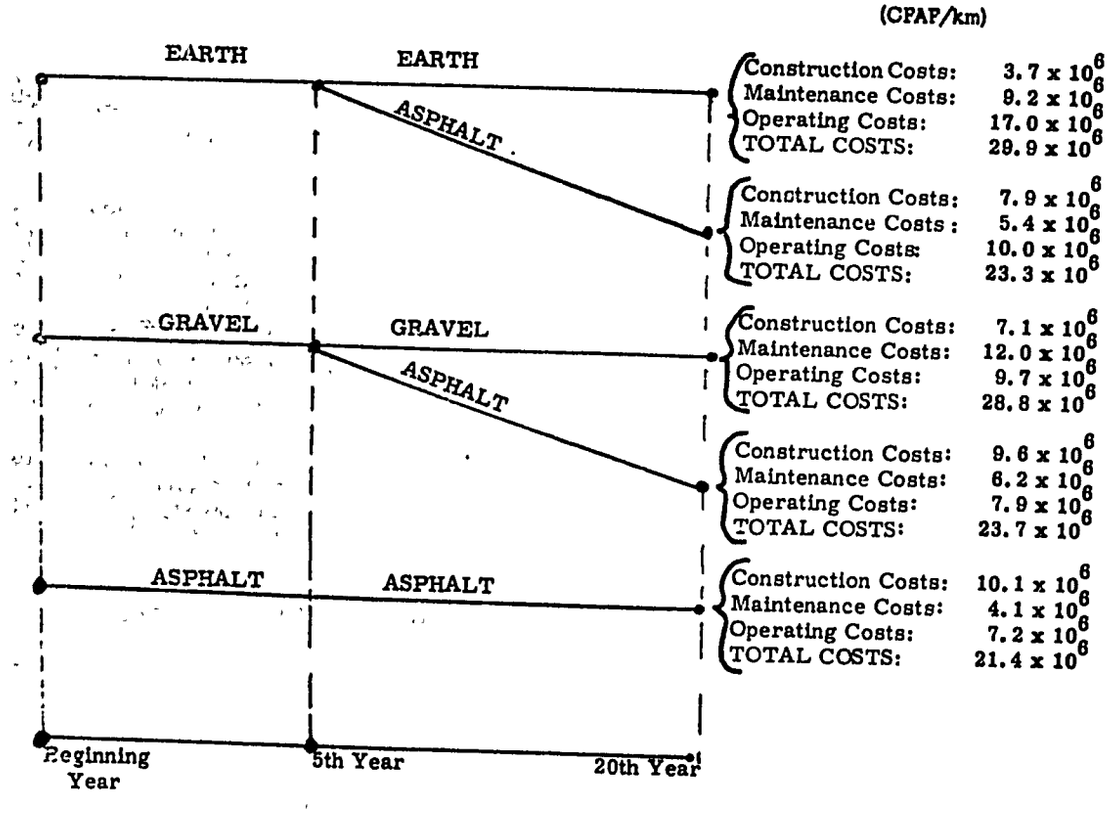


FIGURE 2.4 – 3: Discounted Values of Transport Costs Associated with Staged Construction Strategies for High Traffic Volume (200 or more vehicles/day)

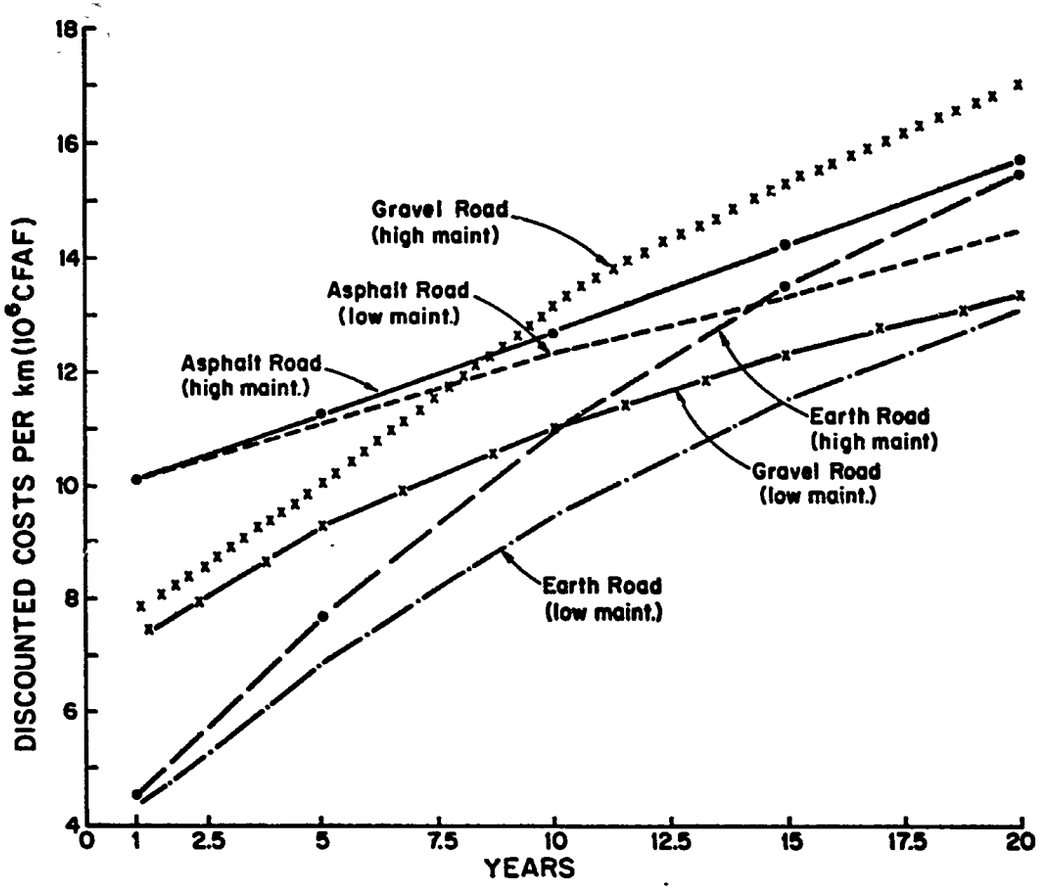


FIGURE 2.4 – 4: Accumulated Discounted Costs of Construction and Operating per km Low Volume Road Link (20 vehicles/day)

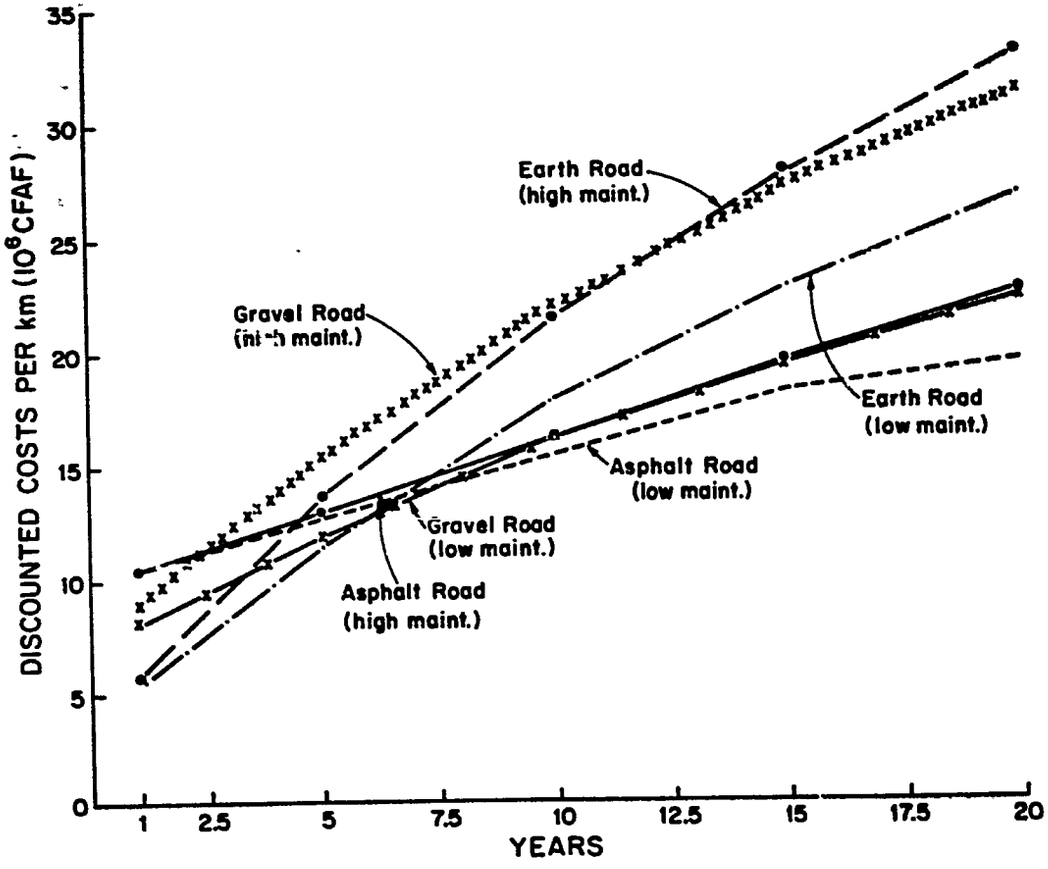


FIGURE 2.4 – 5: Present Value Construction, Maintenance and Operating Costs, per km Accumulated in Each Year: Medium Volume Road Link

(50-200 vehicles/day)

continues to be reinforced as the level of traffic increases as shown in Figure 2.4 – 6.

In order to show the effect of maintenance policies on transport costs more explicitly, consider Figure 2.4 – 7. This shows the costs of construction of various types of surfaces for different maintenance policies. Due to the lack of proper maintenance, the lightly maintained asphalt road exhibits more frequent need for reconstruction, and thus higher total construction costs over the 20 year range than the better maintained road. The computer programs described above allow the examination of a large number of policies so that optimal maintenance and construction strategies can be developed.

2.4.3 Trade-offs among transport cost components: This part deals with the trade-offs among construction, maintenance and operating costs, according to the traffic volumes for low and high maintenance policies.

A number of combinations have been examined. For example, Figure 2.4 – 8 shows the 20 year total discounted costs of construction, maintenance, and vehicle operation for a medium traffic volume, and high maintenance policy. It is seen from this figure that if the objective is to minimize total transport cost, the asphalt road seems to be most suitable. On the other hand, if vehicle operating costs are not considered, the earth road would be the preferred choice.

2.5 Summary and Conclusions

Although the above analysis was neither exhaustive nor site-specific, a number of conclusions may be drawn which can be helpful in future efforts on the study of transport in the Sahel-Sudan region. Greater detailed analyses are needed for specific feasibility or project studies. However, the tools presented here can be very helpful in

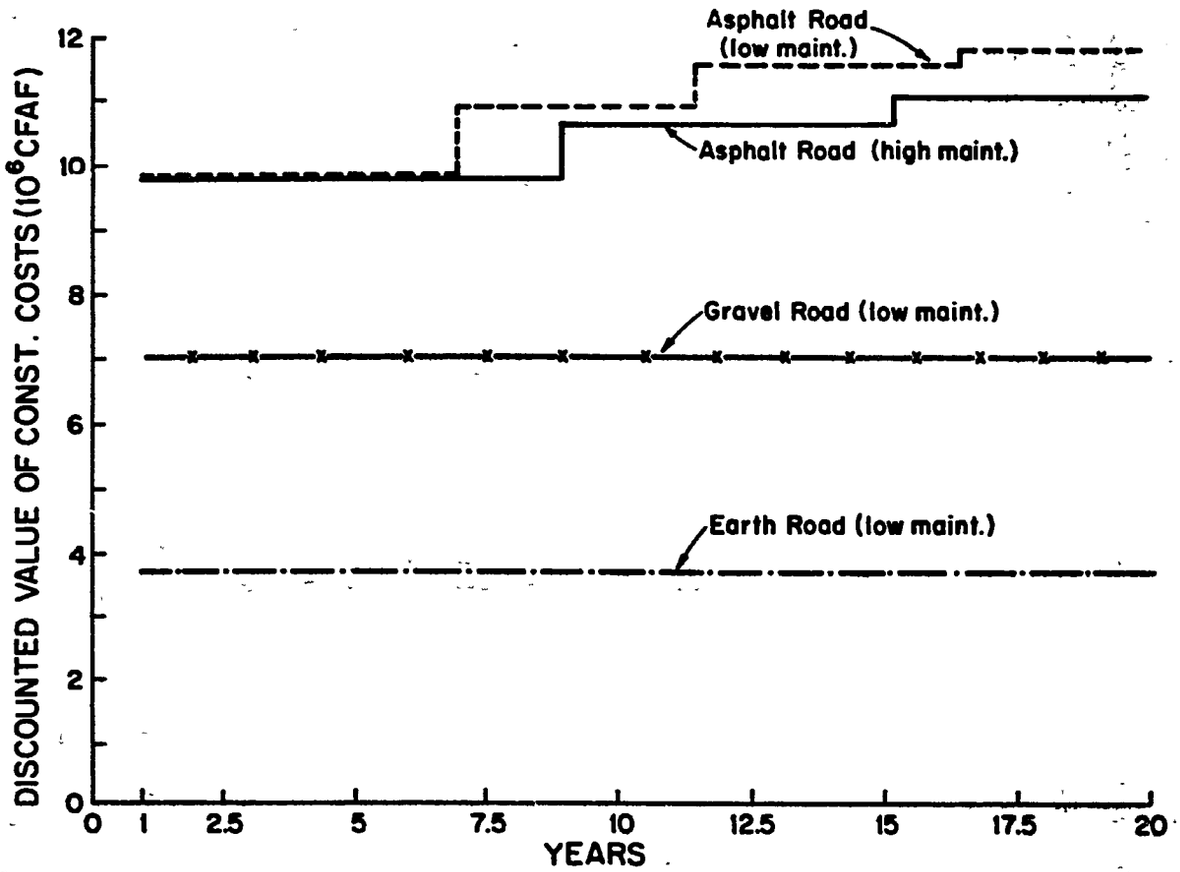


FIGURE 2.4 – 7: Discounted Value of Construction Cost , per km, for Each Year
High Volume Road Link
(200 vehicles/day)

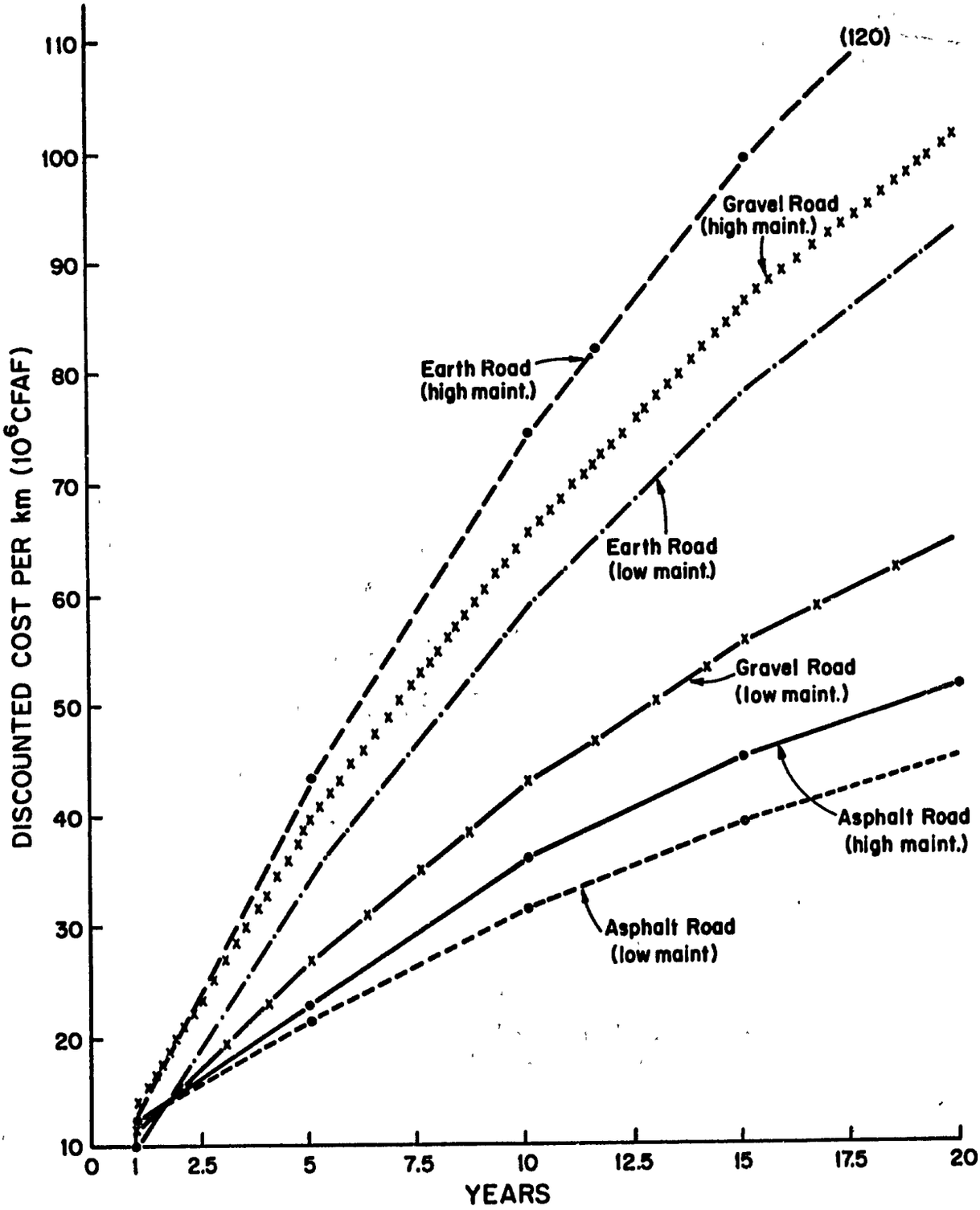


FIGURE 2.4 – 6: Discounted Value Construction, Maintenance and Operating Costs, per km, Accumulated in Each Year High Volume Road Link

(200 vehicles/day)

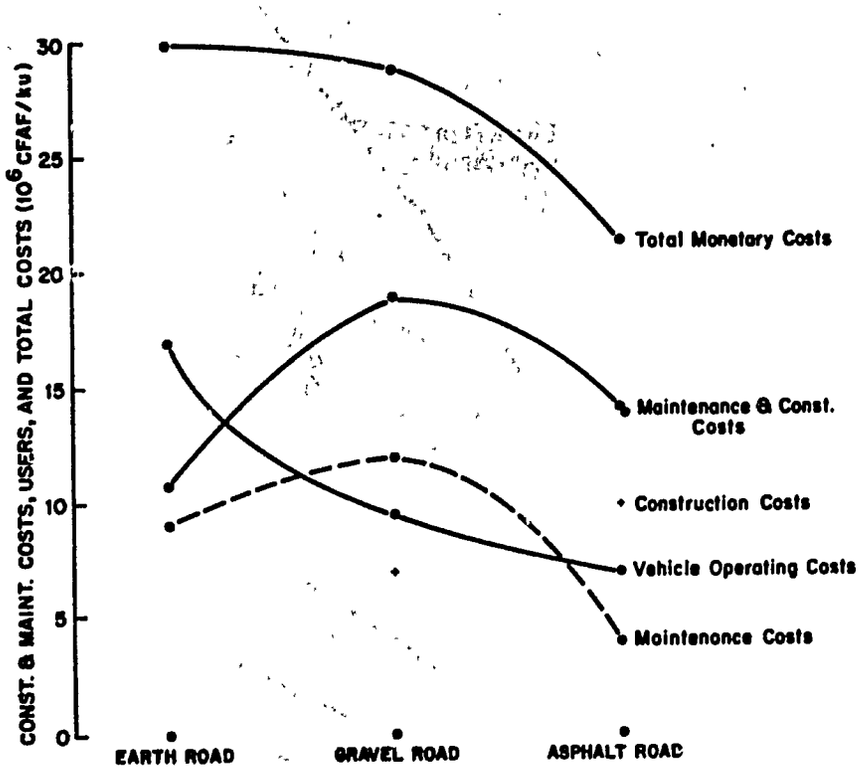


FIGURE 2.4 – 8: Comparison of Costs in a Medium Volume Road (50 vehicles and more/day)

[All costs are for the total period of 20 years, discounted to the present, in CFA/km]

Type of Maintenance: High

arriving at rapid and effective answers for use in the decision-making process.

2.5.1 From shippers and transporters viewpoints The operating costs are considerably smaller when the road surface is of a high quality asphalt-type which is well-maintained throughout its service life. For earth roads with gradually increasing traffic, staged construction and upgrading into gravel and asphalt type seems to be a reasonable approach to meet traffic demand and yet minimize costs to the government. Similarly, present gravel roads can be upgraded as traffic increases into asphalt roads.

2.5.2 From the total transport cost viewpoint: The sum of construction, maintenance and operating costs make earth roads appropriate for low (20 vehicles/day or less) to medium (50 vehicles/day) levels of traffic. An earth road is the most appropriate for the first seven or eight years. Thereafter, it should be upgraded to an asphalt road. For a high level of traffic (200 vehicles/day or more), asphalt surfaces seem to be more appropriate for the region.

In most cases considerable savings can be achieved by reconstructing the upper layer of the pavement rather than performing high maintenace on the road. In the examples presented earlier it was shown that:

- For low-volume roads (20 vehicles/day or less) reconstruction of the upper layer every 10 years results in minimum total costs.
- For medium-volume roads (50 vehicles/day) a reconstruction of the upper layer at about the 7th year, 13th and 18th year provides minimum total cost over the 20 year analysis horizon.
- For high-volume roads (200 vehicles/day or more) a reconstruction of the upper layer every five years or less, depending on the traffic level, is needed.

3. ROLE OF TRANSPORT IN CATTLE MOVEMENTS: MALI, AN EXAMPLE

3.1 Introduction

Perhaps one of the most widely practiced activities in the Sahel-Sudan region is cattle-raising. Many of the nomadic groups are herdsmen and the ownership of cattle is considered to be a sign of wealth in this region. The cattle forage for their food in an environment in which rainfall is extremely sparse and the vegetative support for cattle is limited. Maturity time for these cattle is on the order of five years.

Markets for cattle have developed in all major cities in the Sahel-Sudan zone, particularly those which are rail heads or at the limit of developed road systems. From these major markets the cattle are shipped by truck or rail to the west African coast where their value is much higher because of the larger markets for meat. It is useful for our purposes to focus on one of these markets; the market in Niono, Bamako, and Abidjan. The salient facts are given in Figure 3.1-1, The Cost of Moving Live Cattle Between Major West African Markets.

Niono, a small city in the northern part of Mali, is near the southern border of Mauritania. It is typical of any one of dozens of small cattle markets throughout the Sahel-Sudan region, where local herdsmen sell their cattle to traders in the markets for approximately 32,000 Malian Francs (MF) per head. The trader, using herders, then drives them to Bamako for around 40,000 MF/head. Undoubtedly some of the cattle owners drive their cattle to market without using a trader, but as Table 3.1 – 1 illustrates there are some 3,120 MF of profits which the seller reaps as a result. From Bamako, cattle may be purchased to carry to markets on the coast. For example, Abidjan is some 1,500 kilometers to the south by truck. Transport cost is 14,370 MF/head. At the Abidjan market, cattle can be purchased for around 68,000 MF/head. The price per pound varies from 400 to 450 Mf/kg for an animal weighing 170 kg.

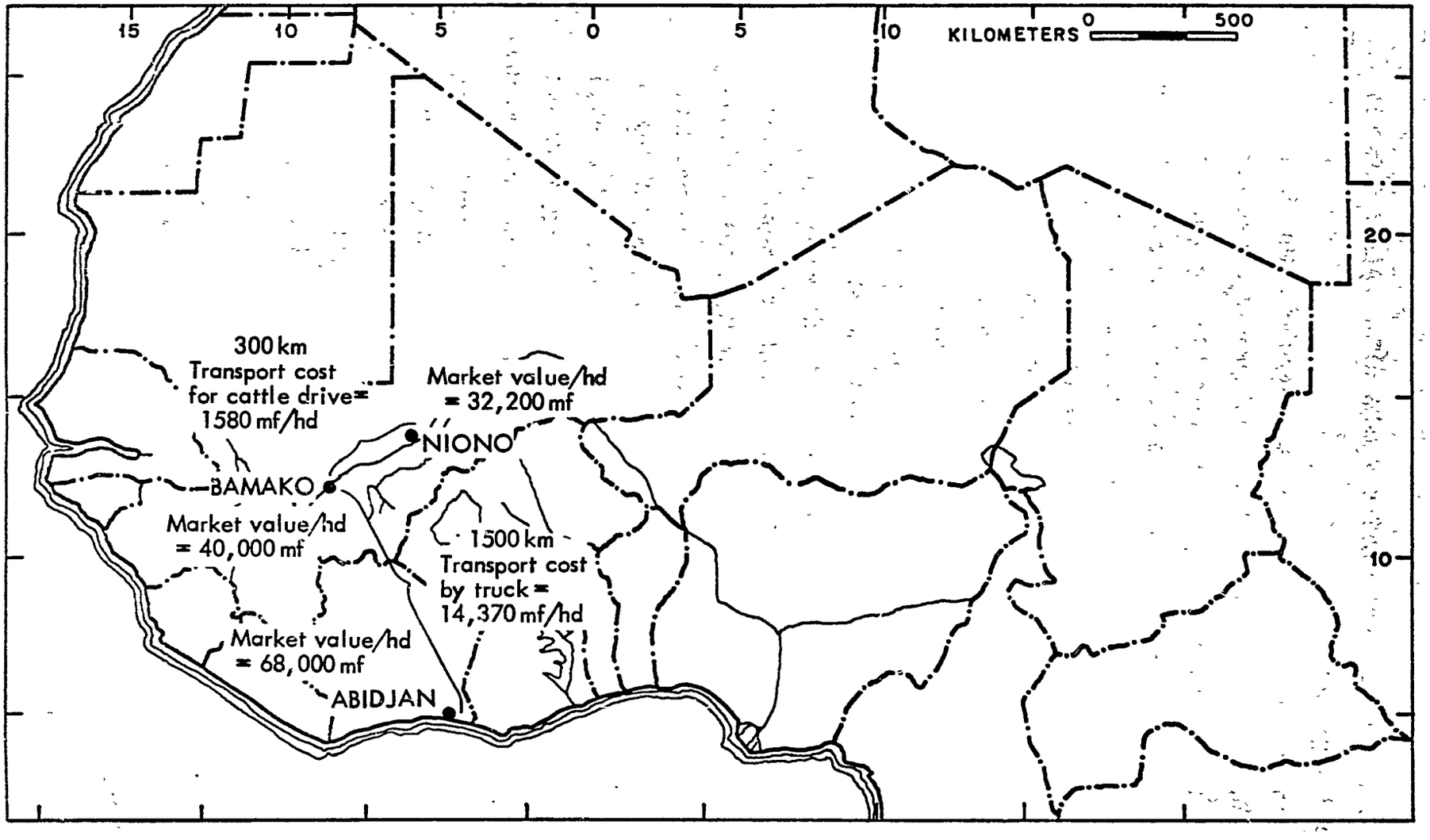


FIGURE 3.1 – 1. The Cost of Moving Live Cattle Between Major West African Markets.

TABLE 3.1 – 1

COSTS OF MOVING LIVE CATTLE BETWEEN MAJOR WEST AFRICAN MARKETS

	Abel-Bagrou-Bogou-Ferkessedougou-Abidjan		Abel Bagrou-Bamako-Abidjan		Niono-Bamako		Bara-Kati	
	Cost/Head (MF)	Total Cost (000 MF)	Cost/Head (MF)	Total Cost (000 MF)	Cost/Head (MF)	Total Cost (000 MF)	Cost/Head (MF)	Total Cost (000 MF)
Time Required for (days)	100-110		60-90		50		20-40	
Collection	30-40		15-21		30		15-30	
Transport	45		17		12		12	
Sale	30		30		7		7	
Distance Traveled (km)	1,600		1,500		300		370	
Average Carcass Wgt (kg)	140		180		140		140	
Size of Herd (head)	80		40		50		50	
Cost of Purchase	33,600	2,688	39,600	1,584	12,200	1,610	29,400	1,470
Cost of Collection	500	40	500	20	600	30	400	20
Cost of Transport	6,440	515 2	14,370	574 8	980	49	1,040	52
Wages of herders	1,000	80	1,300	52	360	18	400	20
Food for herders	600	48	600	24	200	10	200	10
Losses, forced sales	840	67 2	720	28 8	360	18	340	17
Miscellaneous	800	64	500	20	60	3	100	5
Ferry	--	--	--	--	--	--	--	--
Railroad	3 000	240	--	--	--	--	--	--
Truck	--	--	11,000	440	--	--	--	--
Return Trip	200	16	250	10	--	--	--	--
General Costs	6,250	500	5,050	202	1,940	97	2,020	101
Health tax	1 000	80	1,000	40	--	--	--	--
Customs duties	150	12	150	6	--	--	--	--
Licenses	--	--	--	--	600	30	600	30
Financial costs (1)	4,000	320	2,800	112	1,000	50	1,000	50
Wage of Head of convoy (2)	600	48	600	24	240	12	300	15
Travel of merchant	500	40	500	20	100	5	120	6
Cost of Sale	2,200	176	2,200	88	600	30	600	30
Broker	200	16	200	8	60	3	60	3
Food for herders	400	32	400	16	140	7	140	7
Credit (3)	1,600	128	1,600	64	400	20	400	20
Total Distribution Cost	15,395	1,231 2	22,123	884.8	4,120	206	4,060	203
Value of Sale at average carcass wgt of (kg)	56,000	4,480	67,650	2,706	37,800	1,890	33,750	1,687 5
	140		145		135		135	
Commercial Profit (4)	7,010	560.8	5,930	237.2	1,480	74	290	14 5
Commercial Profit Plus Implicit Return to Capital, Trader's Labor, etc. (1) + (2) + (3) + (4)	12,610	1,008.8	10,330	413 2	3,120	156	1,990	99 5
Value Added by Commerce								
Per head of cattle	2[illegible],400	--	28,050	--	4,200	--	4,350	--
Per kg of carcass wgt	160	--	170	--	32.4	--	32.2	--

	Severe-Sikasso-Abidjan		Niono-Ouangolodougou-Abidjan		Mopti-Bobdioulasso		Mopti-Paga		Gao-Bamako	
	Cost/Head (MF)	Total Cost (000 MF)	Cost/Head (MF)	Total Cost (000 MF)	Cost/Head (MF)	Total Cost (000 MF)	Cost/Head (MF)	Total Cost (000 MF)	Cost/Head (MF)	Total Cost (000 MF)
Time Required for (days)	60-100		90-100		70-80		60-70		60-75	
Collection	20-30		30		20-30		20-30		20-30	
Transport	10-15		40-45		15		25		28	
Sale	30		15		30		10-15		10-15	
Distance Traveled (km)	1,250		1,250		450		600		700	
Average Carcass Wgt (kg)	160		160		150		160		160	
Size of Herd (head)	50		50		50		50		50	
Cost of Purchase	36,800	1,840	36,800	1,840	33,000	1,650	36,800	1,840	33,600	1,680
Cost of Collection	400	20	1,000	50	600	30	400	20	600	30
Cost of Transport	7,920	396	5,240	262	1,200	60	1,600	90	2,100	105
Wages of herders	800	40	800	40	400	20	600	30	800	40
Food for herders	300	15	300	15	200	10	300	15	400	20
Losses, forced sales	320	16	640	32	400	20	200	10	400	20
Miscellaneous	400	20	200	10	200	10	300	15	200	10
Ferry	--	--	--	--	--	--	--	--	100	5
Railroad	--	--	3,000	150	--	--	--	--	--	--
Truck	5,800	290	--	--	--	--	--	--	--	--
Return Trip	300	15	300	15	-	--	200	10	200	10
General Costs	11,240	562	12,700	635	10,230	511.5	15,900	795	16,000	800
Health tax	300	15	300	15	600	30	600	30	600	30
Customs duties	4,500	225	4,500	225	4,980	249	9,300	465	9,300	465
Licenses	3,000	150	3,000	150	3,000	150	3,000	150	3,000	150
Financial costs (1)	3,200	160	4,000	200	1,200	60	2,600	130	2,600	130
Wag. of head of convoy (2)	--	--	400	20	300	15	400	20	500	25
Travel of merchant	240	12	500	25	150	7.5	--	--	--	--
Cost of Sale	2,200	110	2,200	110	1,600	80	1,100	55	1,100	55
Broker	200	10	200	10	200	10	100	5	100	5
Food for herders	400	20	400	20	400	20	200	10	200	10
Credit (3)	1,600	80	1,600	80	1,000	50	800	40	800	40
Total Distribution Cost	21,760	1,088	21,140	1,057	13,630	681.5	19,000	950	19,800	990
Value of Sale at average carcass wgt of (kg)	62,000	3,100	60,000	3,000	43,500	2,175	54,000	2,700	54,000	2,700
	155		150		145		150		150	
Commercial Profit (4)	3,440	172	2,060	103	-3,130	-156.6	-1,800	-90	680	38
Commercial Profit Plus Implicit Return to Capital, Trader's Labor, etc (1) + (2) + (3) + (4)	8,240	412	7,660	383	-630	-31.5	1,600	80	4,000	20[illegible]
Value Added by Commerce										
Per head of cattle	25,200	--	23,200	--	10,500	--	17,200	--	20,400	--
Per kg of carcass wgt	142.6	--	156.6	--	72.4	--	114.6	--	136	--

SOURCE: FAC and OMVS, Approvisionnement en Viandes de l'Afrique de l'Ouest, Páris: SEDES, 1973 Part II, pp. 127-35

It is interesting to note that out of the 28,000 MF diffference in market price between Bamako and Abidjan transport accounts for 14,380 MF or slightly more than 50 percent. The balance of this difference consists of general cost, taxes, customs, and cost of sale which, together, amounts to slightly more than 7,000 MF leaving approximately 6,000 MF/head of profit to the trader (only about $12).

3.2 Transport as a Barrier to Trade

At this point a question which arises is the extent to which transport is acting as a trade barrier. A comparison with imported cattle from the U.S may be useful to determine what the cost would be. U.S. beef which could (in 1970) be bought at $.30/lb on the hoof and which (when dressed at a 60 percent yield per carcass) would cost approximately $.50/lb would have to move 7,230 kilometers by containership to enter this market. At a $.05/lb cost for refrigerated containership, the landed cost of imported U.S. beef in Abidjan would be approximately $.55 per pound or 605 MF per kilogram compared with the beef from Bamako whose carcass yield at 165 kg sells at a price of 410 MF/kg. Thus, the Malian meat is less expensive, though it may be of somewhat lower quality.

One could conclude from this example that inland transport is not in itself constraining the production and marketing of beef. However, it is still a large cost which, if reduced, would reduce the costs and increase the profits perhaps in the long run even allowing this meat to compete internationally.

3.3 Cost of Inland Transport

In order to determine what effects transport changes will have on the cost of meat, let us look explicitly at this cost element in the transport picture. Tables 3.3 – 1, through 3.3 – 3 give a break-

TABLE 3.3 – 1

BREAKDOWN OF THE OPERATION COSTS PER KM

BY VEHICLE TYPE

Vehicle Type: 15-ton semi-trailor
Maintenance: Normal

Components of the Operative Costs		ASPHALT ROAD		GRAVEL ROAD		EARTH ROAD	
		H.C.M.	P.A.	H.C.M.	P.A.	H.C.M.	P.A.
Crew	Units	0.020	0.015	0.024	0.020	0.058	0.025
	market costs	5.00	1.559	6.	1.979	24.0	2.541
	real costs	5.00	1.559	6.	1.979	24.0	2.541
Fuel	Units	0.590	0.679	0.708	0.826	0.826	0.964
	market costs	41.0	47.536	50.0	57.822	58.0	67.460
	real costs	29.0	47.536	35.0	57.822	41.0	67.460
Oil (lubricated)	Units	--	0.002	--	0.002	--	0.003
	market costs	--	0.261	--	0.331	--	0.397
	real costs	--	0.261	--	0.331	--	0.397
Tires	Units	--	0.002	--	0.000	--	0.000
	market costs	6.0	18.406	17.0	21.238	39.0	32.061
	real costs	3.0	18.406	7.0	21.238	16.0	32.061
Maintenance and parts	Units	--	--	--	--	--	--
	market costs	7.0	5.593	12.0	8.505	20.0	14.175
	real costs	5.0	5.593	9.0	8.505	14.0	14.175
Labor	Units	--	0.002	--	0.004	--	0.006
	market costs	--	0.248	--	0.278	--	0.630
	real costs	--	0.248	--	0.378	--	0.630
Depreciation	Units	--	--	--	--	--	--
	market costs	8.	1.958	11.0	2.486	18.0	3.193
	real costs	6.	1.958	8.0	2.486	12.0	3.193
Total	market costs	68.0	71.539	95.0	92.74	158.0	120.46
	real costs	48.0	71.539	64.0	92.74	107.0	120.46

TABLE 3.3 – 2

BREAKDOWN OF THE OPERATION COSTS PER KM BY VEHICLE TYPE

Vehicle Type: 3.5-ton truck

Maintenance: Normal

Components of the Operative Costs		ASPHALT ROAD H.C.M.	ASPHALT ROAD P.A.	GRAVEL ROAD H.C.M.	GRAVEL ROAD P.A.	EARTH ROAD H.C.M.	EARTH ROAD P.A.
Crew	Units	0.018	0.015	0.022	0.020	0.055	0.025
	market costs	5.000	1.554	6.000	1.479	24.000	2.541
	real costs	5.000	1.559	6.000	1.979	24.000	2.541
Fuel	Units	0.346	0.434	0.476	0.526	0.555	0.614
	market costs	28.000	30.710	33.000	36.859	39.00	43.002
	real costs	20.000	30.710	24.000	36.859	28.000	43.002
Oil (lubricated)	Units	--	0.002	--	0.002	--	0.003
	market costs	--	0.264	--	0.331	--	0.347
	real costs	--	0.264	--	0.331	--	0.347
Tires	Units	3.000	0.000	--	0.000	--	0.000
	market costs	3.000	4.859	6.000	7.281	14.000	10.992
	real costs	1.000	4.659	2.000	7.281	6.000	10.992
Maintenance and parts	Units	--	--	--	--	--	--
	market costs	12.000	3.386	19.000	5.079	33.000	8.465
	real costs	8.000	3.386	12.000	5.079	22.000	6.465
Labor	Units	--	0.002	--	0.004	--	0.006
	market costs	--	0.252	--	0.378	--	0.630
	real costs	--	0.252	--	0.378	--	0.630
Depreciation	Units	--	--	--	--	--	--
	market costs	16.000	1.423	23.000	1.782	37.000	2.288
	real costs	10.000	1.423	15.000	1.782	24.000	2.288
Total	market costs	63.0	42.25	87.0	53.69	146.0	88.31
	real costs	43.0	42.25	59.0	53.69	102.0	66.31

TABLE 3.3 – 3

BREAKDOWN OF THE OPERATION COSTS PER KM BY VEHICLE TYPE

Vehicle Type: 1-ton truck (van)

Maintenance: Normal

Components of the Operative Costs		ASPHALT ROAD H.C.M.	ASPHALT ROAD P.A.	GRAVEL ROAD H.C.M.	GRAVEL ROAD P.A.	EARTH ROAD H.C.M.	EARTH ROAD P.A.
Crew	Units	0.015	0.015	0.020	0.020	0.050	0.025
	market costs	4.000	1.554	6.000	1.979	24.000	2.541
	real costs	4.000	1.554	6.000	1.979	24.000	2.541
Fuel	Units	0.157	0.153	0.189	0.184	0.220	0.215
	market costs	11.000	10.755	13.000	12.907	15.000	15.058
	real costs	8.000	10.755	9.000	12.907	11.000	15.058
Oil (lubricated)	Units	--	0.002	--	0.002	--	0.003
	market costs	--	0.264	--	0.331	--	0.397
	real costs	--	0.264	--	0.331	--	0.397
Tires	Units	--	0.000	--	0.000	--	0.000
	market costs	2.000	3.106	4.000	4.854	8.000	7.328
	real costs	1.000	3.106	2.000	4.854	3.000	7.328
Maintenance and parts	Units	--	--	--	--	--	--
	market costs	4.000	0.731	2.000	1.096	3.000	1.827
	real costs	4.000	0.731	1.000	1.098	2.000	1.827
Labor	Units	--	0.001	--	0.002	--	0.004
	market costs	--	0.157	--	0.236	--	0.344
	real costs	--	0.157	--	0.236	--	0.344
Depreciation	Units	--	--	--	--	--	--
	market costs	5.000	0.384	7.000	0.481	11.000	0.617
	real costs	3.000	0.384	4.000	0.481	5.000	0.617
Total	market costs	24.0	16.95	32.0	21.88	61.0	28.16
	real costs	16.0	16.95	21.0	21.68	45.0	28.16

down of the operating cost/km by vehicle type in CFAs. These tables (compiled using the Project Analyser and the Highway Cost Model described elsewhere in this report) give a breakdown of the various costs making up the total operating cost for different size vehicles. For our purposes we could assume that a semi-trailer type vehicle with a 15-ton payload would be used. This vehicle has a load area of approximately 200 square feet which could be used with stake-bodied sides to carry cattle. Assuming that the average adult animal weighs 300 kg (see Table 3.3 – 4), the payload is sufficient to carry up to 400 head of cattle. However, the U.S. experience with cattle transport is that each animal requires approximately 11 square feet for a 1,000 pound animal. If we assume that, because of their smaller size, the surface requirements are 10 square feet per head, 20 cattle could be transported by this vehicle.

The roads from Bamako are reasonably good asphalt roads. With operating costs of 71.54 CFA/km from Table 3.1 – 1, this is converted into 153 MF/km. The cost for the 1,500 km Bamako to Abidjan run would be approximately 229,500 MF per truck; totalling 11,475 MF per head which agrees extremely well with the 11,000 MF in Table 3.1 – 1. The low priced 250 MF return trip reflects the fact that imports provide some flow into Bamako. Thus -- with the simulation models at our disposal -- we are able to reproduce the costs incurred for cattle shipment in the Sahel.

It is interesting to examine the cost of the movement from Niono to Bamako on earth roads. Figures from Table 3.3 – 1 suggest that the unit cost would be increased to 120 CFA/km or approximately 240 MF. For a 300 km trip this amounts to approximately 72,000 MF or, with an emply backhaul, it raises the cost to 144,000 MF for 20 head of cattle -- a cost of approximately 7,200 MF per animal. By contrast, the same transfer can be accomplished for approximately 980 MF by

TABLE 3.3 — 4

	Weights (kg) Worldwide[1] Adults	Weights (kg) Worldwide[1] Birth	Weights (kg) Sahel	Assumed Average Weights (kg)	Resting Adult Metabolism C/kg/yr	Young Resting Metabolism C/kg/yr	Fodder Units/yr Resting Average Weight	Feed Units/Yr	Fodder Units/Yr	Assumed Optimal Fodder Units/Yr	UBT	SU	SSU	AU
Cattle	250-900	15-32	300-525	300	7,665	18,250	700	900	1,300-2,370	1,500	0.8	3	0.5	0.6
Sheep	32-50	-	30-90	50	9,490	-	145	300	-	300	0.1	1	0.1	0.1
Donkey	80-100			150	-	-	-	-	-		-	2	-	0.3
Horse	350-750	200(3 mo)		500	11,680	1,340	-	-	-	2,700	-	-	-	1.1
Goat	28-70	2 (1 mo)	25-35	35	12,410	47,450	190	300	-	400	0.1	1	0.1	0.1
Camel	450-700	31		600				1,500	-	2,000	1.0	5	1.0	1.3

herders who drive the cattle from Niono to Bamako. If the roads were asphalt, the cost would be lowered to a figure on the order of 2,145 MF per head, but this is still too expensive to make it competitive with herded cattle. Even with a full backhaul, the cost would drop to only 1,072 MF. Obviously, not all of the factors have been taken into account in the herded case since there is bound to be a weight loss in the animals as well as capital being tied up. However, wage rates for herders are so low that it is difficult for trucks to compete. It will continue to be difficult to compete until the productivity of individual farmers or herdsmen in the Sahel-Sudan region increases.

3.4 The Cattle Raising Process

The existing extreme drought situation in the Sahel-Sudan region of Africa is apparently an infrequent but recurring phenomena. This is explained in more detail elsewhere in other studies on the region; however there are annual drought conditions which limit the growth of forage crops and restrict cattle feeding, resulting in weight losses. The result is a weight gain pattern for cattle similar to that shown in Figure 3.4 – 1. This greatly constrains the meat producing capabilities of the region and lowers overall productivity. An animal born toward the beginning of the rainy spell at year zero will not achieve a full market weight of 300 kg until after 4 1/2 years (5 rainy seasons). If herd replenishment (losses due to death and disease) and bulls are included in the overall complement of animals, then there is a yield of approximately one per 6.2 animals in the herd per year. The sale of this one animal is worth 32,000 MF in the Niono market. Thus, a herder who owns 6.2 animals could sell one per year, netting a total sum which in U.S. currency would amount to slightly more than $60.

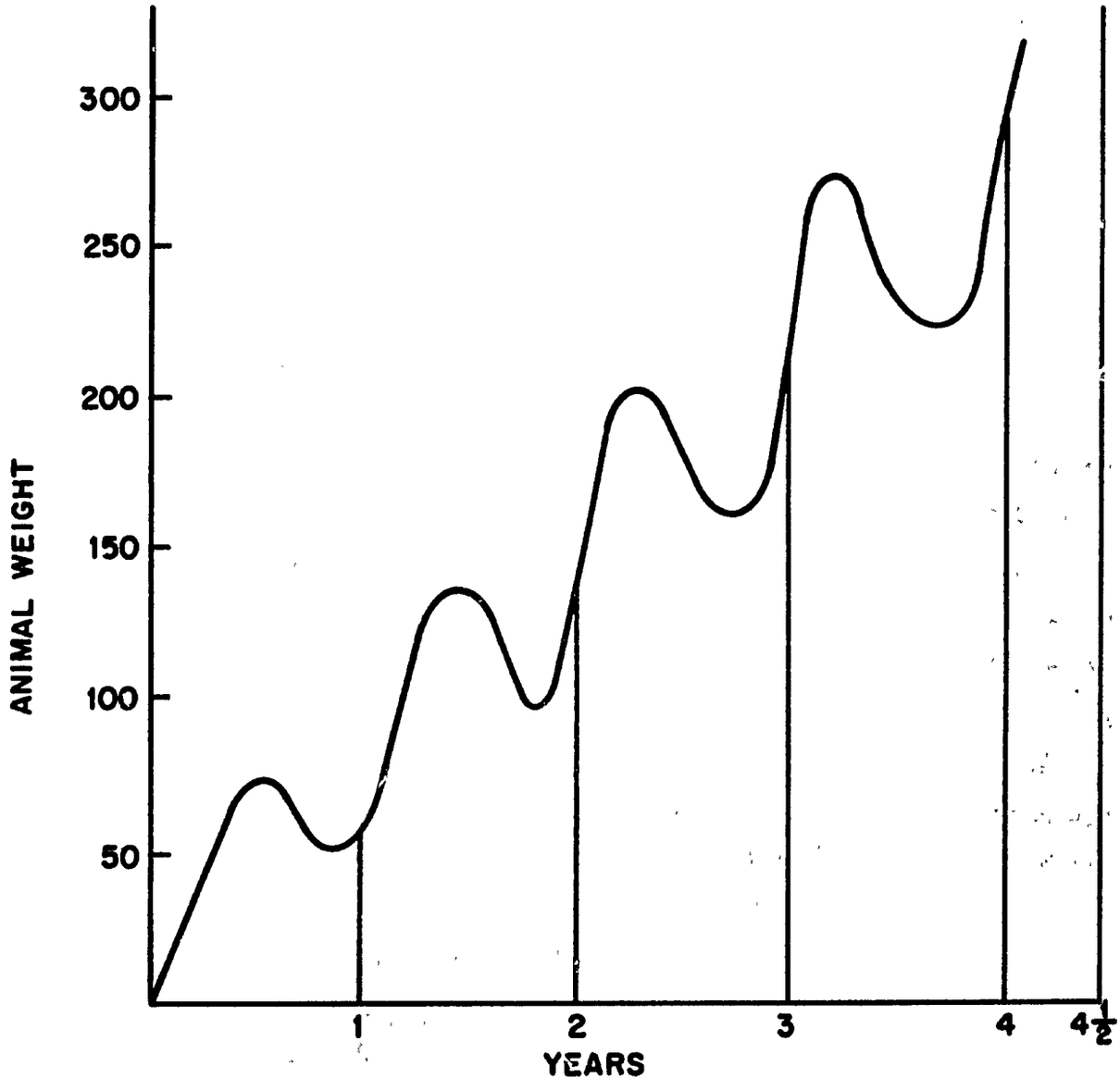


FIGURE 3.4 – 1

This is extremely low productivity -- apparently the result of the long period to get an animal ready for market. The question is: Is there a way to improve the current situation by using supplemental feeding to reduce the time to market a young calf?

If we assume that grain is available and can be imported from growing areas in the south at distances of approximately 1,000 kilometers, then how much supplemental feed would be required to allow the calf to grow steadily to maturity? If out of each year, supplemental feeding is required for six months, then almost two years could be cut from the 4 1/2 years currently required. Supplemental feeding would be necessary approximately 40 percent of the time period if it were instituted. If 40 percent of the weight gain of 300 kg total must be fed, then this would amount to 120 kg. Assuming that one half of this weight gain comes directly from supplemental feed, then the cost of feeding can be determined.

Possible feed includes millet, sorghum, barley and other grains, as well as hay. Using prices for millet and sorghum of 50 MF/kg, U.S. experince would yield a cost for hay or around 25 MF per kilogram. . . .

The cost of transport is estimated by the following method: the same open, stake-bodied truck can be used with a tarpaulin; the grain density is high enought so that it would not fill the truck before the basic payload of 13,635 kg is achieved. With a vehicle operating cost of 143,000 MF, this amounts to 10.5 MF/kg for grain. Thus, the delivered cost of grain would be approximately 60.5 MF/kg.

The cost of hay, which is lighter and tends to cube out in the truck, would be 13 MF/kg and the total cost of hay delivered would be approximately 38 MF/kg.

The next question that arises, if we assume that feed will run on the average 50 MF/kg, concerns the amount that will have to be fed the

cattle per kilogram of weight gain. Average figures in the United States suggest that this will be on the order of 7 kg feed per kg of weight gain; so, to account for one-half the weight gain of 120 kg would require feed costing 21,000 MF/head.

There would, at the same time, be a higher productivity of cattle. For every animal harvested there would have to be only 3.7 cattle overall. Or, for 6.2 cattle, the offtake would be 1.6 cattle per year rather than the one animal per year previously experienced. However, in order to accomplish this there would be an additional cost of 21,000 MF/head for feed. Thus, although total revenues would be 53,775 MF/year for each 6.2 cattle held, the cost would have risen to more than 130,000 MF per year. Consequently, a loss of more than 80,000 MF is incurred.

3.5 The Requirements for Feedlot Operations

If it is too expensive to ship the grain to the cattle, perhaps it will be less expensive to ship the cattle to the grain. This is the basic theory of a feedlot operation, and it is worth investigating in this situation.

If, after nine months on the range, calves were shipped by truck to a feedlot located within the grain growing region, more of them could be shipped for the same transport cost than previously considered. At nine months the calf should be approximately 60 kg in weight, thus, the offtaken from the herd would be three calves per 6.2 total animals in the herd.

If a mature animal sells for approximately 107 MF/kg, then a younger animal should sell for approximately the same price per kilogram. This would yield 6,435 MF/animal or for the three animals sold during this year, approximately 19,310 MF. The herder would therefore lose

money over previous time periods unless he could increase his herd size. Since almost one-half of the herd would be sold and not have to be carried through the dry period of the year, it is conceivable that a larger herd could be managed. If the herd size doubled, 25 percent more income per year could be made than previously.

There should be economies in the transport of calves to the feeding areas to the south. For U.S. calves at equivalent weights, approximately 3.8 square feet per animal is required for transport. If we used four square feet per animal, this would be 50 calves per truck and the transport cost would work out to 2,860 MF/head. This is considerable saving over the 11,000 MF for full grown cattle.

In order to understand the technology of the feedlot, it is useful to examine U.S. experience. The usual procedure is to start with a feed program comparable to the protein content experience on the range. This is slowly switched to grain and higher protein foods. Once the cattle are ready for slaughter, they are moved immediately to the slaughter house and killed.

In Imperial County, California (the largest cattle-feeding county in the United States), which is a desert area irrigated for local growth of feed grains and forage crops, it is interesting to note for comparison purposes the feedlot practices. Calves are purchased from all over the western part of the United States and from the south as far east as Florida and Georgia. Then they are trucked to the Imperial Valley when they are approximately 6 to 9 months old and weigh in the vicinity of 250 pounds per head. Feedlot operators have reported gains of as much as 750 pounds in 250 days, or 3 pounds per day. The overall statistics for the area in 1971 showed average annual weight gains per animal of approximately 468 pounds, but the weight gain has been going up over time since 1960 when the reported gain was approximately 315 pounds per year.

The makeup of the diet for feedlot cattle is illustrated in Table 3.5 – 1. Grain and other high-protein foods amounted to 82 percent of the total. For the 697,000 animals in feedlots, the average consumption was 1.675 tons/animal or 3,343 pounds/animal. This amounts to 6.89 pounds of feed per pound gained average ratio. By working with the other statistics that are available, it is possible to deduce average gain rates. A 250 pound yearling calf on the range experienced an average gain of 0.68 pounds/day, while the figures given above for the feedlot indicate that approximately 1.74 pounds/day are achieved in that environment. One can deduce, therefore, that with good pasture land a 1 pound/day gain is approximately what one can expect. This results in the overall gain figures given in Table 3.5 – 2.

If we now attempt to extrapolate some of these findings into the situation in west Africa, we might reason as follows. Once the 60 kg calf is moved to the south (e.g. Ivory Coast) it could be placed on pasture where it would require 88 days to reach a weight of 100 kg (accomplished at a rate of 1 lb/day = .45 kg/day). Then we place the calf in a feedlot to gain the final 200 kg. If Malian feed is estimated to cost 50 MF/kg, then the total cost to achieve the 300 kg final weight would be 70,000 MF. The total cost associated with the operation is summed up in Table 3.5 – 3. The result is a loss of 22,473 MF/head. The problem is the high cost of feed in the Ivory Coast. If U.S. prices for feed were used at $60/ton this would translate to a local equivalent of 33 MF/kg. Applying this to the 200 kg weight gain, the overall cost would be 46,200 MF which when substituted into the figures of Table 3.5 – 3 would leave the feedlot operator with a very small profit. It may be possible to subistitute lower cost feeds as part of the feeding program, but it appears that until cost for feeding can be reduced a feedlot operation is not economically feasible.

TABLE 3.5 – 1

FEED DIET

for 679,000 cattle in Imperial C. 1971

FOOD DIET	QUALITY FEED	PERCENT	VALUE
Grain	586,200 tons	51%	$58/ton
Alfalfa	174,000 tons	15	$32/ton
Straw	27,000 tons	3	12/ton
Other High Protein	349,780 tons	31	60/ton
TOTALS	1,136,980 tons	100%	$53/ton*

*Weighted Average

TABLE 3.5 – 2

RATE OF GAIN FOR IMPERICAL CO. CATTLE

RANGE		PASTURE		FEEDLOT			
250 lbs. / 365 days	+	189 lbs. / 189 days	+	486 lbs. / 279 days	=	925 lbs. / 833 days	= 2.28 yrs.
.68 lbs/day		1 lb/day		1.74 lbs/day			

SOURCE: Board of Superintendents, Imperial County Agriculture Newsletter, 1973.

TABLE 3.5 – 3

COST VERSUS MARKET PRICE FOR FEEDLOT OPERATIONS

Calf 107.3 MF/kg x 60 kg/hd.		=	6,438 MF/hd.
Transport to Feedlot		=	2,860 MF/hd.
Transport to Market	$\frac{500 \times 71.52 \text{ CFA/km} \times 2}{20 \text{ head}}$	=	3,575 MF/hd.
Feed		=	70,000 MF/hd.
General Costs		=	5,050 MF/hd.
Cost of Sale		=	2,200 MF/hd.
	TOTAL		90,123 MF/hd.
	MARKET PRICE		67,650
	LOSS		22,473 MF/hd.

3.6 A Final Improvement Strategy

One other possibility for improving the current situation remains to be investigated. Suppose that feeder cattle were taken from the range areas in the north while they were still calves and placed on pasture in the south for fattening. This would avoid the severe weight losses which cattle experience in the drought areas and would shorten time for maturity. If the calves were transported at a weight of 60 kg, then this leaves 240 kg to be gained in pasture. If the previous rate of weight gain for cattle was assumed as .45 kg/day, then 533 days would be required to achieve the needed gain. Adding the range time of 270 days, this gives a total time to maturity of 803 days, or 2.2 years. If one assumes 2.5 years overall, then the yield is one animal per 3.7 in the herd size. It is difficult to say what the total cost of pasturing the animal is, since this depends on the availability of land, etc., but it is clear that there is ample margin for profitability since the major cost of food has been eliminated and transport costs have been greatly reduced.

Due to the extremely low shipping density of cattle, it is possible to reduce transport cost even further by using a double-decked truck so that twice the number of calves can be carried. Recomputing the transport cost with this change in technology results in a cost of 2,145 MF per head. This is a substantial reduction is costs when compared to the 11,000 MF transport cost in the current situation.

A concept is needed whereby the differential herd sizes can be explicitly taken into account in the analysis. This could be done if we were to put a value on the stock in inventory. This might be viewed as the opportunity cost of capital. In the case of the 6.2 current cattle, an estimate of the inventory cost might be made as shown in Table 3.6 – 1. With a herd size of 6.2 cattle, the inventory cost per year at an interest rate of 10 percent would be 13,563 MF, while for a

TABLE 3.6 – 1

VALUE OF STOCK HELD IN INVENTORY

Herd Size -- 6.2 Cattle	Total Value (MF)
1.0 Breed Cow	32,000
.2 Breed Reserve	6,400
5 yr. Calf	32,200
4 yr. Calf	26,000
3 yr. Calf	19,500
2 yr. Calf	12,900
1 yr. Calf	6,438
	135,838 MF
Interest/year forgone @ 10%	13,563 MF

Herd Size -- 3.7 Cattle	
1.0 Breed Cow	32,200
.2 Breed Reserve	6,400
1.5 One Year Calves	9,657
	48,257 MF
Interest/year forgone @ 10%	4,826 MF
Difference in Inventory Costs	13,563 MF
	– 4,826 MF
	8,737

herd size of 3.7 cattle, the interest would be only 4,826 MF. The difference of 8,737 MF/year could be thought of as the value of the difference in strategies over and above differential costs and revenues.

3.7 Conclusions

Putting both transport and inventory savings together it is difficult to estimate the costs to the cattle owner since we do not know his wages or other costs. However, we can get a feel for the difference between current practice and moving the calves to pasture in the south by determining the ratio of the contribution of the sales less costs to capital invested in inventory for the two strategies. This is done in Table 3.7-1. The resulting ratio, 0.338 for current practice and 1.13 for the new strategy reflects the possible improvements that could result.

The conclusions that can be drawn from this effort are relatively few but important. First, it is clear that driving cattle to the initial market is cheaper than trucking it, even with adequate roads. This can only be explained in terms of the low productivity of the area reflected in the fact that current wage rates are so low that there are few more important things a farmer could be doing. This also ignores weight loss, but apparently this is not a large factor in the movement of the cattle. Once productivity has risen and wage rates are developed accordingly, this will begin to change.

A second conclusion that can be drawn is that the cost of moving supplementary feed to cattle is prohibitively expensive. It would be cheaper in any event to take the cattle to the food than to take the food to the cattle, because there is a factor of approximately 7 times the volume of food that must be moved over the volume of meat that is produced.

The current situation, with feed grain costs at their present level, makes feedlot operations too expensive to be viable. Until grain costs

TABLE 3.7 – 1

OVERALL COMPARISON OF STRATEGIES

STRAGETY 1

Herd Size 6.2 Cattle Offtake 1 animal/year

5.5 years to maturity (Left in the Sahel zone)

Transport	14,370 MF/hd.
General Costs	5,050 MF/hd.
Cost of Sale	2,200 MF/hd.
Total Cost/hd.	21,620 MF/hd.
Market Price	67,500 MF/hd.
Contribution to Overhead and Profit	45,880 MF/hd.
Capital Invested inventory	135,838 MF/hd.
Ratio of Contribution/Capital	$\frac{45,880}{135,838} = .338$

STRATEGY 2

Herd Size 3.7 Cattle Offtake 1 animal/year

2.5 yerars to maturity (Moved to pasture in Sudan zone)

Transport	2,145 MF/hd.
Herders & Misc. Costs	3,370 MF/hd.
General Costs	5,050 MF/hd.
Cost of Sale	2,200 MF/hd.
Total Cost/hd.	12,765 MF/hd.
Market Price	67,500 MF/hd.
Contribution to Overhead and Profit	54,735 MF/hd.
Capital Invested in Inventory	48,257 MF/hd.
Ratio of Contribution/Capital	$\frac{54,735 \text{ MF/hd.}}{48,257 \text{ MF/hd.}} = 1.13$

can be brought down, it appears that feedlot operations should not be undertaken.

It is possible, however, to use feeder cattle and pasture them in the south. This, however, can only be done as long as the cost of the pasture is relatively cheap and there are no tsetse fly problems. This may require the implementation of some eradication programs, but it should not be impossible.

Finally, from a transport perspective, the trucking of cattle to the south as calves would cut the transport cost from 11,000 MF/head to 2,145 MF/head, if they can be transported all the way to Abidjan in double decker trailers.

Overall, one can conclude that the factors of production in west Africa are somewhat different in price than they are in north America at the moment; therefore, differences in practice should emerge. However, there are improvements that can be made to feedlot operations, and transport costs are an important element in their achievement.

4. A MODEL FOR THE ANALYSIS OF JOINT AGRICULTURE AND TRANSPORT ACTIVITIES

4.1 Feeder Roads

Among the major shortcomings of the transportation system of the Sahel-Sudan region is the lack of feeder roads. The main reason for justifying investments in feeder roads is the incentive they give for increasing production in agriculture. Feeder roads coupled with adequate agriculture extension services can help facilitate the shift from a subsistence economy to one which is market oriented.

Aside from the fact that a well-planned feeder road system allows the transport of food from areas where there is an agricultural surplus to areas where it can be marketed, the social benefits involved in the construction of a feeder road can also be important. These social benefits include providing access to education, medical care, and to agricultural extension services.

Assuming that a feeder road leads to an increase in production, the planner is faced with the problem of appraising an appropriate level of investment. A number of questions need to be addressed. These include:

1. What are the costs of the feeder road project?
   What type of 'grid' or network is appropriate?
   How should the construction be staged?
2. What are the benefits derived from the feeder road construction?
3. Who receives them?
4. At what level of agricultural production will benefits and costs break even?

The analysis of feeder road investments must jointly account for the interaction between agricultural production and the transportation system required. We will examine an agricultural region in a situation

without the feeder road system and compare it to the situation in which the feeder road system is available. The application of a net present value analysis to benefits and costs will allow the ranking of transport projects from an economic standpoint.

4.2 Structure of a Model of Agriculture and Transport

A number of constraints are typically present in most agricultural situations such as: farm and cattle land, skilled and unskilled labor, animal power, truck power, investment capital, and subsistence agriculture to support the farmers beyond the cash crop. Techniques are needed to determine the optimal configuration and extent of the transport needed to support various levels of agricultural activities in a given region.

One approach for modeling the trade-offs to be considered in the design of a joint agriculture and production system is the use of a mathematical programming model of the joint agricultural and transport system. This approach identifies the constraints in the system, the activities which can be used to produce items of value and the contribution to net revenues or the costs associated with each activity. The result is the best possible schedule of activities. Although the approach is exemplary, it is both simple and easy to apply and the results are easily put into practice for any locale in the region or elsewhere.

This model is only one among several approaches which are possible. A number of approaches to analysis of feeder roads have been examined in the literature (see, for example, Nible 1973). It does, however illustrate the interdependence of planning in the agricultural and the transport sectors. It is this interdependence which we feel is lacking in much of the current planning efforts and which we wish to emphasize.

4.2.1 Objectives of the model: The purpose of this model is to provide a framework for the analysis of the joint agriculture and

transport activities in a region, in order to appraise the feeder road projects that will best serve the region. The model attempts to identify the feeder road system that maximizes the benefits resulting from the agricultural activities in the region. In this model one can identify several configurations and types of construction standards for the road system as well as transport technologies, and determine their effect on agriculture activities.

Among the questions which can be addressed by the model are: What mix of agriculture should be used and what transport should be developed to serve it? Should we provide the region with off-road vehicles, and leave the road system as itis, or should we improve the road system and provide a mixed pack animal and truck technology to the region?

The model is rather simplistic, however, it can provide valuable information to be used in the decision-making process. This includes information regarding the levels at which the agriculture activity should be maintained, so that maximum benefits can be obtained for the region. The shadow prices of the resources can also be determined. Finally, the model provides the number of ton-kms of commodities transported in each type of facility allowing the analyst to judge what type of construction standard will best serve the region.

Although the model demostrates a region subdivided into small farms (disaggregated form), a more aggregated analysis can be accomplished with relative ease should it become desirable to perform a disaggregate analysis.

To apply this model correctly the analyst must attempt to develop a full understanding of the agricultural activities of the region, as well as of the marketing structure, and of the organization related to that agricultural activity. It is meaningless to discuss transport in this context without a detailed knowledge of the agricultural system, and

vice versa, since both activities interact rather extensively.

4.3 The Model

The model proposed for the analysis of the joint agriculture and transportation activities of the region, can be stated as follows:

Maximize the revenue, A, per unit of yield to be derived from total yield, X, in activity, i, for each zone, j, in each time period, t, less the cost, C, of providing transport to market for TR, ton kilometers of good by means of mode, n. That is:

maximize:

$$\sum_i \sum_j \sum_t A_{ijt} X_{ijt} - \sum_n C_{nt} TR_{nt} \qquad (1)$$

This objective is subject to the following constraints. The first is a constraint on the transport capacity of each mode that is available to carry the product of each zone by mode, n, at a use rate of d.

$$\sum_i \sum_j d_{ijnt} X_{ijt} - TR_{nt} = 0 \text{ for all } j,n,t \qquad (2)$$

The second set of constraints is a limitation of the various resources, b', associated with the production, X, and the transport, TR. These must not exceed the total amount of resources, B', available to the region.

$$\sum_i b'_{ijkt} X_{ijt} + \sum_n b'_{nkt} TR_{nt} < B'_{jkt} \text{ for all } j,n,t \qquad (3)$$

Where the precise meaning of each variable is as follows:

A_{ijt} = the value, in year t dollars, of one unit of activity i in the jth zone within the region in period t.

b'_{ijkt} = resource k requirement of one area of activity i in zone j in period t, for those resources which are specified as available to zone j.

B'_{jkt} = The amount of resource k available in period t, in the jth zone.

C_{nt} = The operating cost per ton-km of transport by mode type n, in period t.

d_{injt} = The requirement for transport type n of one hectare of activity i in zone j in period t.

i = subscript referring to activities.

j = subscript referring to zones within the region.

k = subscript referring to the type of resource required in each activity

n = subscript referring to the type of transport facility.

This subscript does <u>not</u> imply the construction standard of the facility. For example, n=1 corresponds to animal trails and n=2 corresponds to dirt roads; the b'_{nkt} (resource requirement per ton-km of transport on facility n) imply the construction standard.

t = subscript referring to time period.

TR_{nt} = Total use of transport type n (in ton-kms) in period t.

X_{ijt} = Amount (in hectares) of activity i in zone j in period t.

Equation (1) is the objective function to be maximized, and consists of the value of all regional activities minus the transport costs required to bring the products to market.

Equation (2) specifies that the amount of transport used on each type facility in each time period does not exceed the sum of the transport requirements of all the productive activities in that period. For example, an hectare of cotton production in zone 3 will result in an assumed yield which must be transported a given distance along animal trails (n=1) to reach a dirt road (n=2), where it is transported until reaching the gravel road (n=3) until getting to the paved road (n=4) that leads to the market. Thus each TR_{nt} (ton-kms on mode "n") equals

the sum of all the products of the per unit transport requirements of the activity (d_{ijnt}, in ton-kms per hectare) multiplied times the corresponding activity (X_{ijt}, in hectares).

The consumption of the available resources by the production activities and by transport is described by Equation (3). This equation is concerned with the resources which are specified by zone. For example, it could state that the farm land requirement per unit of productive activity in zone "j", times all the activities there, must be less than or equal to the total available land in zone "j". Note also that in this formulation, it is assumed that transport activities (TR_{nt}) use only specified resources on a zonal basis. This assumption, of course, is not central to the model and can be easily dropped.

The consumption of the available resources by the productive activities and by transport could be described on a regional basis rather than in a zonal basis, as it was done. The following constraint could be used to deal with those resources that are available in one regional pool from which all activities may draw:

$$\sum_i \sum_j b''_{ijkt} \; X_{ijt} + \sum_n b''_{nkt} \; TR_{nt} \leq B''_{kt} \quad \text{for all } k, t$$

where

b''_{ijkt} is the requirements for resource k of one hectare of activity i in zone j in period t, for those resources specified as available to any area within the region. For example, one pool of available skilled man-hours is specified for the entire region. The b''_{ijkt} for skilled man-hours required by, say, one hectare of zone 3's cotton production has the units of (skilled man-hours per hectare of cotton production in zone 3).

B''_{kt} is the amount of resource k available in period t, where resource k is specified on a region-wide basis.

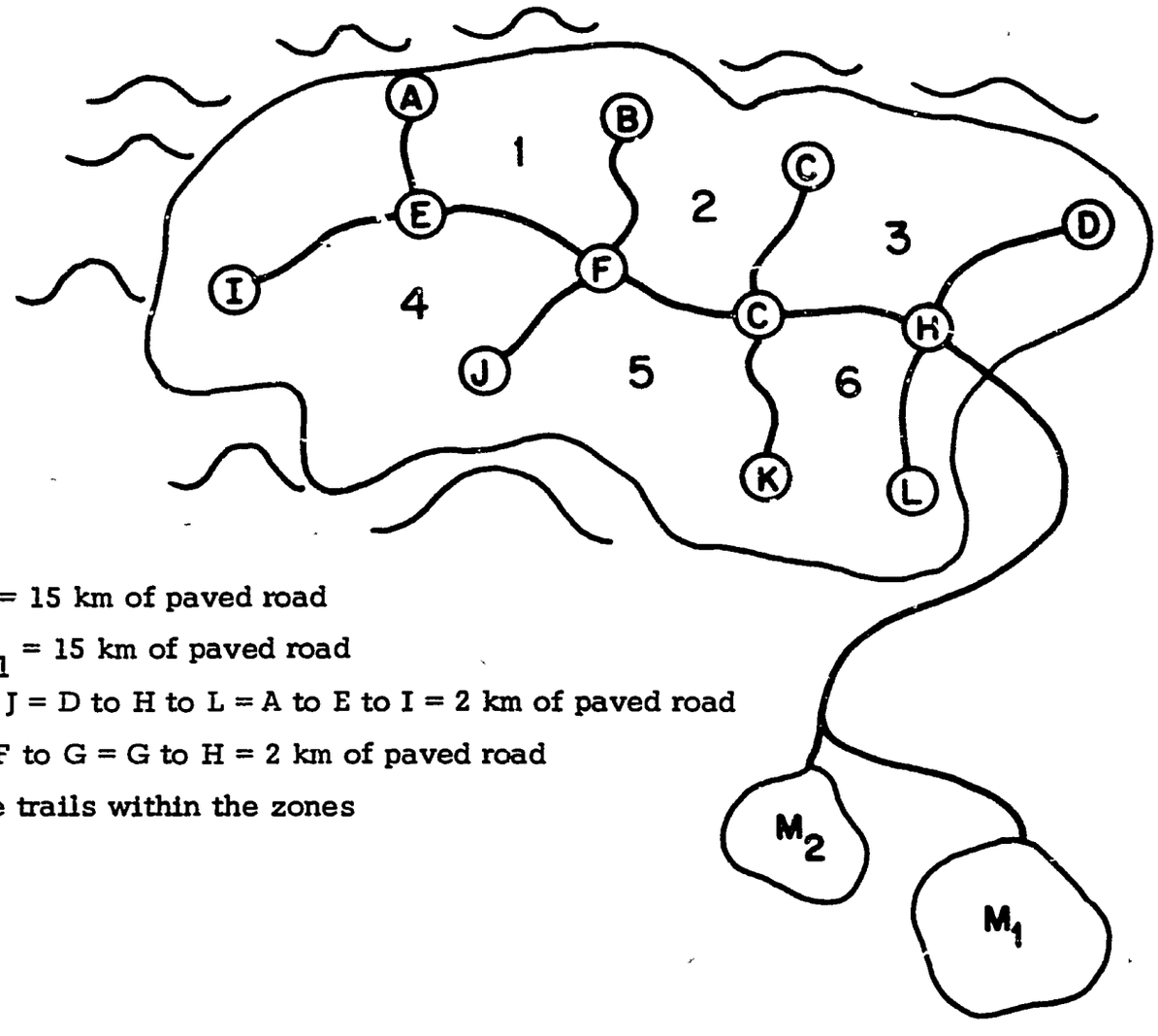
4.4 An Example of Application

The following example illustrates the proposed model in which several alternatives for the joint production and transportation system of a rural area are analyzed. Although the rural area used in this case study is hypothetical, its characteristics correspond to similar areas of the Sahel-Sudan region. Considerable effort was expended in collecting data from real situations in order to provide realistic estimates of the range of values involved. The major emphasis in this example, however, is placed on understanding the overall capabilities of a model rather than on analyzing the specific activities in a given area.

The problem can be stated as follows: Given an agricultural area, what is the most appropriate transport system for the region? At what level should each product be produced, given the resources of the region, so that the joint production and transportation activity is most profitable.

A map of the area is shown in Figure 4.4 – 1. Four main production activities are considered: Cotton, X_1, Peanuts, X_2, Subsistance Agriculture, X_3, and Livestock, X_4. The region is divided into six zones. In each of these zones a certain degree of homogeneity of the soil and growing conditions is assumed. Table 4.4 – 1 gives the yield of various crops. The region serves a primary market (M_1) as indicated in Figure 4.4 – 1 where all cotton and peanuts and three-fourths of the livestock production is sold. A smaller market M_2 also gets one-fifth of the subsistence production of the region. The balance of the livestock and a major portion of the subsistence agriculture is consumed within the region.

Tables 4.4 – 1 — 4.4 – 8 present the resource requirements for various agricultural and transport activities. Tables 4.4 – 9 and 4.4 – 10 give transport costs; Table 4.4 – 11 gives the net benefits accrued to the area from various agricultural activities. The transport



H to M_2 = 15 km of paved road

M_2 to M_1 = 15 km of paved road

B to F to J = D to H to L = A to E to I = 2 km of paved road

E to F = F to G = G to H = 2 km of paved road

There are trails within the zones

FIGURE 4.4 – 1

TABLE 4.4 – 1

YIELDS (Metric Tons/Hectare)

Zones \ Activity	Periods	COTTON	PEANUTS	SUBSISTENCE	LIVESTOCK
1	WOUTP	1.8		.5	3
	WPP0	1.8		.5	3
	WPP1	2.0		.8	3
2	WOUTP	1.8		.5	3
	WPP0	1.8		.5	3
	WPP1	2.0		.8	3
3	WOUTP	1.8		.5	2
	WPP0	1.8		.5	2
	WPP1	2.0		.8	2
4	WOUTP		1.5	.5	1
	WPP0		1.5	.5	1
	WPP1		2.0	.8	3
5	WOUTP		1.5	.5	2
	WPP0		1.5	.5	2
	WPP1		2.0	.8	3
6	WOUTP		1.5	.5	1
	WPP0		1.5	.5	3
	WPP1		2.0	.8	3

WOUTP Without Project
WPP0 With Project - Period 0 (5 years)
WPP1 With Project - Period 1 (10 years)

TABLE 4.4 – 2

UNSKILLED LABOR REQUIREMENTS (Man-hours/Hectare of Activity)

Zone \ Activity	Period	COTTON (x1)	PEANUTS (x2)	SUBSISTENCE (x3)	LIVESTOCK (x4)
1	WOUTP	1520		476	600
	WPP0	1520		476	600
	WPP1	700		280	600
2	WOUTP	1520		476	600
	WPP0	1520		476	600
	WPP1	700		280	600
3	WOUTP	1520		476	600
	WPP0	700		476	600
	WPP1	700		280	600
4	WOUTP		400	476	600
	WPP0		400	476	600
	WPP1		200	280	600
5	WOUTP		400	476	600
	WPP0		400	476	600
	WPP1		200	280	600
6	WOUTP		400	476	600
	WPP0		400	476	600
	WPP1		200	280	600

TABLE 4.4 – 3
RESOURCE REQUIREMENTS
(Animal-hours/per Hectare of Activity)

Zone	Activity / Periods	COTTON (x1)	PEANUTS (x2)	SUBSIS-TENCE (x3)
1	WOUTP	260		100
	WPP0	260		100
	WPP1	120		60
2	WOUTP	260		100
	WPP0	260		100
	WPP1	120		60
3	WOUTP	260		100
	WPP0	260		100
	WPP1	120		60
4	WOUTP		200	100
	WPP0		200	100
	WPP1		100	60
5	WOUTP		200	100
	WPP0		200	100
	WPP1		100	60
6	WOUTP		200	100
	WPP0		200	100
	WPP1		100	60

TABLE 4.4 – 4

RESOURCE REQUIREMENTS: Farm Land and Cattle Land (Hectares)

Zones \ Activity	Periods	COTTON Fland	COTTON CLand	PEANUTS Fland	PEANUTS Cland	SUBSISTENCE Fland	SUBSISTENCE Cland	LIVESTOCK Fland	LIVESTOCK Cland
1	WOUTP	1	0	0	0	1	0	1	6
	WPP0	1	0	0	0	1	0	1	6
	WPP1	1	0	0	0	1	0	1	6
2	WOUTP	1	0	0	0	1	0	1	6
	WPP0	1	0	0	0	1	0	1	6
	WPP1	1	0	0	0	1	0	1	6
3	WOUTP	1	0	0	0	1	0	1	6
	WPP0	1	0	0	0	1	0	1	6
	WPP1	1	0	0	0	1	0	1	6
4	WOUTP	1	0	1	0	1	0	1	6
	WPP0	1	0	1	0	1	0	1	6
	WPP1	1	0	1	0	1	0	1	6
5	WOUTP	1	0	1	0	1	0	1	6
	WPP0	1	0	1	0	1	0	1	6
	WPP1	1	0	1	0	1	0	1	6
6	WOUTP	1	0	1	0	1	0	1	6
	WPP0	1	0	1	0	1	0	1	6
	WPP1	1	0	1	0	1	0	1	6

TABLE 4.4 – 5

RESOURCE REQUIREMENTS

Total Availability of Truck-Hours (TPOW)
And Skilled Labor (SLAB in Man Hours)

Resource Zone	Period	TPOW	SLAB
1	WOUTP		
	WPP0	5,000	30,000
	WPP1	5,000	30,000
2	WOUTP		
	WPP0	5,000	30,000
	WPP1	5,000	30,000
3	WOUTP		
	WPP0	5,000	30,000
	WPP1	5,000	30,000
4	WOUTP		
	WPP0	5,000	30,000
	WPP1	5,000	30,000
5	WOUTP		
	WPP0	5,000	30,000
	WPP1	5,000	30,000
6	WOUTP		
	WPP0	5,000	30,000
	WPP1	5,000	30,000

TABLE 4.4 – 6

RESOURCE REQUIREMENTS

TRACTOR-HOURS/HECTARE (MPOW)

Resources Zones	Periods	COTTON (X1)	PEANUTS (X2)	SUBSISTENCE (X3)	LIVESTOCK (X4)	TOTAL AVAILABILITY (Tractor-Hours)
1	WOUTP WPP0 WPP1	8.		6.	10.	3000
2	WOUTP WPP0 WPP1	8.		6.	10.	3000
3	WOUTP WPP0 WPP1	8.		6.	10.	3000
4	WOUTP WPP0 WPP1		8.	6.	10.	3000
5	WOUTP WPP0 WPP1		8.	6.	10.	3000
6	WOUTP WPP0 WPP1		8.	6.	10.	3000

TABLE 4.4 — 7

RESOURCE REQUIREMENTS

LOCAL FERTILIZER IN KG. PER HECTARE (FACT)

Resource Zone	Period	COTTON	PEANUTS	SUBSISTENCE	LIVESTOCK	TOTAL RESOURCE AVAILABILITY (Kg)
1	WOUTP WPP0 WPP1	263		125	125	50,000
2	WOUTP WPP0 WPP1	263		125	125	50,000
3	WOUTP WPP0 WPP1	263		125	125	50,000
4	WOUTP WPP0 WPP1		263	125	125	50,000
5	WOUTP WPP0 WPP1		263	125	125	50,000
6	WOUTP WPP0 WPP1		263	125	125	50,000

TABLE 4.4 – 8

TRANSPORT REQUIREMENTS PER TON - KM

Technology / Resource	BURROS ON BURRO-TRAIL	BURROS ON ANY ROAD	TRUCKS ON DIRT ROAD	TRUCKS ON GRAVEL ROAD	TRUCKS ON PAVED ROAD
Unskilled Labor (man-hours)	.67	.5	.08	.04	.03
Skilled (man-hours)	--	--	.04	.02	.01
Animal hour	.67	.5	--	--	--
Truck hours	--	--	.04	.01	.008

TABLE 4.4 – 9

CONSTRUCTION COSTS

(Thousand of CFAF)

	PAVED	GRAVEL	DIRT	IMPROVED TRACKS
Construction Cost per KM	18,000	8,000	4,000	2,000
Maintenance Cost/Year/KM	270	200	150	100

TABLE 4.4 – 10

TRANSPORT OPERATING COSTS

(CFAF/TON-KM)

BURROS ON TRAILS	BURROS ON ANY ROAD	TRUCKS ON DIRT ROAD	TRUCKS ON GRAVEL ROAD	TRUCKS ON PAVED ROAD
28.	24.	12.	9.	6.

TABLE 4.4 – 11

NET BENEFITS EXCLUDING TRANSPORT COSTS

PER HECTARE OF ACTIVITY (CFAF)

Activity / Period	COTTON	PEANUTS	SUBSISTENCE	LIVESTOCK
WOUTP	48,000	62,000	28,000	35,000
WPP0	48,000	62,000	28,000	35,000
WPP1	46,000	60,000	27,000	33,000

capacity per hectare of agricultural activity is shown in Tables 4.4 – 12 through 4.4 – 14.

4.5 Results of the Model

The actual computer runs used for the numerical examples in this case study were accomplished at the Information Processing Center at M.I.T., using IBM's Mathematical Programming Systems Extended (MPSX) linear programming solution package. The general capabilities and features of MPSX are explained in IBM Manual #H20-0849, "MPSX Introduction." A more detailed discussion of that package's applicability to the solution of linear programming formulations such as used for this study is given in Manual #H20-0968, "MPSX Linear and Separable Programming PD."

Examples of the input and ouput used by this particular LP Solution package will be presented later. The assumptions which were used in this particular example include: 1) a 15-year planning horizon is considered, which consists of either two planning periods of five and ten years respectively or a single 15 year period, and 2) all monetary values shown reflect a discounting to present value using a 10 percent discount rate.

In our analysis we consider several alternatives listed in Table 4.5–15. For each alternative the model gives information about the yearly benefits of that alternative, levels of activity, input resources used and left unused (slacks), and the shadow prices of the resources. This information is available in Tables 4.5 – 16 through 4.5 – 20. The costs associated with each alternative, i.e. with each production plus transportation system were calculated separately with the help of the models discussed in Chapter 2 and also using other available information (UN 1974).

In the case study presented here, Situation 0 represents the existing situation with only trails and animal pack. Whenever the animal

TABLE 4.4 – 12

TRANSPORT PER HECTARE OF ACTIVITY
BY CONSTRUCTION STANDARD (SITUATION 2)

(Ton-Kms/Hectare)[1]

Zone \ Activity	COTTON	PEANUTS	SUBSISTENCE	LIVESTOCK
Trail				
TRT1	13.9		.77	17.3
TRT2	8.8		.49	11.0
TRT3	3.2		.35	5.3
TRT4		11.4	.77	5.8
TRT5		7.4	.49	7.3
TRT6		3.2	.35	2.7
Dirt				
TRE1	64.8		9.	81.
TRE2	64.8		9.	81.
TRE3	64.8		9.	63.
TRE4		54	9.	27.
TRE5		54	9.	63.
TRE6		54	9.	27.

[1] (Yield/hectare)X(distance) X (weight = 1.4 trails, 1.2 dirt, 1.1 gravel, 1.0 paved)

TABLE 4.4 – 13

TRANSPORT PER HECTARE OF ACTIVITY BY CONSTRUCTION STANDARD (SITUATION 4)

(Ton-Kms/Hectare)

Zone \ Activity	COTTON (X1)	PEANUTS (X2)	SUBSISTENCE (X3)	LIVESTOCK (X4)
Trail				
TRT1	1		.06	1.26
TRT2	1		.06	1.26
TRT3	1		.06	.84
TRT4		.84	.06	.42
TRT5		.84	.06	.84
TRT6		.84	.06	.42
Dirt				
TRE1	.76		.04	.95
TRE2	.76		.04	.95
TRE3	.76		.04	.63
TRE4		.63	.04	.32
TRE5		.63	.04	.63
TRE6		.63	.04	.32
Gravel				
TRG1	9.9		.55	12.4
TRG2	5.9		.33	7.4
TRG3	2.0		.11	1.7
TRG4		8.3	.55	4.1
TRG5		5.0	.33	4.9
TRG6		1.7	.11	.83
Paved				
TRP1	54.		1.5	67.5
TRP2	54.		1.5	67.5
TRP3	54.		1.5	45.
TRP4		45.	1.5	22.5
TRP5		45.	1.5	45.
TRP6		45.	1.5	22.5

TABLE 4.4 – 14

TRANSPORT PER HECTARE OF ACTIVITY BY CONSTRUCTION STANDARD (SITUATION 11)

(Ton-Kms/Hectare)

Zone \ Activity	COTTON	PEANUTS	SUBSISTENCE	LIVESTOCK
Trail				
TRT1	1.1		.10	1.26
TRT2	1.1		.10	1.26
TRT3	1.1		.10	.84
TRT4		1.1	.10	.42
TRT5		1.1	.10	.84
TRT6		1.1	.10	.42
Dirt				
TRE1	.84		.064	.95
TRE2	.84		.064	.95
TRE3	.84		.064	.63
TRE4		.84	.064	.32
TRE5		.84	.064	.63
TRE6		.84	.064	.32
Paved				
TRP1	69.3		3.2	78.8
TRP2	65.3		2.9	74.2
TRP3	61.4		2.5	45.9
TRP4		69	3.2	26.25
TRP5		65	3.9	49.5
TRP6		61	2.5	23.25

TABLE 4.5 – 15

CHARACTERISTICS OF THE TRANSPORT SYSTEMS

SITUATION	TRANSPORT INFRASTRUCTURE	TRANSPORT TECHNOLOGY	ANIMAL HOURS AVAILABLE IN REGION	TYPE OF AGRICULTURE YIELD
0	Non Improved Trails	Animal - Pack (Mainly Mules)	APOWO = 36,600	Ox Drawn Low Yield
1	"	"	2 x APOWO	"
2	Non Imp. Trails within Zones Imp. Trail (EFGH) Dirt Road (H M_2 M_1)	Animal - Pack	APOWO	"
3	"	"	2 x APOWO	"
4	Non Imp. Trails Within Zones Dirt Roads (AEI, BFJ, CGK, DHL) Gravel Road (EFGH) Paved Road (H M_2 M_1)	Animal - Pack Animal - Pack Animal - Pack Trucks (5 metric tons)	APOWO	"
5	"	"	2 x APOWO	"
6	Non Imp. Trails Within Zones Dirt Roads Gravel Roads	Animal - Pack Animal - Pack Trucks	APOWO	"
7	"	"	2 x APOWO	"
8	Non Improved Trials	Trucks	2 x APOWO	"
9	Trails Within Zones Dirt Roads (EFGH) Gravel Roads (HM_2M_1)	Trucks	2 x APOWO	"
10	Trails Within Zones Dirt Roads (EFGH) Gravel Roads (HM_2 M_1)	Animal - Pack Animal - Pack Trucks	APOWO	"
11	Trails Within Zones Dirt Roads (EFGH) Paved Roads (HM_2M_1)	Animal - Pack Animal - Pack Trucks	APOWO	Mechanized Power (Tractor) High Yield
12	"	"	2 x APOWO	"
13	(Only change is a drop in market price of peanuts)	"	APOWO	"
14	"	"	2 x APOWO	"

power (APOW) was found to be a binding constraint, the same alternative was tested again but with doubling APOW. Then, the other resources become binding (generally unskilled labor). Situation 0 is what we call a situation "without project" i.e. without transport project. Several situations "with project" have been considered. If a 15 year horizon is considered for implementation of the situation with the project, benefits and costs can be estimated for that time span. Results are shown in Table 4.5 – 19 for several alternatives.

It is clear that the analyzed region by itself does not justify any of the high standard infrastructure. The problem is then: How many surrounding regions using the same road do we need to "economically" justify the road investment? What we have is a break-even analysis. Assuming regions with similar characteristics along the road, and considering that their transport costs will be smaller for being closer to the market, we can determine the number of farms per kilometer of road which make the project economically viable, obtaining what is generally called the "scale factor." This can be done for each of the situations considered in our analysis.

The model assumes two kinds of variables -- exogenous and endogenous. The exogenous variables are under the control of the planner of the region, which in most cases would be the government. These variables include such things as the transport infrastructure that will be provided, the type of transport technology available (animal, truck) and its overall quantity, as well as the type of agricultural equipment used, such as tractors, plows, etc.

The endogenous variables are those presumably controlled by the local population, namely the amount of each of the crops that will be grown, the decision to produce livestock, the amount and the overall manner in which the local factors of production are used to produce the agricultural products of the region. This assumes that the

levels of manpower, the amount of truck and animal uses, the amount of land tilled, etc. are all decided by the local population in a manner that maximizes their total benefits from the agricultural production scheme.

Our approach to using the model has been one of postulating alternative combinations of exogenously assigned variables. With these alternatives the best use of endogenous variables to achieve the highest possible benefits are then determined by the model. This, in effect, is what happens when a public action is followed by a private sector response.

Examination of the characteristics of the transport systems presented in Table 4.5 – 15 reveals several major alternatives. With respect to transport infrastructure there are several possibilities. The trails can be used as they are. They can be upgraded to improved earth roads. Alternatively the major spine roads and farm to market connectors can be either gravelled or paved. Within the category of transport technology trucks can be used throughout, or animals can be used throughout, or there can be a combination in which trucks are used on the smaller roads with consequent inefficiencies of so doing. Another possibility is to increase the stock of available pack animals. Apparently the system is extremely short of animal power in the base condition. Finally, there is the possibility of using low-yield ox-drawn cultivatiors or the use of mechanized tractors.

The analysis of the various situations is presented in Table 4.5 – 16. Here, the yearly benefits are the revenues that are achieved from the sale of crops. Costs include those of construction and maintenance incurred by the government, and the cost of animals, trucks and their operation as incurred by the local population. Both are discounted at 10 percent interest rate, so that it is possible to compare benefits to

costs directly. Doing so reveals that the cost of road construction and maintenance in this environment is extremely high and tends to wipe out most of the yearly benefits, except in a few plans. There is apparently, a real constraint caused by the lack of pack animals to carry goods to market. This constraint is relieved by either increasing the number of pack animals or making trucks available to carry goods to market.

The implications of the results shown in Table 4.5 – 16 can be interpreted from Table 4.5 – 17 through 4.5 – 19. These show the average shadow prices of some of the resources in the region, the resources used and those left unused and the usage of animals and trucks on various types of roads. From these tables one can conclude that there is a shortage of land available for cattle. Farm land, however, is not a constraint in most cases. The shadow prices indicate that there is a shortage of animal power which is solved when trucks are provided. Some indication of what is required by a transport scheme involving all truck transport without paved roads is provided by situation number 8. Table 4.5 – 19 shows the number of truck hours used for transport and it is substantially higher than any of the other schemes. This is because of the use of small, low-speed trails. Reference to Table 4.5—18, which shows the levels of activity in each of the plans, reveals that as more infrastructure is developed the higher activity levels increase. These higher levels of activity are made possible by better transport. Also, there tends to be a shift to cash crops such as cotton and peanuts and away from subsistence and livestock production.

A summary of the various strategies is presented in Table 4.5 –21, where the total benefits and total costs are shown along with net benefits after costs have been subtracted. A strict accounting of benefits and costs reveals that strategy 1 is the one with the highest net benefits. Strategy 1 is the one in which non-improved trails with pack animals are

TABLE 4.4 – 16

SITUATION**	YEARLY BENEFITS* (CFAF)	YEARLY COSTS (CFAF)				
		CONSTRUCTION	MAINTENANCE	ANIMALS	TRUCKS	TOTAL
0	8,609,083	---	---	51,910	---	51,910
1	15,216,032	---		123,820	---	123,820
2	9,011,457	3,353,250	6,000,000	51,910	---	9,405,160
3	15,856,894	3,353,250	6,000,000	123,820	---	9,457,070
4	10,056,813	8,653,950	10,350,000	51,910	1,134,134 (1) 5 yrs.	20,189,994
5	17,312,908	8,653,950	10,350,000	123,820	1,134,134 (1) 5 yrs.	20,261,904
6	10,142,939	8,653,950	10,350,000	51,910	1,134,134 (1) 5 yrs.	20,189,994
7	17,386,941	8,653,950	10,350,000	123,820	1,134,134 (1) 5 yrs.	20,261,904
8	15,997,938	---	---	123,820	7,561,980 (3) 2 yrs.	7,685,800
9	17,320,311	5,523,000	7,500,000	123,820	5,136,090	18,282,910
10	17,400,190	10,967,100	10,920,000	123,820	5,136,090	27,147,010
11	17,922,146	10,967,100	10,920,000	51,910	3,544,060	25,483,070
12	28,992,900	10,967,100	10,920,000	123,820	5,136,090	27,147,010
13	15,651,540	10,967,100	10,920,000	51,910	3,544,060	25,483,070
14	23,828,132	10,967,100	10,920,000	123,820	5,136,090	27,147,010

* Net benefits excluding construction costs, but including agriculture costs and transport operating costs

** Situations 13 and 14 are not distinct from 11 and 12 except for the fact that a possible drop of the market price of one of the crops is forecasted which affects the benefits received.

TABLE 4.5 – 17

AVERAGE SHADOW PRICES OF SOME RESOURCES IN THE REGION

Resource / Situation	ULAB (CFAF/ man-hour)	SLAB (CFAF/ man-hour)	FLAND (CFAF/ha)	CLAND (CFAF/ha)	APOW (CFAF/animal hour)	CTRT (CFAF/ton-km. of trail)	CTRE (CFAF/ton-km. of dirt)	CTRG (CFAF/ton-km. of gravel)	CTRP (CFAF/ton-km. of paved
0	--	--	--	7,388	197	160	--	--	--
1	25	--	--	2,782	110	119	--	--	--
2	--	--	--	8,283	209	168	128	--	--
3	22	--	--	3,472	131	130	100	--	--
4	--	--	--	10,398	244	191	145	146	6
5	58	--	--	1,447	38	92	72	72	8
6	--	--	--	10,532	247	193	147	9	6
7	70	--	--	1,460	--	75	59	12	8
8	63	--	--	930	--	75	--	--	--
9	70	--	--	1,439	--	77	18	12	--
10	70	--	--	1,463	--	78	18	--	8
11	--	--	--	9,886	400	296	188	--	6
12	32	--	7,093	1,813	141	144	111	--	7
13	--	--	--	9,878	484	352	266	--	6
14	32	--	9,926	1,809	197	182	139	--	7

TABLE 4.5 – 18

LEVELS OF ACTIVITY

SITUATION \ ACTIVITY	COTTON (HA)	PEANUTS (HA)	SUBSISTENCE (HA)	LIVESTOCK
0	31	26	180	20
1	82	89	198	20
2	36	40	155	20
3	85	115	155	20
4	44	55	143	20
5	88	139	143	15
6	44	55	143	20
7	88	141	143	14
8	85	136	143	14
9	88	140	143	14
10	89	142	143	14
11	120	128	155	20
12	150	300	150	4
13	120	135	143	20
14	150	304	143	4

TABLE 4.5 – 19

SITUATION	YEARLY BENEFITS (CFA)	ANIMAL-UNITS USED FOR TRANSPORT (HOURS)	TRUCK-HOURS USED FOR TRANSPORT	TON-KMS. IN			
				TRAIL	DIRT	GRAVEL	PAVED
0	8,609,083	5,326	0	7,950	--	--	--
1	15,216,032	11,348	0	16,938	--	--	--
2	9,011,457	4,031	--	807	6,981	--	--
3	15,856,894	8,341	--	1,804	14,265	--	--
4	10,056,813	436	45	113	87	631	5,840
5	17,312,908	802.8	90	228	172	1,328	11,998
6	10,142,939	121	51	115	87	639	5,910
7	17,386,941	240	83	229	173	1,333	12,041
8	15,997,938	0	3,179	19,467	--	--	--
9	17,320,311	0	211	190	173	15,775	--
10	17,400,190	0	150	229	173	--	13,179
11	17,922,146	350.3	96	290	198	--	13,173
12	28,992,900	270	170	491	312	--	24,219
13	15,651,540	228	93	283	196	--	--
14	23,828,132	482	169	487	312	--	23,975

TABLE 4.5 – 20

INPUTS (RESOURCES) USED AND INPUTS UNUSED IN THE REGION

Resource / Situation	ULAB (man-hours)		APOW (animal-hours)		SLAB (man-hours)		FLAND (hectares)		CLAND (hectares)		TPOW (truck-hours)		MPOW (tractor-hours)		FACT (kilos)	
	Used	Unused	Used	Unused	Used	Unused	Used	Unused	Used	Unused	Used	Unused	Used	Unused	Used	Unused
0	130,861	113,139	36,600	--	--	--	256	644	60	--	--	--	--	--	--	--
1	237,274	6,726	70,014	3,186	--	--	389	511	60	--	--	--	--	--	--	--
2	133,790	110,210	36,600	--	--	--	250	650	60	--	--	--	--	--	--	--
3	238,519	165,319	68,579	4,621	--	--	375	525	60	--	--	--	--	--	--	--
4	143,438	100,562	36,600	--	57	174,943	259	641	60	--	44	29,956	--	--	--	--
5	244,000	--	65,671	7,529	120	174,880	386	514	33	27	88	29,912	--	--	--	--
6	144,298	99,702	36,600	--	72	174,928	261	639	60	--	51	29,949	--	--	--	--
7	244,000	--	53,033	20,167	147	174,853	386	514	30	30	103	29,897	--	--	--	--
8	244,000	--	63,057	10,143	3,894	171,106	378	522	30	30	3,179	26,821	--	--	--	--
9	244,000	--	65,010	8,190	366	174,634	386	514	30	30	211	29,789	--	--	--	--
10	244,000	--	65,703	8,127	184	174,816	387	513	30	30	150	29,850	--	--	--	--
11	163,738	80,262	36,600	--	128	174,871	419	181	60	--	93	29,907	3,083	14,917	86,462	213,138
12	210,570	33,430	57,565	15,635	239	174,761	603	297	20	40	170	29,830	4,538	13,462	137,712	162,788
13	161,828	82,172	36,600	--	131	174,868	414	486	60	--	93	29,907	3,069	14,931	86,840	213,160
14	209,454	34,546	57,565	15,635	241	174,758	600	300	20	40	169	29,831	4,529	13,471	137,883	162,117

TABLE 4.4 – 21

ANALYSIS OF STRATEGIES

(In Millions CFAF)

STRATEGY	TOTAL BENEFITS	TOTAL COSTS	NET BENEFITS (Strategy i - Strategy 0)
0	129.1	.8	0
0 - 1	228.2	1.8	98.0
0 - 2	135.3	141.1	-134.3
0 - 3	237.8	141.1	- 32.4
0 - 4	150.8	302.8	-280.9
0 - 5	260.8	303.9	-172.6
0 - 6	152.1	302.3	-297.1
0 - 7	260.8	303.9	-172.5
0 - 8	239.9	115 2	- 3.7
0 - 9	259.8	274.[illegible]	- 14.4
0 - 10	261.0	407.2	-274.5
0 - 2 - 11	224.3	301.8	-206.9
0 - 3 - 12	334.9	318.5	-111.8

used but with double the animal hours available. This scheme provides a substantial benefit to the region with almost no cost. In an actual situation this animal constraint is likely to already have been preceived by the local population and steps may have been taken to increase the size of the animal power available to the region.

Another plan which looks interesting in spite of the fact that its net benefits are slightly negative is Strategy 8. Here the use of trucks on the non-improved trails has released the constraint on transport. Benefits are even higher than in strategy 1. Strategy 9 is also an interesting one. It includes dirt roads and gravel roads along with a large truck fleet and an increase in animal power. Benefits to the local population reach 17.4 millions of CFAF/year.

It may be deemed socially desirable to select one of these plans in which net benefits are zero in order to redistribute income to the rural poor at a reasonably small cost. Note that for strategy 9 there has been a substantial shift in the agricultural production pattern. Cotton yields have been almost tripled. Subsistence agriculture has declined somewhat as has livestock. Peanuts have increased almost five-fold. In other words, there has been a substantial shift in the pattern of agricultural activity within the area.

The overall results revealed here may or may not be typical of those actually found in the Sahel-Sudan region. Nevertheless, the overall generality of the approach remains valid. Using it one can trace the changes in agriculture and the requirements for transport and other scarce resources under a variety of assumed changes in infrastructure by the government. However, the model's outputs provide a basis for helping the decision maker in understanding the underlying trade-offs and interrelationships involved.

The results of this model suggest that the decision of how to provide transport for agricultural areas in the Sahel-Sudan should be

directly linked to the producing characteristics of the area. For example, the animals that till the land are often used for transport, and therefore one must anticipate the resource hours for each of the activities. The case study shows clearly the differences in the benefits which accrue to the region when animal power is doubled.

Obviously, one cannot draw out of this case study too many conclusions that can be extrapolated and generalized. Each situation must be studied and evaluated individually. This model, however, is flexible and can be applied in any agricultural situation. It is also fast, allowing an expeditious first-cut analysis of the system. In general the agriculture data can be compiled from statistics of the offices of development of the different countries in the region, while a detailed geographical layout can be obtained using aerial photographs. However, when there is difficulty in obtaining data, careful use of data applicable in similar regions to the one under study can be of great help in giving at least first-cut estimates.

The data required by this model is general economic data, which is normally available in annual statistical records. Transport operating costs are estimated through the models discussed in Chapter Two, and compared with existing information for validation purposes.

Though we did not use them in this model, several additional constraints can be added. For example, in the case of irrigated agriculture a constraint on water requirements can be considered. Rainy seasons can limit the number of ton-kilometers, and this can in turn be accounted for.

4.6 Conclusions

The case study presented here is an example of how alternative feeder road investments can be quantified. Since this is a hypothetical case, it was aimed at developing a framework which can be applied for investment considerations in feeder road systems generally. The following points highlight the major conclusions resulting from this case study.

If both the costs and benefits of the transport project are incurred by the same party, the project becomes more viable when several regions are using the system (this is what happened in our case study). The model allows us to estimate how many regions are needed.

In the case study it was assumed that the portion of the transportation from the field to a collection point was provided by the farmer. This may or may not be the case in many situations, since several factors are at play in actuality. For example, in Senegal, the crop is typically bought at the farm by an organization called ONCAD which pays a relatively small price for it. This same organization transports the crop and sells it to another ogranization (OCAS), which has a monopoly for the crop within the country, as well as outside. OCAS is the group that normally transports the crops from the mills to the port of export. When there is more than one actor involved, several options are possible.

(a) The farmer may sell the crop to the government at a fixed price and have the government transport it.

(b) The farmer may transport his own crops.

(c) The transport is performed by private companies which either buy the crop at the farm and sell it at a higher price, or only transport the crop -- simply charging the transportation costs.

Option (a) is attractive -- if a reasonable price is set for the crop. The government would provide the trucks and drivers as well as the transportation infrastructure and breeding animal power which the farmer could use to increase production. However, there can be some problems associated within this scheme. If the price paid to the farmer does not encourage a better production and, at the same time, the transport system is not properly planned, no improvement is expected. The government, in case it elects this option, must balance the foreign exchange costs of trucks and other facilities with the benefits received from selling the

crop, as well as the construction and maintenance costs.

Option (b) does not seem viable in developing countries because the farmer would have to incur the transportation costs (trucks, construction costs, etc.) though he would be able to get larger profits from his crop. There is typically a problem of lack of initial capital as well as skilled labor to construct the roads and buy the trucks.

Option (c) would be attractive if the amount of crop production in the region will justify the establishment of a trucking company. This, in turn, depends on whether or not a good infrastructure exists. However, selling the crop to the trucker can be less attractive to the farmer, unless the price at the farm is properly regulated,because there would be a tendency to exploit the farmer, turning most of the profits to the transporter.

Therefore, before using the model all the factors involved should be evaluated. This involves the building of the transport system and estimating its overall benefits, but also the determination of who (what particular group: the farmers, the transporters, the government) gets the benefits and what the trade-offs are between the benefits accrued to the several groups involved and the associated costs. This can be estimated with the imformation provided by this model, plus a thorough understanding of the agriculture institutions that market the products. Without such analysis, feeder road investment appraisal may lead to unproductive conclusions.

So far, we have only looked at the economic aspects of feeder road investments. Several feeder road projects show, however, that the benefits derived transcend purely economic factors to include social benefits. In a number of cases, the social benefits of the road are realized before any economic benefit can be foreseen. For example, the road allows medical, as well as educational, services to reach the region. How can this be quantified?

Instead of a simple objective analysis, as the one presented by the model, the consideration of social goals will require a multi-objective approach. One possibility is to try to attribute a monetary value to each social goal as a utility function and introduce it into the objective function of the proposed model. This may help the decision-maker in the quantification of the benefits of social activities.

4.7 Further Research

The model presented here is overly simple and further research should be undertaken for a more comprehensive and detailed analysis in any particular situation. We should consider not only a simple road servicing a limited area, but also a network of roads servicing several regions, so that flows of different products within different regions can be studied. This type of analysis would help the planner in deciding which links of the system to build, how, and when.

We do believe that the present model can be a first generation and a starting basis for further models, which analyze transport and its relationship to other economic activities. Most important, however, we feel that to make effective transport investments one cannot ignore the economy. The more "local" the road is, the more important it is to incorporate the production process into the analysis. This model provides the planner with a first approach which may be useful in this process.

5. GENERAL CONCLUSIONS

The transport picture depicted in this study, and the review of previous studies in the Sahel-Sudan region lead to a number of conclusions. These conclusions are presented under four general categories: (1) Threshold levels of economic activity; (2) Infrastructure-operating cost tradeoffs; (3) Operating policies; and (4) Equipment stragegies. Finally, a set of more specific findings resulting from this discussion is presented in section 5.5.

5.1 Threshold Levels of Economic Activity

A major effort has been made throughout this study to demonstrate the interrelationships of the transport system (infrastructure and vehicles) with agriculture and other forms of economic activity, as well as the powerful economies of scale involved in such interactions.

As the national economies of the region experience shifts from the present subsistence levels to higher cycles of production and consumption, the demand for transport will increase both in magnitude and in quality. The present transport network is fairly extensive, especially in terms of the road system and airport or landing strips. Therefore, it can be argued that major additional investments in transport infrastructure are needed under the following conditions:

(1) As the general level of economic activity (predominantly agricultural production) increases over time, thereby generating traffic flows to local and international markets, additional transport investments will be required to support the increased traffic. In line with the agricultural production potentials, as production levels develop in time and space, transport expansion can be phased accordingly in a time-staged fashion. Seaonality and directionality could play a dominant role in the costs of transport. Considerable attention must then be given to the feeder road system to provide access in the farming areas. Finally, efforts for the maintenance and upgrading of present main roads must also be

examined in the light of increasing traffic flows.

(2) When a specific mining or industrial activity is set up, which alone or in combination with other sectors of the economy generates sufficient flows to justify the construction of a new road or railroad line, additional investments will be justified. An example of this, is the potential copper mining operation in Tambao, Upper Volta, where a railroad extension can possibly be justified to link this area with the Niger line or even with Dahomey. These cases can be examined separately through economic feasibility studies based on the potential flows which are generated by the activity itself.

(3) In the absence of the latter condition, and with the slowly growing production system, the present network can be improved through frequent maintenance operations, the provision of drainage facilities to prevent accelerated deterioration of the roadway support and foundation, and the upgrading of existing links to allow a continuous traffic flow and to postpone future major rehabilitation efforts.

In summary, because of the economies of scale exhibited in the transport system, the relatively high investment costs, and the irreversible nature of the transport investment, it is not advisable to commit funds for expansion of the transport system (other than scheduled maintenance and rehabilitation) unless a significant change in patterns of consumption and production are anticipated or carfully planned and executed. Unless specific development projects are undertaken, the best strategy to meet these changes is to time-stage the construction and upgrading of roads in harmony with increased activities. The exception to this approach occurs when sizeable agricultural, mining, or industrial projects are conceived for which new transport links are economically feasible. At this point, the multi-mode transport approach presently in use can be adequate, provided that adequate and improved storage and transfer facilities are instituted.

5.2 Infrastructure-Operating Cost Trade-Offs

The high cost of transportation in the region is mainly a reflection of the scarcity of capital affecting the transport sector, since most of the region is not inherently difficult for construction of transport facilities. Typically, transport is characterized by a poor quality of the infrastructure resulting in higher travel time, more fuel consumption, increased vehicle deterioration, less vehicles in use, and possibly smaller and less efficient vehicles.

Additionally, ox-carts and pack animals are more frequently used for short hauls and even over relatively long distances in some areas. Under limited agricultural production, this set of conditions may not constitue a bottleneck insofar as transport is concerned, except in a threshold sense. The demands for transport may be prohibitive for any new type of economic activity, however. Where this is the case, serious consideration must be given to developing the transport needed to reduce costs to vehicle operators and allow access to more remote markets for the presently subsistence farmers.

In the context of road transport, the relationships between the quality of the road, and therefore the investments in construction and maintenance activities, and the vehicle operating costs are neither linear nor are they straightforward. The simulation models discussed in this study can be used to establish these relationships through a series of analyses and trade-offs. The results shown in this study indicate clearly the type of trade-offs which exist between costs of infrastructure and the vehicle operating costs. The nature of these two cost elements are different. The first is the cost of providing and maintaining the physical facilities generally occurring at distinct time periods. The second is mostly expressed in the cost associated with the time, fuel, and vehicle parts that result from operating on a specific road link on a continuous time basis. The trade-offs between these cost components has been a

subject of controversy for many years. As a general rule for connector roads, a minimum volume of vehicles is considered to be required for the construction of a road surface, be it earth, gravel, or paved. Paved roads require a traffic density of at least 150 vehicles per day or more where savings in operating costs could justify the investment costs. Obviously considerations of directionality, seasonality, and peaking must be addressed before such a rule is validated.

Traffic of over 30-50 vehicles per day can be served adequately by a gravel road, and below that dirt roads can be quite adequate. It must be kept in mind that improved road surfaces generally require higher maintenance costs and could be quite costly if maintenance is not adequately performed. Therefore, in many circumstances, well maintained earth roads (with sufficient drainage facilities) can provide better service than improperly maintained paved roads, especially when a conscious shadow pricing of vehicle parts, labor, and equipment is undertaken. The ability to stage the construction of a road can be used to gradually upgrade the road network as traffic grows. The procedures described in this study allow the examination of various staging strategies to determine the one which fits the particular conditions encountered in any part of the region.

Currently, in the Sahel it is felt that most of the capital allocated to the road network can be most properly used by improving the present network, especially the feeder roads, which provide access to the farming areas. Drainage facilities can be provided, and frequent blading and surface treatment can keep these roads serviceable most of the time while reducing total transport costs. Improvement in paved roads can be centered on main line-haul links, such as those leading to ports and railroad connections as well as major production and processing areas. Significant savings in transport costs can be achieved in improving those major links, while the rest of the capital should be devoted to scheduled

maintenance activities on those and other secondary and feeder roads.

5.3 Operating Policies

The examination of the transport conditions in the region has led to a number of observations insofar as operating policies are concerned. These policies relate to the technology used in the maintenance and upgrading of the infrastructure including the emphasis on feeder roads, transfer facilities and transit, and tariffs and taxation.

5.3.1 Technology in construction and maintenance: As has been pointed out earlier, the scheduling of maintenance and upgrading of roads must become an integral part of the construction and operation of the roads. In many cases, maintenance becomes the principal factor in road capacity and operating cost. Therefore, emphasis must be placed on training of labor and management and on proper maintenance and upgrading practices of the existing road network. In this context, feeder roads play a very important role in the agricultural production activities and a great deal of attention must be given to the choice of technology and materials for construction and maintenance of these roads. A recent World Bank study (1974) on labor substitution indicates the need for development of "intermediate" technology for civil construction, such as road building -- since labor-intensive methods can be uneconomical especially for construction of paved roads. It seems, however, that a serious consideration must be given to the use of labor-intensive techniques and local materials in earth and gravel roads especially in areas where capital equipment is not available due to lack of skills in operation and repairs. Significant savings of foreign exchange can be achieved when labor-intensive techniques and local materials are used.

5.3.2 Transfer facilities and transit: Among the major transport problems that the four landlocked countries of Chad, Mali, Niger, Upper Volta, and even Mauritania, to some extent, are facing are those

of port transfers and long-hauls outside of their national boundaries. The bulk of imports and exports are shipped in transit through neighboring countries with port outlets. Therefore, the costs of port transfer and long-haul rail and road transport become a major component of the overall cost of imports and exports. Since, the volumes of such imports and exports of the landlocked countries are relatively small and mostly in one direction, there does not seem to be a strong incentive on the part of the transit countries to improve efficiences of loading and unloading through the major ports, or to invest considerably in maintenace of links leading to these countries. Even those exceptions to this argument that exist in form of bilateral agreements between Niger and Dahomey, and Senegal and Mali to jointly operate the railroads has not always worked smoothly. If transport costs for the landlocked countries are to be reduced, joint ventures must be undertaken to construct, maintain, and jointly manage the transport facilities that are used by both the landlocked and transit countries.

5.3.3 Tariffs and Taxation policies: Furthermore, bilateral or regional agreements must be arrived at to develop uniform tariff and tax structures on commodity transport across national boundaries. These include not only commodities in transit, but also animals, animal products, and agricultural products from one country destined for markets in the other country. For example, Nigeria levies higher taxes on meat products coming into Niger than on live animals. Such a policy has some significant effects on trade between the two countries, and can have a long range implication on the patterns and policies of trade among these countries. Presently, it seems that the relatively high taxes imposed on movement of animals across national boundaries encourage the illegal flow of animals "on the hoof" across these boundaries. There is a certain economic loss involved in such movements due to potential weight losses and time delays in delivery, which must be avoided if a stable and steady-state market condition is sought.

5.4 Equipment Strategies

This section addresses the question of equipment utilization for transport along two lines: rolling stock and vehicles; and possible new technology such as lighter-than-air craft .

5.4.1 Rolling stock: The long distances involved in transporting commodities in the Sahel-Sudan region, the lack of extensive high-quality infrastructure, and the lack of extensive repair shops and supply stations throughout the region, all lead to higher vehicle operating costs due to frequent breakdowns, high cost of spare parts, and delays in repairs and road service. A number of trucks of various sizes and specifications exist throughout the region. It would seem plausible that an attempt can be made to unify the trucking service by limiting the choice of trucks to two or three types and/or manufactures through governmental regulations on imports. The choice of these types would take into account the type of prevailing shipments, size, and other characteristics where each vehicle type can satisfy best the region's requirements. The unification of the trucking fleet can result in many advantages for the operators including the availability of spare parts, the development of skilled mechanics for the maintenance and repairs which become much easier for a smaller variety of vehicles. It is recognized, however, that there may be some problems associated with limiting the choice to a small number of vehicles and a detailed study is needed to pursue this subject.

Similar arguments can be drawn for other modes of transport including railroads, air, and river. The unification of equipment and facilities can be helpful in improving the management and logistics involved in transport operations.

Air transportation can provide a good means of transporting goods and passengers over relatively long distances, especially for the land-locked countries. However, the high costs involved in airport con-

struction and purchase or lease of aircraft result in limiting the number of locations serviced by aircraft. Furthermore, the commodities which can be carried by air must be of a sufficiently high value to justify the costs involved. Among other things, high-value vegetables and processed meats can be carried between the region and southern Europe using chartered freight airplanes. It is estimated that this results in a cost range between $0.14 - 0.35 per pound of vegetables or meat to be carried over the estimated 3,000 mile distance. There are significant economies of scale involved in such operations and larger shipments on more frequent basis might justify the use of the more economical jumbo jets for this purpose.

5.4.2 New transport technology: Another alternative which is becoming of interest to many analysts is the use of dirigibles for long-haul of bulk commodities. This alternative utilizes the economies of scale and offers several advantages in capacity and cost. A 250-ton payload dirigible (as compared with the 80-ton payload for a Boeing 747) has been reported to have a cost totaling about $15 million which is less than that of $20-25 million for a B-747. This cost will greatly depend on the levels of demand and usage of these facilities which still remain to be investigated. However, amortizing the investment cost over a 20 year period, one could estimate that it would cost about $0.06 to 0.08 per pound of vegetables or meat from the Sahel-Sudan region to Southern Europe. (This is less than one-third of the cost by jumbo jets). The advantage offered by dirigibles are numerous including less fuel consumption, lesser need for investments in infrastructure and ground facilities for normal operations. They may also have the ability to reach rather remote areas of production which are normally not served by aircraft at a reasonable cost. There may still be operational and technical problems, but this potential deserves investigation by the international agencies.

5.5 Summary and Findings

-Despite the apparent difficulties and problems encountered in the transport sector in the region, the transport network appears to be capable of handling a substantially larger volume of traffic than at present.

-Roads constitute the dominant transport mode in the region. They provide the major access within the region and into the coastal areas. Most of the infrastructure for road transport already exists in the region and with proper maintenance and modest upgrading, the capacity of the network to handle larger traffic volumes could be increased significantly.

-Improvements in the road system require extensive planning for construction and maintenance of the feeder roads connecting agricultural production areas to main access roads and to markets and distribution centers. Substantial benefits can be realized from improved and well-planned feeder road systems. Presently, the lack of feeder roads is a major barrier to increased agricultural potential since traditional animal transport is too costly for large-scale shipment of food. Apart from their role as social integrators, feeder roads can play a significant role in increased agricultural production and help the farmers to shift from subsistence to market activities. Increased access to markets provides the farmers with the incentive to utilize agricultural technology, such as animal traction, and thereby increase their production and revenues. The economy will benefit from reduced transport costs as well as increased production.

-The main road system connecting urban and market areas to each other and to production zones and ports can be improved by better maintenance operations, better drainage facilities, and staged reconstruction and expansion programs. Development of more extensive storage facilities to spread peak loads would also permit better utilization of available transport.

-Among the major problems relating to the road network of the region is the lack of proper maintenance. This deficiency is due in large part to

frequent breakdowns and ineffective utilization of equipment. Therefore, the feasibility of using local materials and labor intensive techniques in the construction, maintenance, and reconstruction of roads should be studied from both engineering and economic viewpoints. Training programs for personnel and better road maintenance workshop operations are necessary to keep the major roads operational over longer periods of time.

-River transport does not constitute a very significant portion of total traffic within the region because navigability of rivers is subject to large seasonal variations. Some improvements can be achieved by regulating water levels to make the major rivers navigable over extended distances and for longer periods of the year. Modern vessels also could be introduced along with these improvements. However, river traffic will continue to provide only a small part of the total transport, at least over the next decade or two.

-Improved management and operation of the railroad system is needed to make this mode more efficient. Traffic volumes are presently too small to justify major expansions in the network, and, except for specific mining or industrial activities, no such expansion appears to be required within the next decade.

-A serious transport problem facing the landlocked countries of the region lies outside of these countries. Improvements in transport routes which provide access to the major ports as well as improvements in the ports themselves are crucial to gain substantial cost savings and efficiencies for import and export. Currently, the commodities destined to, or originating from, landlocked countries are not in themselves of sufficent volume to justify major improvements in the ports or inland transport links in the transit countries. Joint arrangements between the transit and landlocked countries must be made to provide incentives for operation of the railroads, roads, and ports of the transit countries. Some of these are already in effect, such as the Niger railroad, but improvement

of the port facilities, including storage and loading and unloading equipment, is necessary.

-Because of the long distances involved and the dispersed traffic volumes within the region, air transport can be an attractive mode if used effectively in conjunction with the road network. Many landing strips already exist and others can be built at a minimal cost to provide access to remote areas and to transport high-value commodities in or out of those areas using relatively small aircraft, such as the DC-3s which require only limited runway and navigational facilities.

-The use of larger aircrafts, such as jumbo jets to carry larger quantities over longer distances offers some economies of scale, but require rather large investments in infrastructure and navigational facilities. Therefore, technological innovations such as high-volume lighter-than-air vehicles may in the future prove economically attractive for the transport of high-value agricultural products, such as vegetables and meat, to European markets. Interest in these facilities has recently increased because of the minimal infrastructural requirements and the large economies-of-scale and relatively high speeds that can be realized. For short-range activities, air cushion equipment such as the Hovercraft can be utilized to reach remote areas rapidly to distribute food or medical supplies, circumventing the need for infrastructural investments. Conceivably, long-term application of such techniques could be planned, but the economies of their specific application must be carefully considered.

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APPENDIX

INVENTORY OF TRANSPORT FACILITIES

The transport in the Sahel-Sudan countries could be divided into three categories: (a) domestic transport within each country; (b) intra-regional transport among the countries -- mainly between the landlocked countries and the coastal ones; and (c) international transport with the rest of the world. Therefore the traffic is mainly in the north-south direction, and only partially east-west. Following is a summary of the inventory of the physical road network, railways, and air-transport facilities country by country.

I. ROAD NETWORK

A country-by-country breakdown description of the road network is presented in this section. Only the physical and geographic aspects are addressed here. The economic aspects are mostly addressed in the main report.

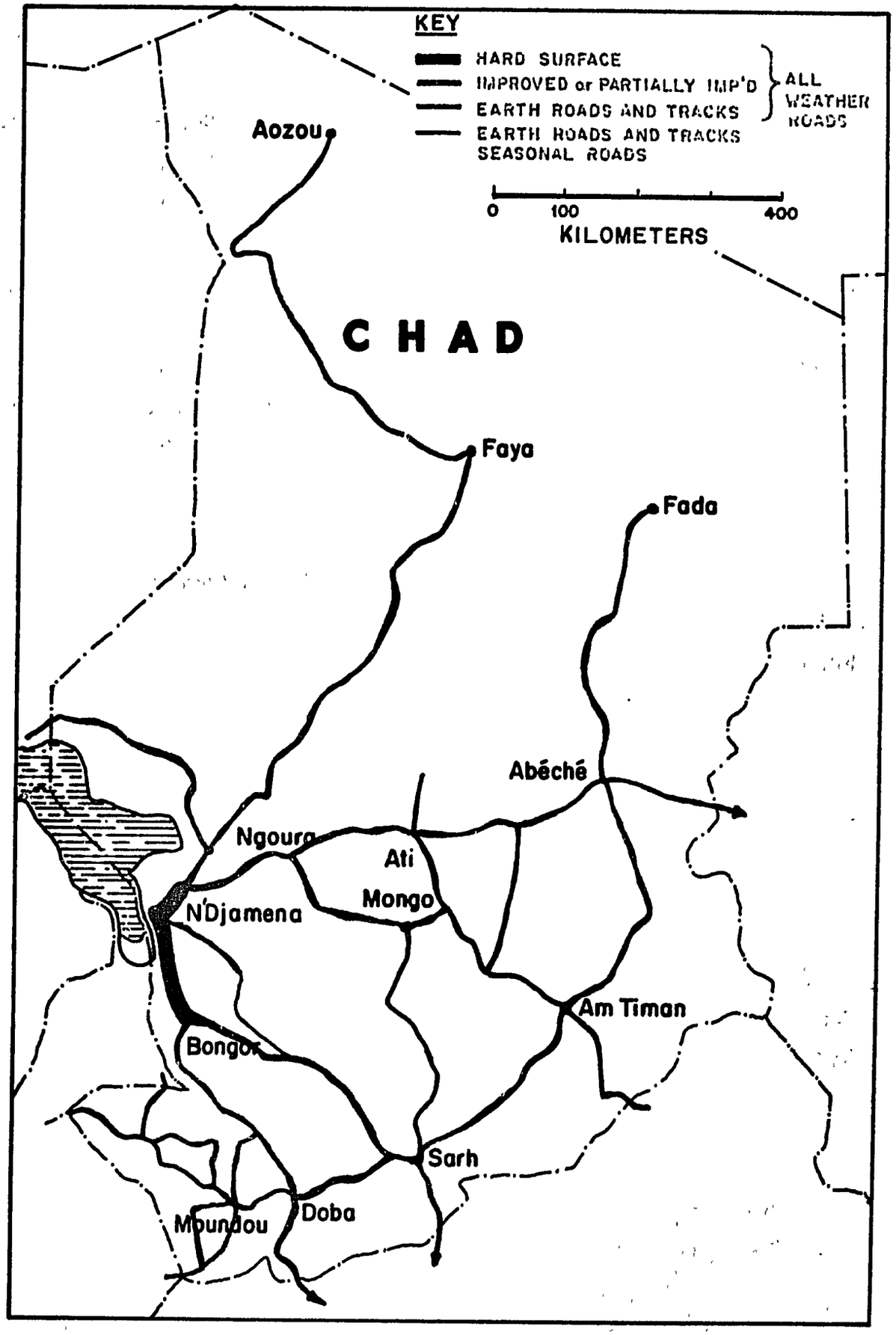
A. Chad

The existing network is approximately 30,000 km long of which 25,000 km are tracks and unmarked roads. Map 1 gives an overall view of the network.

Chad is a landlocked country which has a rather difficult access to the sea through the following routes.

1. Via Congo (Equatorial Route

Freight is transported by trucks from Chad to Bangui, Central African Republic; from Bangui to Brazzaville, Congo, through the Oubangui river; and from Brazzaville to Pointe-Noire by rail. The distance from N'Djamena to the sea following the equatorial route is 2,975 km. This route is used only for cotton exports from the south of Chad to Bangui and Point-Noire. It is not used for imports. There are delays during February and May due to the low water level of the Oubangui River.



MAP 1. Road Network in Chad

2. Via Cameroun

Freight is transported by trucks from Chad to Belabo, Cameroun, and from Belabo to Douala by rail. By the end of 1974, the railroad should be extended to N'Gaoundere in northern Cameroun and the construction of the highway N'Gaoundere-Moundou, Chad, should be finished. It is the most expensive route but the most secure and a quick one. The distance from N'Djamena to Douala is 2,060 km. There are several interruptions in the travel on this route during the rainy season (June through December). There is no direct road from Moundou to N'Gaoundéré and transport is done through Garoua, Cameroun, and from there to N'Gaoundéré.

3. Via Nigeria

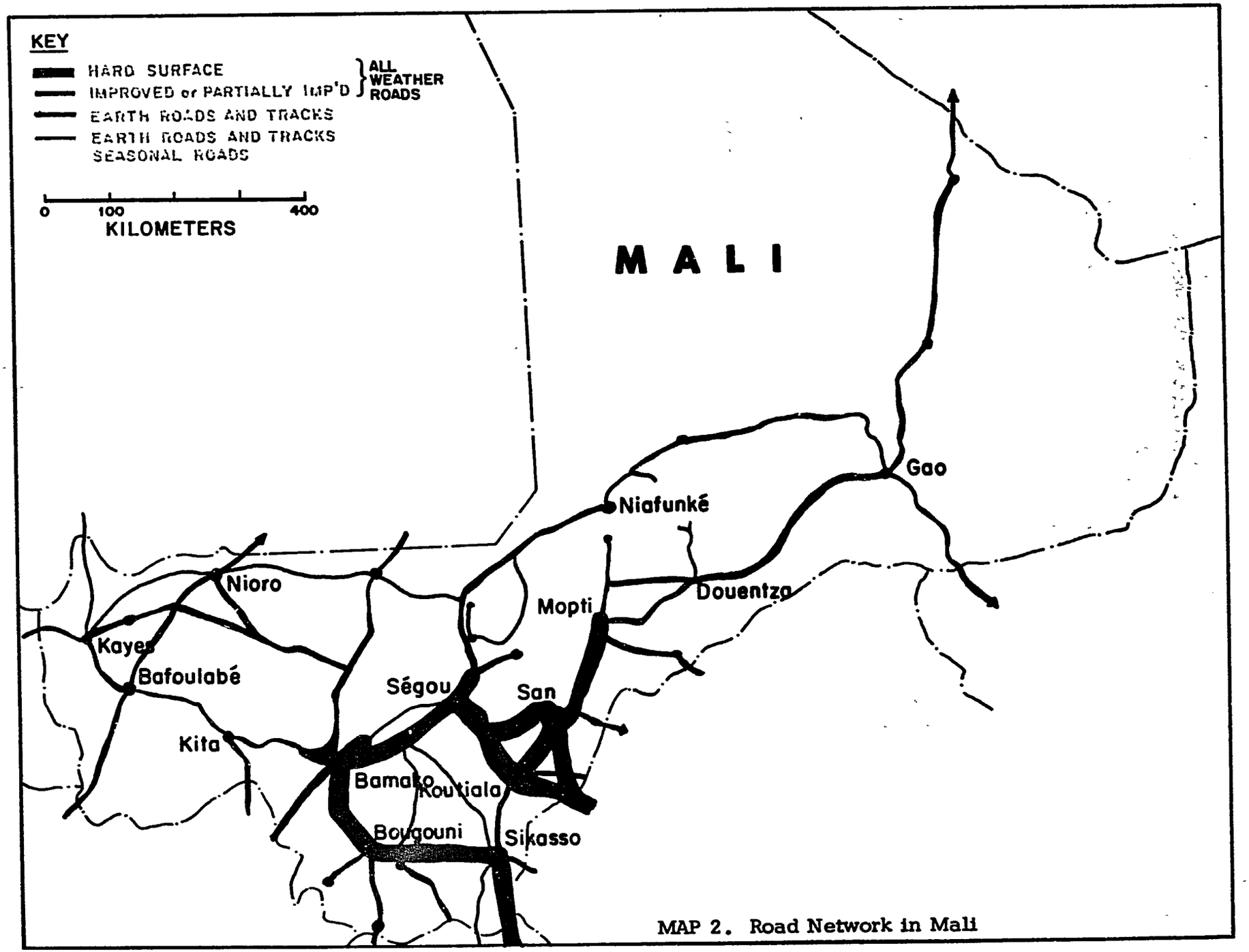
Freight is carried by trucks from Chad to Maiduguri, Nigeria, and from there by rail to Lagos or Port-Harcourt. This route is used infrequently due to the length of the journey and the delays in the congested ports. The distance from N'Djamena to Lagos is 2,100 km and from there to Port-Harcourt 1,765 km. An alternate route would be from N'Djamena to Garoua, Cameroun, by trucks and then to Port-Harcourt.

4. Via Sudan

This route is used infrequently because of the distance involved. The distance from Abeche to the Red Sea area is 2,660 km. Transport is done by trucks to Nyala, Sudan, and then by rail from Nyala to Port Sudan.

B. Mali

The existing network has a length of 12,000 km. There are 1,643 km of paved road. The total length of all weather roads is 3,327 km. Map 2 gives an overall view of the network.



MAP 2. Road Network in Mali

Mali is a landlocked country. Access to the seas exist through:

1. Via Senegal

From Bamako – Koulikoro – Kayes to Dakar by rail -- 1,290 km. The length of the trip is two to four months because of over-loading on the line.

2. Via Ivory Coast

There are two connections between Bamako and Abidjan, Ivory Coast: Bamako – Sikasso – Ouangolodou, Ivory Coast, by road (570 km). One from Ouangolodougou, either by rail or by road to Abidjan (610 km) taking 20 days; the other from Mopti to Bobo-Dioulasso, Upper Volta, by road (485 km). The route from Bobo-Dioulasso to Abidjan is the most frequently used since the road through Senegal is too congested.

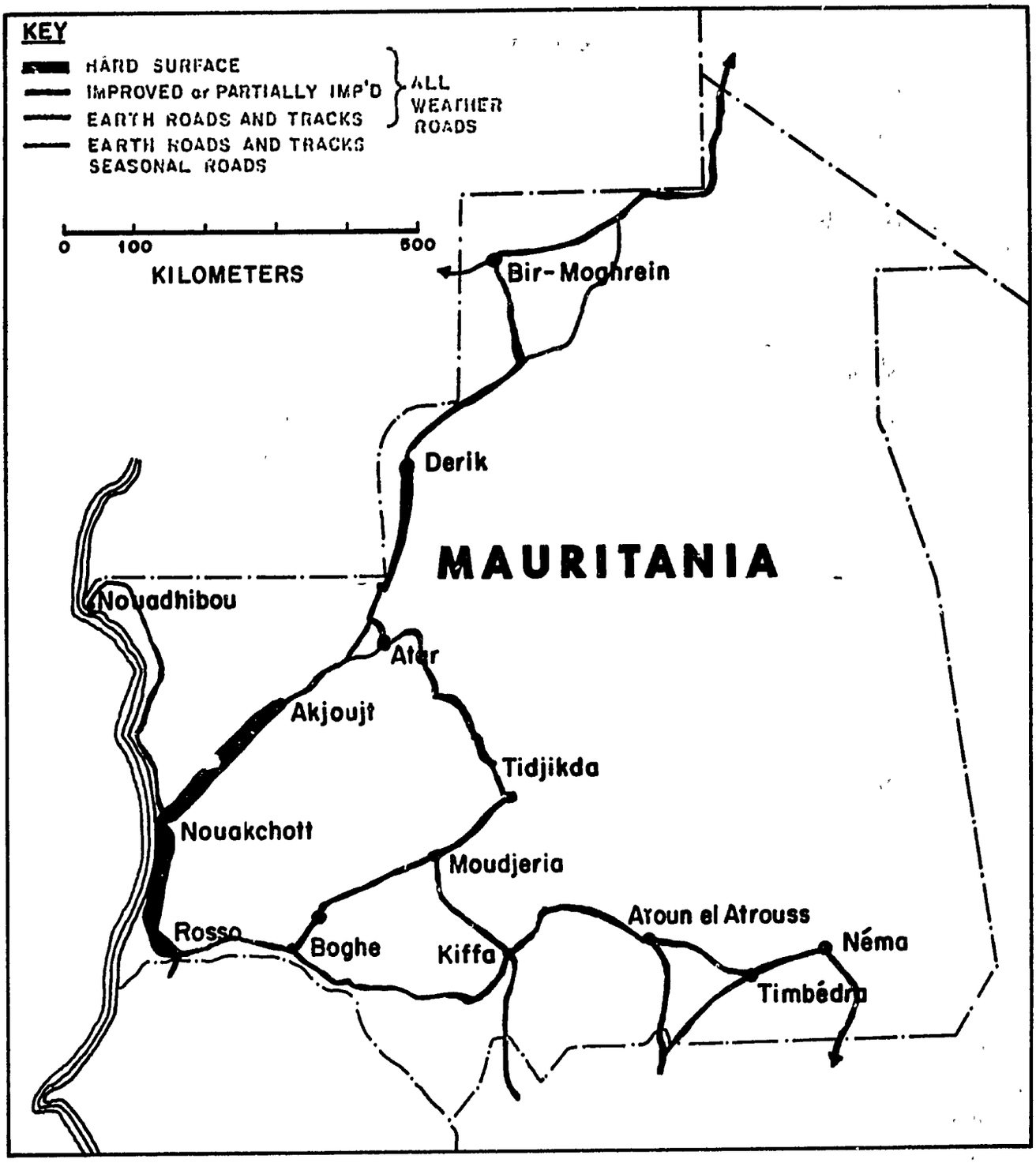
3. Via Guinea

This route is seldom used. Transport is done by road from Bamako to Kankan, Guinea, and from Kankan to Conakry by rail -- a distance of about 1,000 km.

C. Mauritania

Mauritania meets the sea at its western coast, where there are two ports: Nouadhibou and Nouakchott. The road network is oriented to provide access to these prots. However, the road conditions are very poor throughout the network and the journeys last longer due to this fact.

The existing network has a length of 6,000 km and the improved roads have a length of 1,000 km. Map 3 gives an overall view of the network.



MAP 3. Road Network in Mauritania

D. Niger

The existing network in Niger consists of 600 km of paved roads and 6,970 km of improved, earth roads, and tracks. Map 4 gives an overall view of this network.

A landlocked country, Niger has the following connections to ports in neighboring countries:

1. Nigeria

Freight is transported by truck from Maradi to Kaura-Namoda, Nigeria, a distance of 260 km and from there by rail to the ports of Lagos or Port-Harcourt. It is also trucked from Zinder to Kano, Nigeria, a distance of 260 km and from there by rail to the ports of Lagos or Port-Harcourt. These routes are suitable for exportation of agricultural products grown in the Maradi – Zinder region which is one of the most productive regions of Niger. There is, however, serious congestion problems in the ports in Nigeria which causes considerable delays.

2. Dahomey

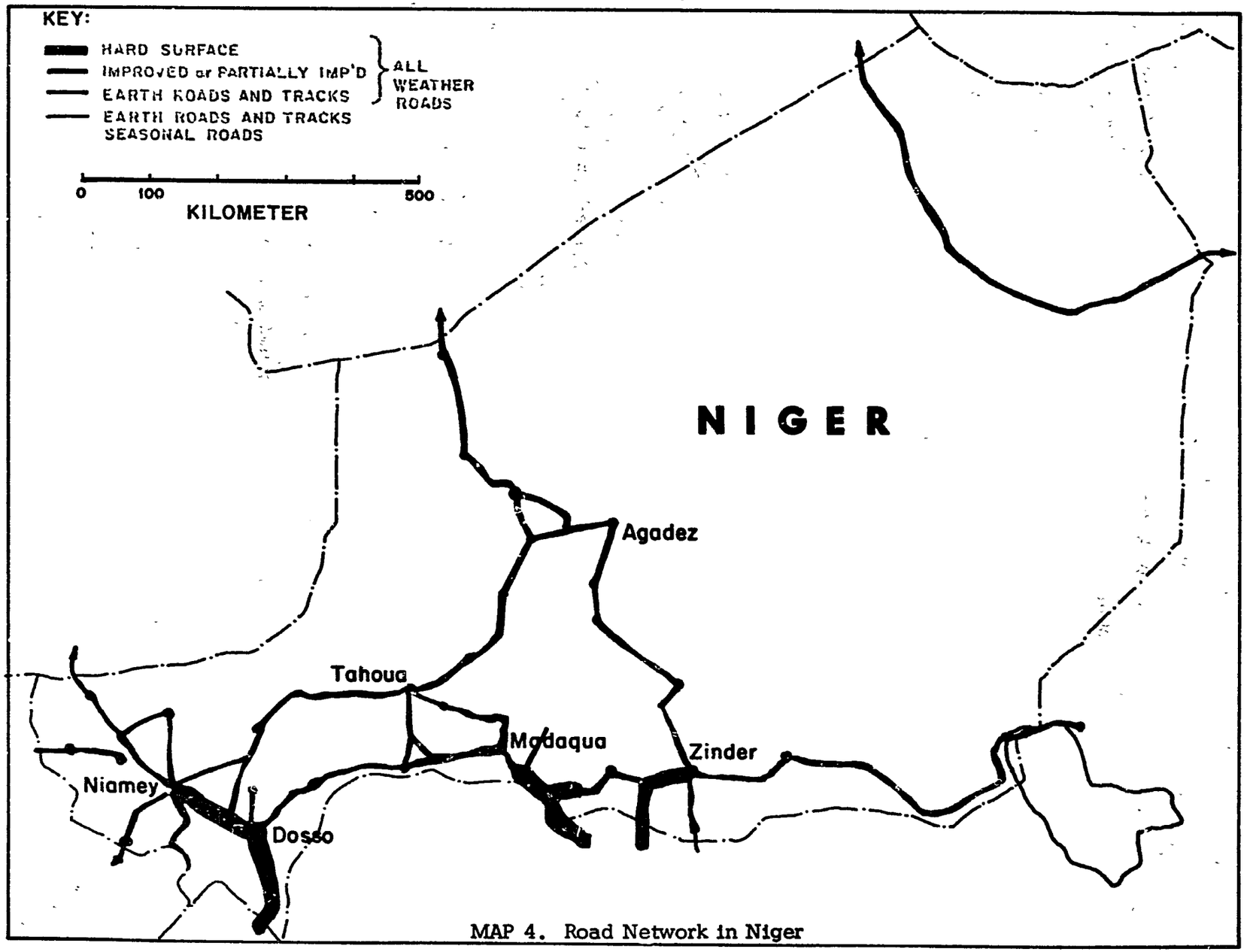
Freight is transported by truck from Niamey to Parakou, Dahomey, a distance of 600 km, from there by rail to the port of Cotonou, a distance of 438 km. This route is utilized mainly for imports.

3. Ivory Coast

A small portion of the total freight is transported by truck from Ouagadougou and by rail from Abidjan. This mode which is mainly used for imports.

E. Senegal

Senegal has an extensive road network. All the axes connect the interior with the ports in the west, and extend to neighboring countries



MAP 4. Road Network in Niger

as well.

The existing network consists of a road network length of 13,145 km of which 2,168 km are paved. Map 5 gives an overall view of the network.

F. Upper Volta

The existing network has a total road length of 4,450 km of which only 350 km is paved. This network is illustrated on Map 6.

Upper Volta is also a landlocked country. The following routes provide access to ports:

1. Ivory Coast

Freight is transported by rail from Ouagadougou to Abidjan, a distance of 1,200 km. Although this route is rather long, it is the most frequently used.

2. Ghana

Freight is trucked on a paved road from Ouagadougou to Accra, a total distance of 845 km.

3. Togo

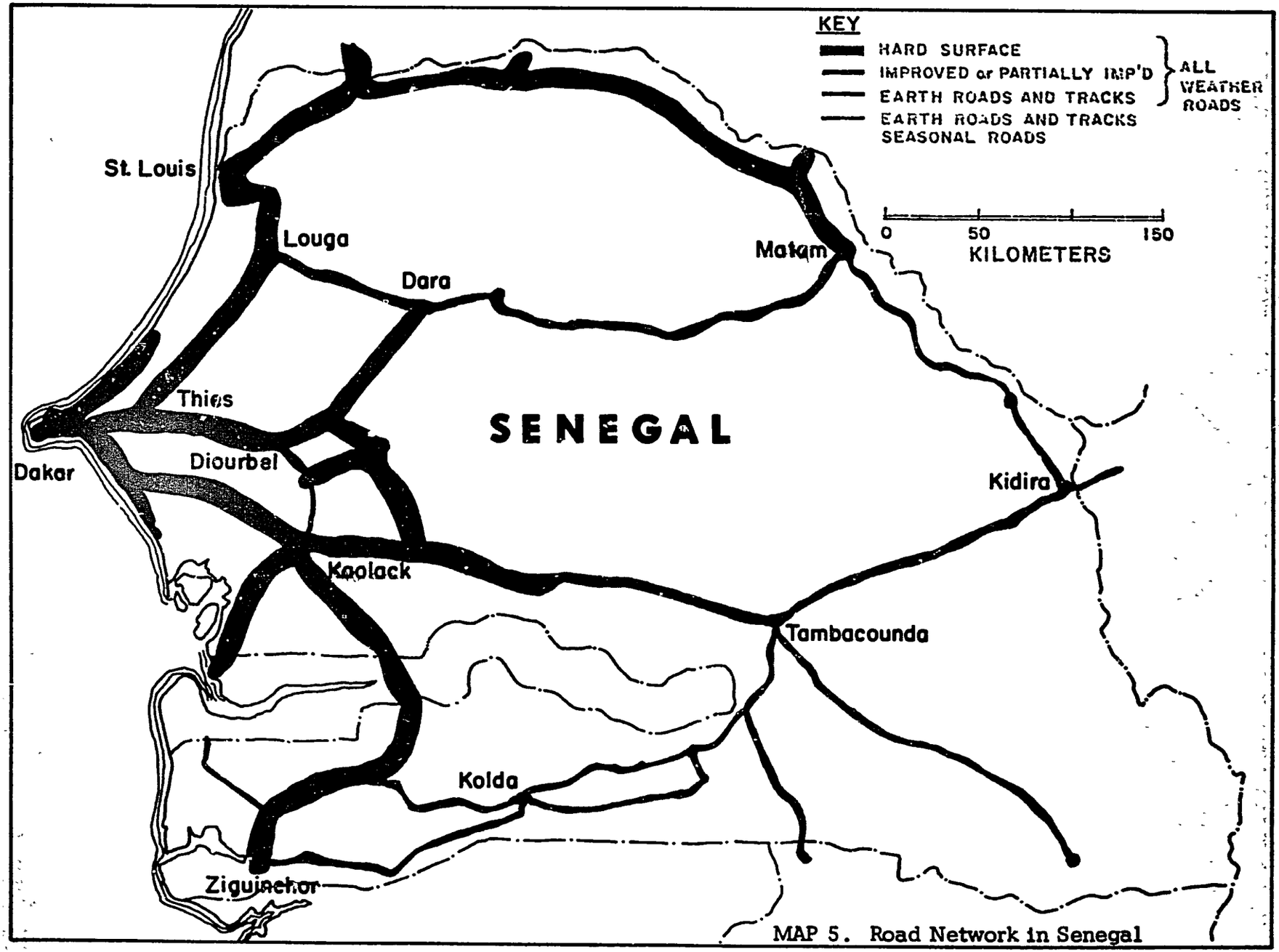
Freight is transported a distance of 1,000 km to Lome on a road which is an improved one and in good condition.

4. Dahomey

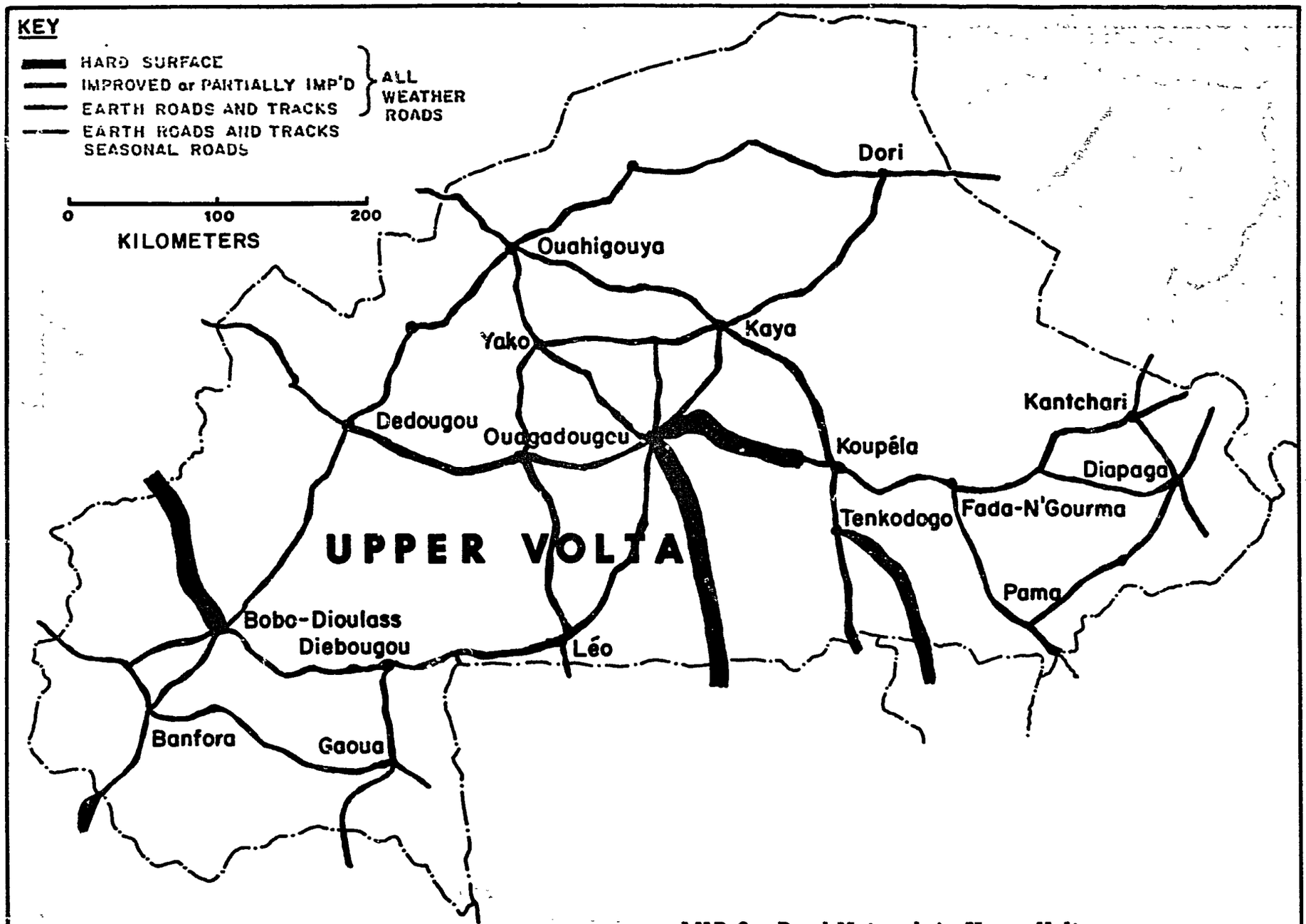
This route, an improved road, starts from Ouagadougou, passes through Fada-N'Gourma and continues to Cotonou, a distance of 1,095 km.

G. Improvements in the Network

The following is a summary of improvements proposed by the ministries of the six countries, as a result of a meeting held in



MAP 5. Road Network in Senegal



MAP 6. Road Network in Upper Volta

Ouagadougou in September 1973:

Construction of the following roads was proposed (see Map 7 for the proposed trans-west-African highway):

1. Trans-Sahelian Road (Dakar to N'Djamena)

There are two possible routes the road could follow: (a) Dakar – Tambacounda – Nioro du Sahel – N'Djamena; or (b) Dakar – Nouakchott – Nioro du Sahel – N'Djamena.

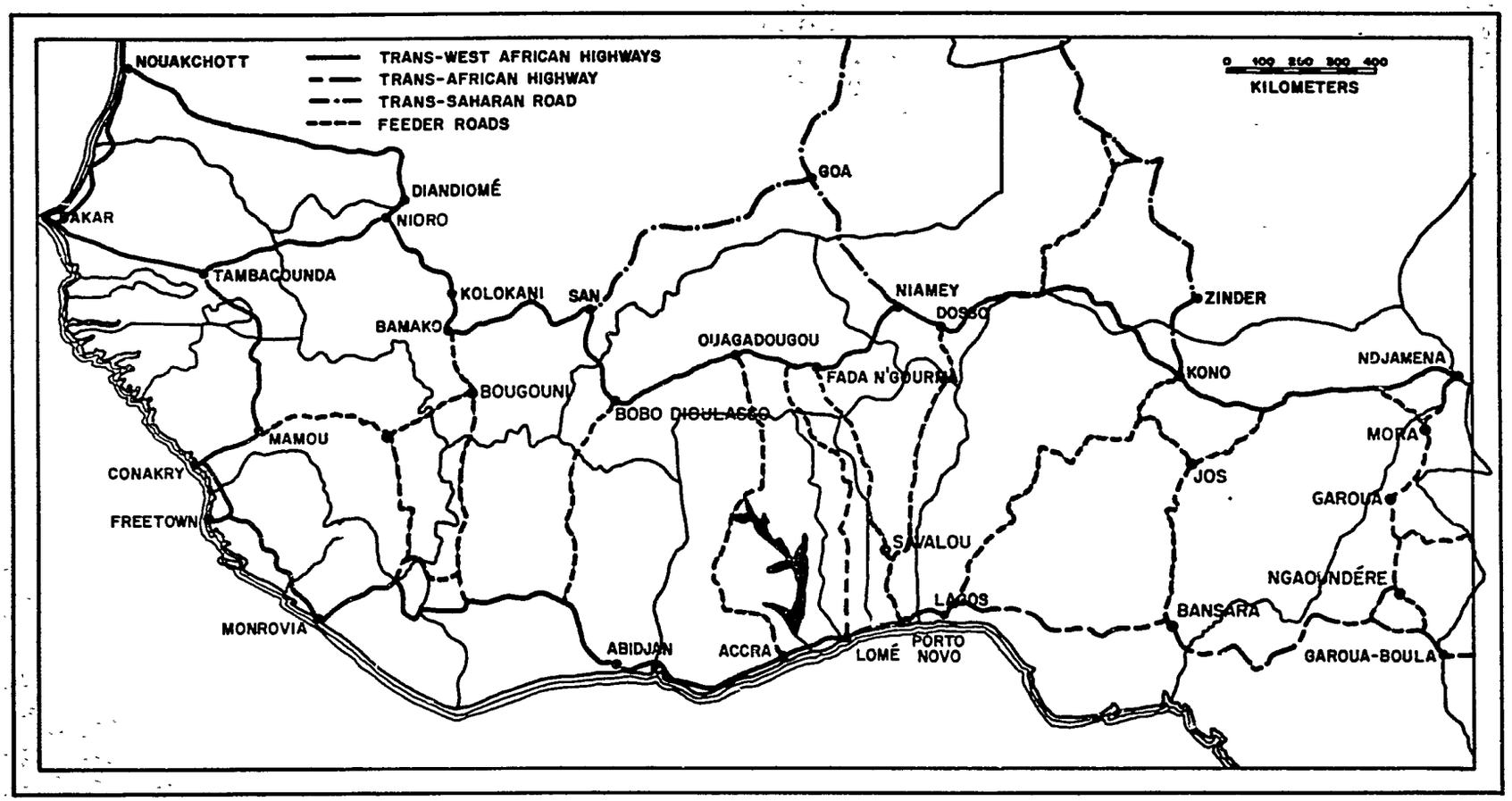
1.1 Dakar – Tambacounda – Nioro du Sahel – N'Djamena Route: This route will pass through the major town. Dakar – Tambacounda – Nahé (in Senegal); Nioro du Sahel – Bamako – San – Douri (in Mali); Falmana – Bobo-Dioulasso – Ouagadougou – Gouina (in Upper Volta); Gouina – Niamey – Maradi – Jibiya (in Niger); Jibiya – Maiduguri – Fotokol (in Nigeria); Fotokol – Maltam – Fort-Foureau (in Cameroun); Fort-Foureau – N'Djamena (with a bridge over the Chari River in Chad).

An improved road will connect Mauritainia with this route. The total length of this route is expected to be 4,840 km, with an existing paved portion of 2,175 km. The partially improved portions include: (a) Goudiry – Nahe: 70 km in Senegal; (b) Nahe – Segala: 180 km and Ségala – Kolokani 485 km in Mali; and (c) Fada N'Gourma – Gouina: 170 km in Upper Volta.

1.2 Dakar – Nouakchott – Nioro du Sahel – N'Djamena Route: This route is about 5430 kms long, i.e. about 590 kms longer than the previous one. The portion from Nioro du Sahel to N'Djamena is the same as the above route. Other connections include: Dakar – Rosso (in Senegal); Rosso – Nouakchott – Diandioume (in Mauritania); Diandioume Nioro du Sahel (in Mali).

Already there is an existing paved portion of 2,460 km. The following portions are partially improved:

a. Nouakchott – Diandioume – Nioro du Sahel: 1,015 km in Mauritania.



MAP 7. Proposed Trans-West African Highway

b. Nioro du Sahel – Kolokani : 308 km in Mali.

c. Fada N'Gourma – Gouina: 169 km in Upper Volta.

d. Gouina – Niamey: 128 km in Niger.

e. Maiduguri – Fotokol: 138 km in Nigeria.

f. Fotokol – Mataur: 64 km in Cameroun.

2. Ouagadougou – Mopti Route

This route would connect Mali with Upper Volta with a 408 km of paved surface.

3. Koupela – Fada – Niamey Route

This route would run in Upper Volta and Niger with a total paved length of 285 km.

4. Dori – Tera – Niamey Route

This involves a total length of 200 km of paved road in Niger.

5. Mopti – Gao – Niamey Route

This connects the western parts of Niger with Mali with a total length of 1,030 km of an improved all-weather road.

6. Niamey – N'Djamena Route

This connects Niger, Cameroun and Chad with an improved all-weather road of about 1,800 km with some paved portions along the way.

7. Tambacounda – Kayes Route

This route connects eastern Senegal with Mali with a total 285 km of paved road.

8. Nioro – Markala Route

This involves the construction of 69 km of improved all-weather road in Mali.

II. RAILROAD NETWORKS

There are no railroad lines in either Chad or Niger. The railroad links in the other countries are briefly described below:

A. Mali

There is a railroad link which runs from Senegal to Kayes – Mahina – Kita – Bamako – Koulikoro. The track length is 685 km. The gauge is 3'3 3/8" (one meter). The RCFM* has 22 diesel locomotives, 11 diesel-electric railcars, 24 passenger cars, and 246 freight-train cars. The total number of employees is 1,605.

B. Mauritania

There is a railroad line owned and operated by the mining firm MIFERMA. The gauge is the standard one: 4' 8 1/2 (1.435 meters). MIFERMA posesses 31 diesel-electric locomotives, 950 freight-train cars and has 1,240 employees.

C. Senegal

Senegal Railways, the "Regie des Chemins de Fer de Senegal," include the old Dakar to St. Louis railway, and the Thies to Kayes railway. The remainder constitute the present Mali railway described above. Senegal's railways are administered by the Ministries of Public Works and Planning.

1. Characteristics of the Network

The total length of the network is 1,032 km with a track length of 1,184 km. The gauge is 3'3 3/8" (one meter). This consists of the following lines:

a. Dakar – Thiès – Kidira (to Kayes in Mali): 643 km

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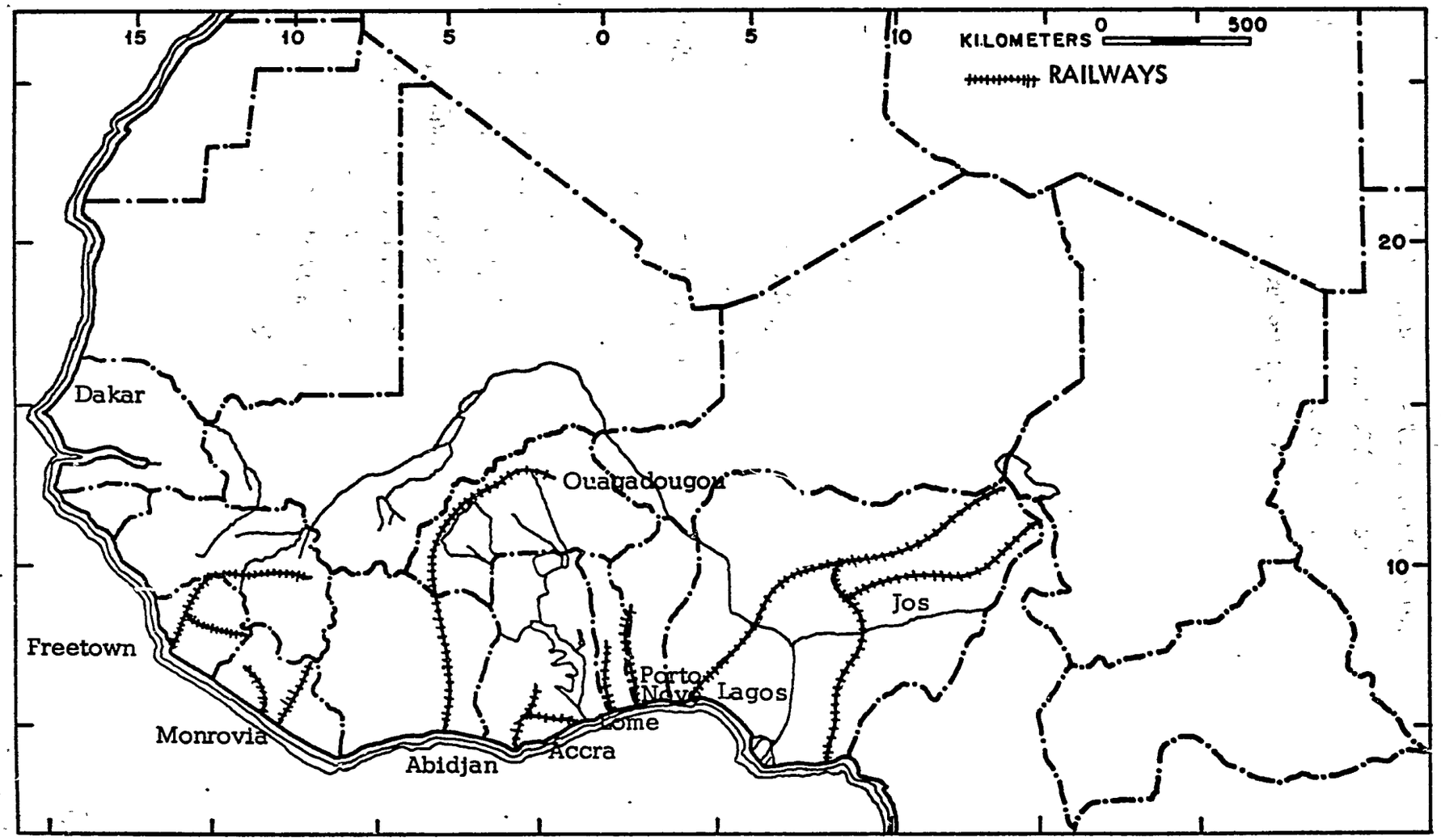
* Regie de Chemins de Fer du Mali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RAILWAYS
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Freetown
Porto Novo
Lagos
Lome
Monrovia
Accra
Abidjan

b. Diourbel – Touba: a 47 km branch of (a).

c. Thiès – St. Louis: 193 km.

d. Louga – Linguere: 129 km

e. Guinguineo – Kaolack: a 21 km branch of (a).

The rolling stock includes 27 diesel-electric locomotives, 21 hydrocarbon locomotives, 31 diesel-electric railcars, 65 passenger-train cars, 431 freight-train cars. A total of 4,028 employees operate the railroad.

D. Upper Volta

The Republics of Ivory Coast and Upper Volta jointly manage the "Regie Abidjan-Niger"(R.A.N.), which is a railroad company serving the two countries. It connects Abidjan and its port with Ouagadougou -- a line 1,173 km long and a track length of 1,318 km.

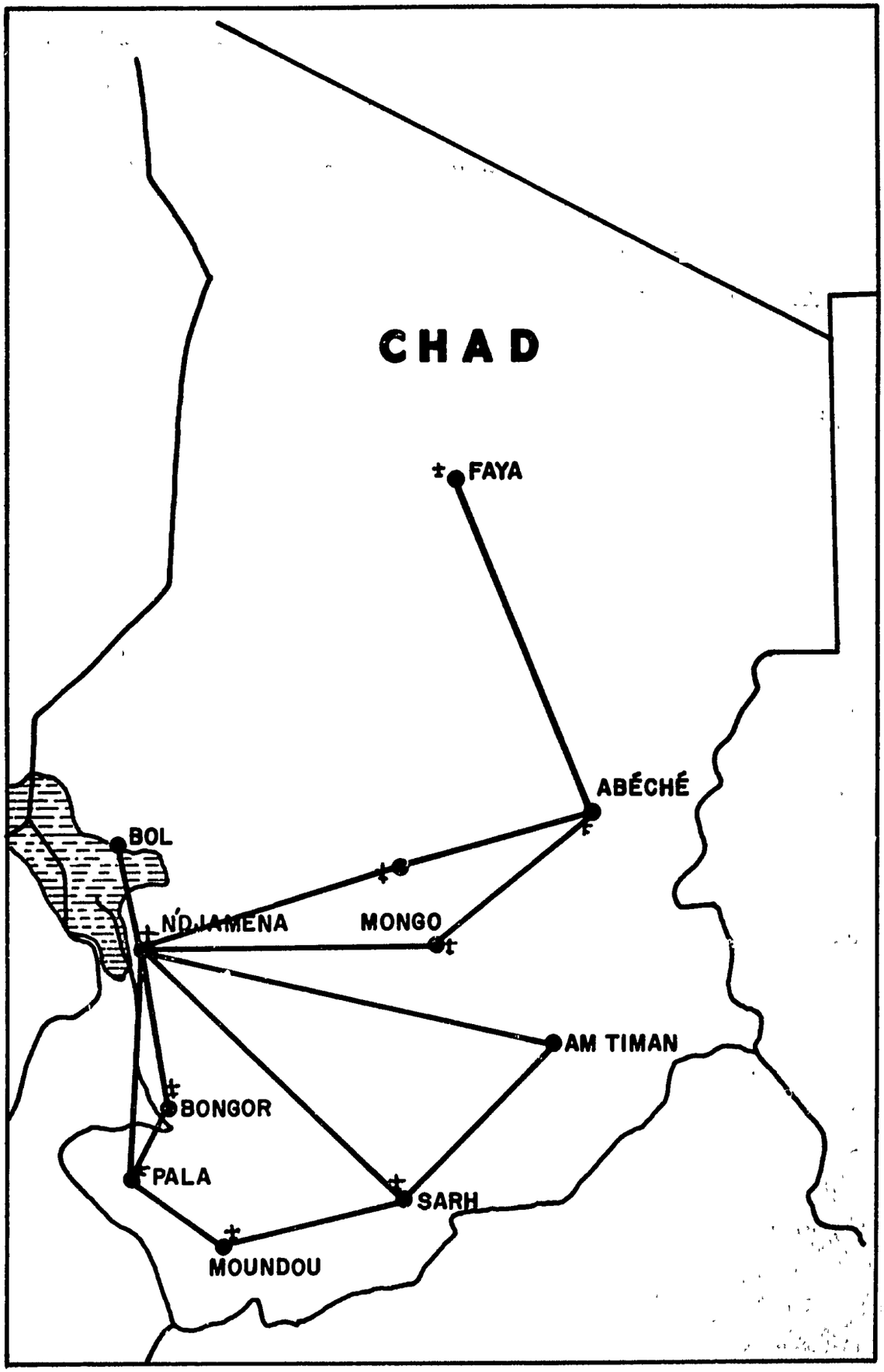
1. Characteristics and Operations of the Network

The gauge is one meter, with a rolling stock of 41 diesel locomotives, 23 diesel-electric railcars, 63 passenger cars, and 753 freight cars.

III. AIR-TRANSPORT FACILITIES

A. Chad

The main airport is in N'Djamena with a latitude of 12-08 N, longitude of 15-02E, and elevation of 295 m with a 2,300 m runway which is equipped with a lighting system. There are meteorological and radio facilities, a control tower, an approach control office and an instrument landing system. There are also facilities for refueling operated by Mobil Oil.



MAP 9. Air Transport in Chad

1.1 Other Local Airports

Abeche: This has radio and meteorological facilities, a 1,600 m runway and refueiling facilities operated by Mobil Oil. It also has a customs office.

Bongor: It has radio facilities and its longest runway is 1,600 m.

Faya-Largeau: It has radio facilities and its longest runway is 2,300 m. There is also a customs office.

Sarh: This airport is equipped with radio, meteorological, refueling -- also by Mobil Oil -- facilities, and a control tower. The longest runway is 1,800 m with a lighting system. There is a customs office at this airport.

Moundou: It has radio and meteorological facilities, a control tower, a customs office. The longest runway is 1,800 m supplied with a lighting system.

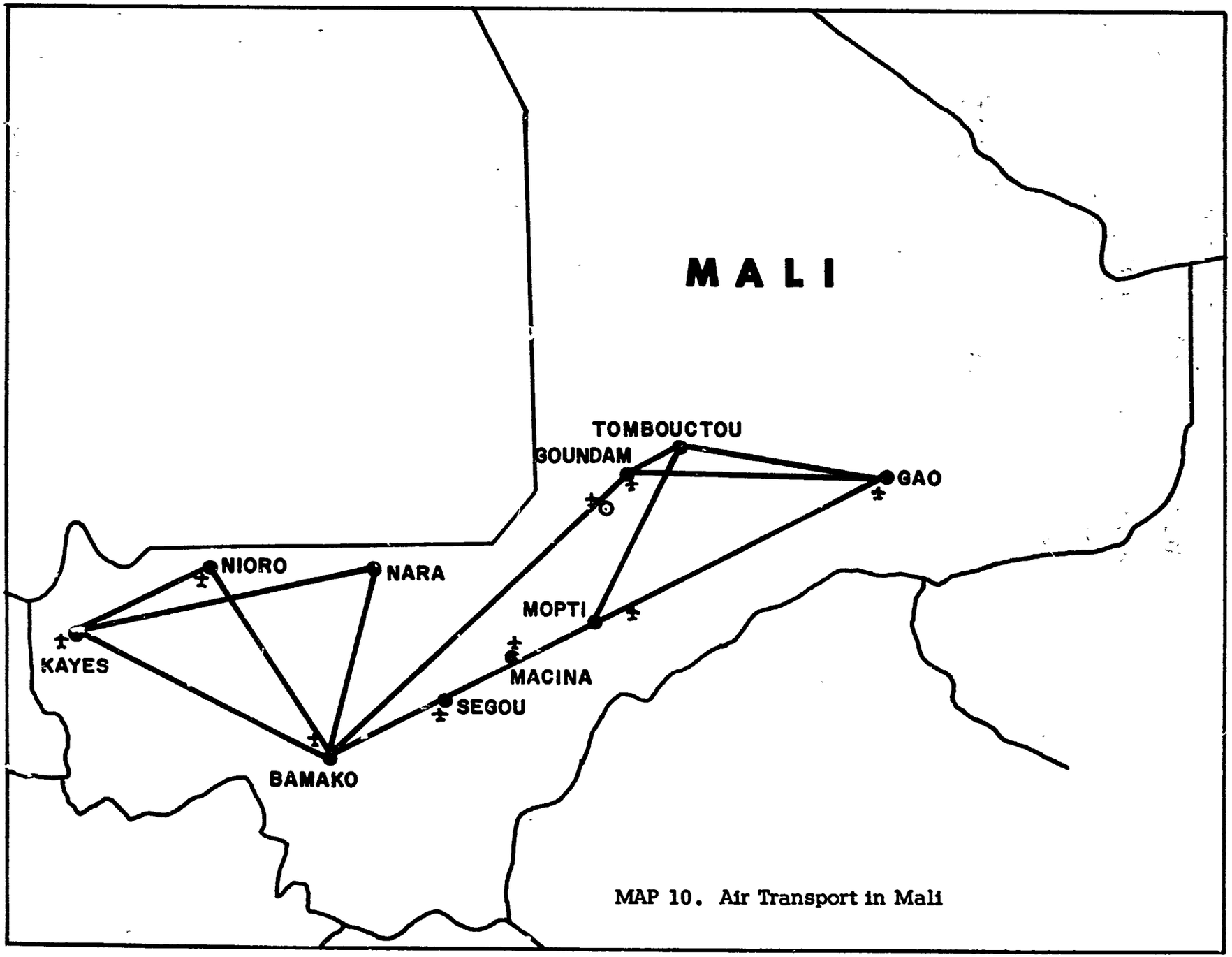
Mongo: This has radio and meteorological facilities with the longest runway being 1,400 m.

Pala: It has radio and meteorological facilities, a customs office, with the longest runway 1,600 m.

There are also several smaller airports and landing strips throughout the country.

2. Mali

The main airport is in Bamako. It has a latitude: 12-38N, Longitude: 08-01W and an elevation of 329 m. It has meteorological, radio, repair and refueling facilities (Mobil Oil, Total Afriques Ouest), an air-traffic control system, a lighting system and customs. The longest runway is 2,107 m.



MAP 10. Air Transport in Mali

2.1 Other Local Airports

Goco: The longest runway is 1,850 m. There are radio, meteorological, and refueling facilities, an air traffic control system, customs and a lighting system.

Goundam: It has radio facilities, the longest runway is 1,500 m.

Kayes: It has radio facilities and a control tower. The longest runway is 1,164 m.

Mopti: This airport is equipped with radio facilities and a control tower. The lonest runway is 1,600 m.

Nara/ Keibune: Radio Facilities. Longest runway: 1,200 m.

Nioro: Control tower. Longest runway: 1,500 m

Segou: Radio facilities, control tower, 1,500 m runway.

Tessalit: Radio facilities. Two runways of 1,210 m and 2,515 m.

Tombouctou: Control Tower. Longest runway is 1,500 m.

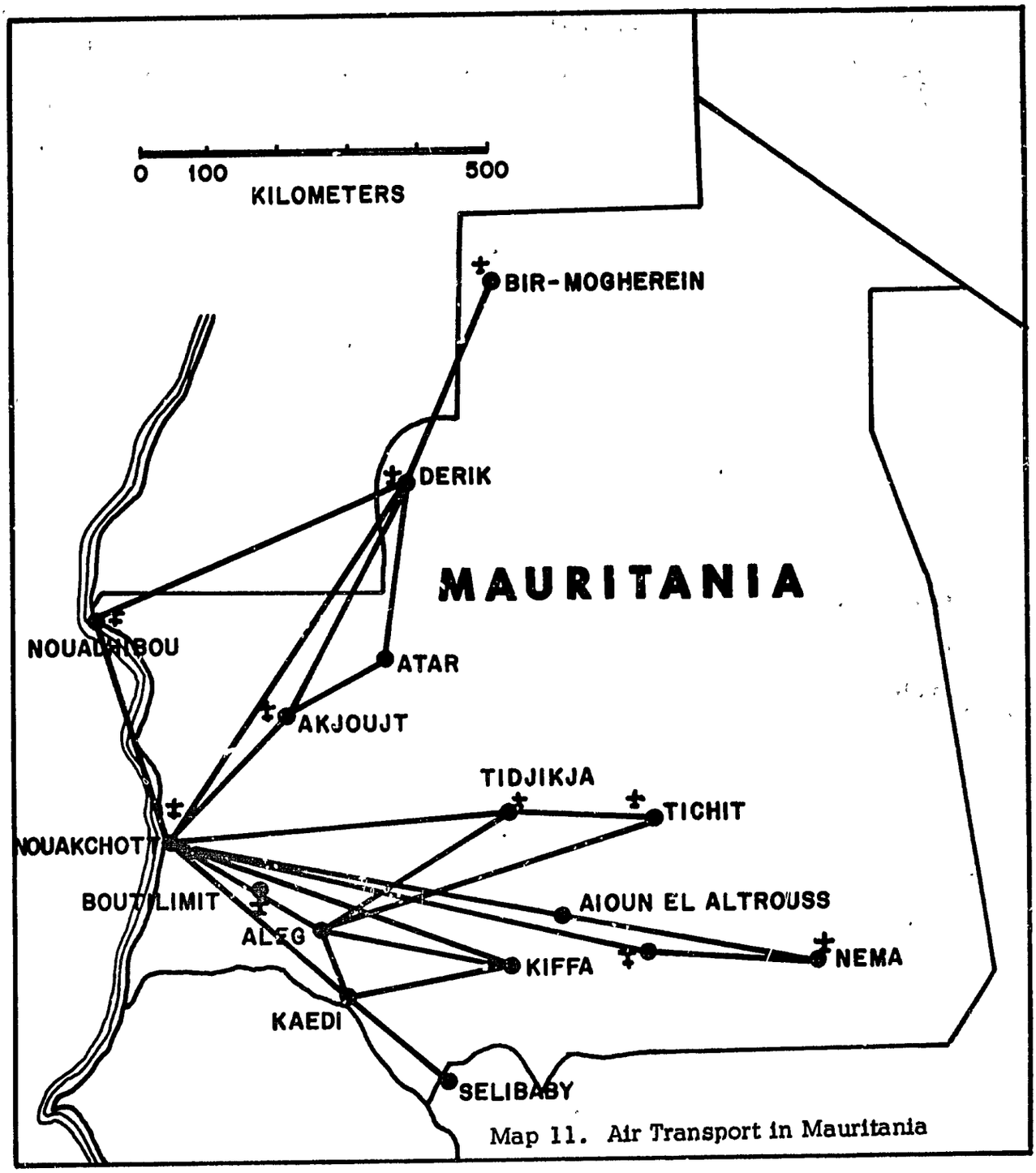
In addition to these, there are several smaller airports and numerous landing strips throughout Mali.

3. Mauritania

There are two main airports:

Nouadhibou: Latitude: 20-56 N, longitude: 17-02W, elevation: 5m above sea level. There are radio, meteorological, refueling facilities, a lighting and air-traffic control system along with a control tower. The longest runway is 2,425 m. There is a customs office also at this airport.

Nouakchott: Latitude: 18-06N, longitude: 15-57W, elevation 2 m. The facilities and equipment in this ariport include radio, meteorological, and refuling facilities, a light and an air-traffic control system, and a control tower. The longest runway is 1,600 m.



Map 11. Air Transport in Mauritania

3.1 Other Local Airports

Aioun-el-Atrouss: Radio, meteorological and refueling facilities, a lighting system with the longest runway 1,590 m.

Akjouit: Radio and meteorological facilities, a lighting system and two runways of 2,000 m.

Atar: Radio and meteorological facilities, a lighting system, customs, with two runways of 2,100 m.

F'Derick: Meteorological facilities and two runways of 1,800 m.

Kaedi: Radio and refueling facilities. Longest runway: 1,600 m.

Kiffa: Radio and refueling facilities. Longest runway: 1,600 m.

4. Niger

The main airport is in Niamey. Latitude: 13-24 N. Longitude: 02-10E. Elevation: 223 m. Radio, meteorological and refueling facilities, customs, control tower, air traffic control and lighting system with three main runways of 2,570 m.

4.1 Local Airports

Agadez: Refueling and radio facilities, lighting system -- longest runway: 1,800 m.

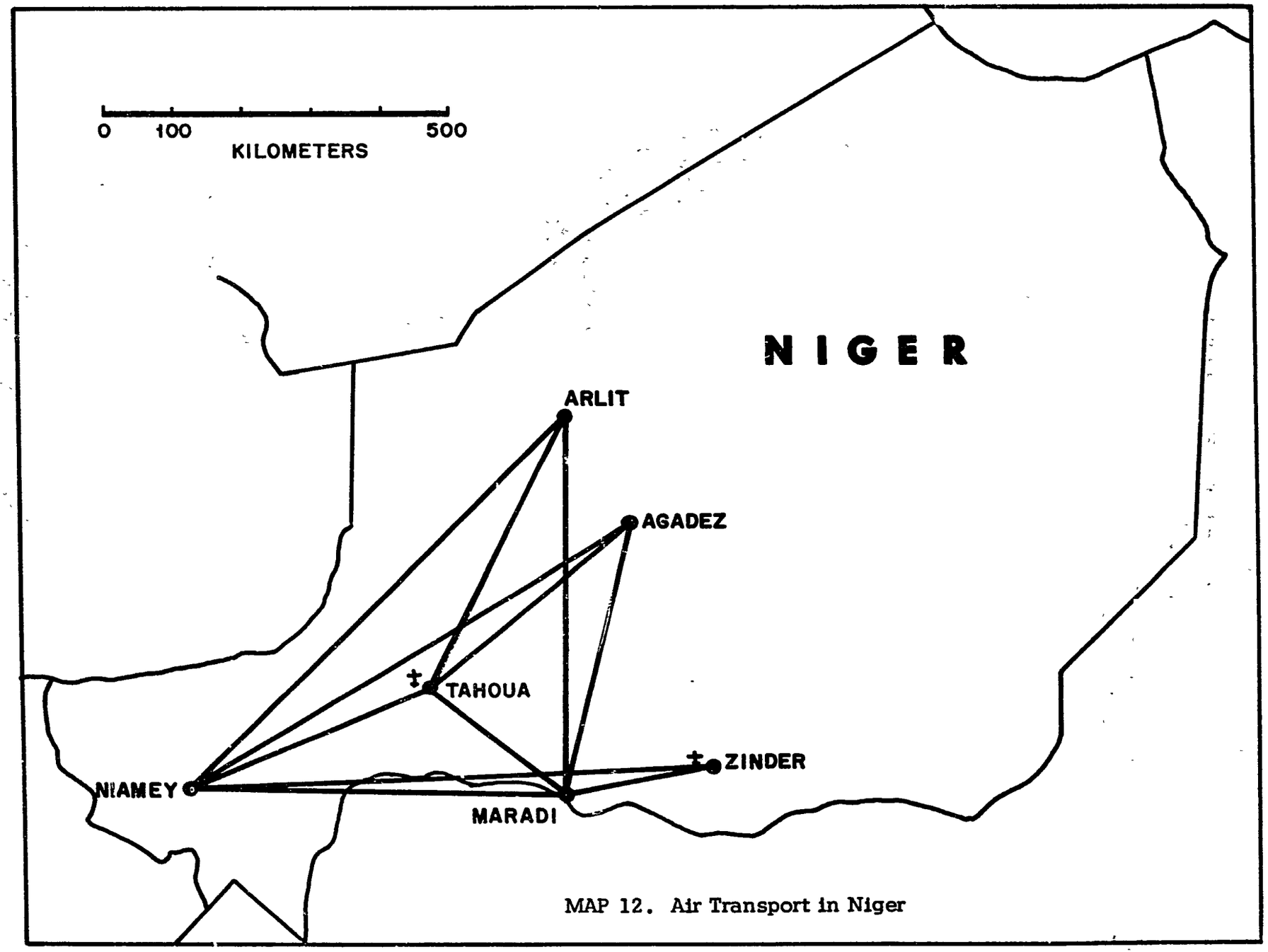
Maradi: Refueling, meteorological, and radio facilities, and lighting systems. The longest runway is 1,650 m.

Tahoua: Refueling, radio, and meteorological facilities along with a lighting system. The longest runway is 1,750 m.

Zinder: Radio, meteorological and refueling facilities, customs, control tower, air-traffic control and lighting system. The longest runway: 1,825 m.

5. Senegal

The main airport is Dakar-Yoff. This is an international airport,



MAP 12. Air Transport in Niger

which forms the crossroad for the routes from South America to Europe and from Europe to West Africa. Latitude: 14-44N, longitude: 17-29W, elevation: 27 m. It has refueling, repair, radio, and meteorological facilities, lighting and air-traffic control system, customs, control tower with three main runways of 2,900 m.

5.1 Other Local Airports

Bakel: Main runway of 1,750 m.

Cap Skirring: Main runway of 1,800 m.

Diourbel: Two main runways of 800 m.

Kaolack: Meteorological facilities. Two main runways 1,200 m.

Kolda: Main runway: 1,300 m.

Linguere: Main runway: 1,390 m.

Matawi: Main runway: 1,600 m.

Podor: Main runway 1,250 m.

Richard-Toll Main runway, 1,550 m.

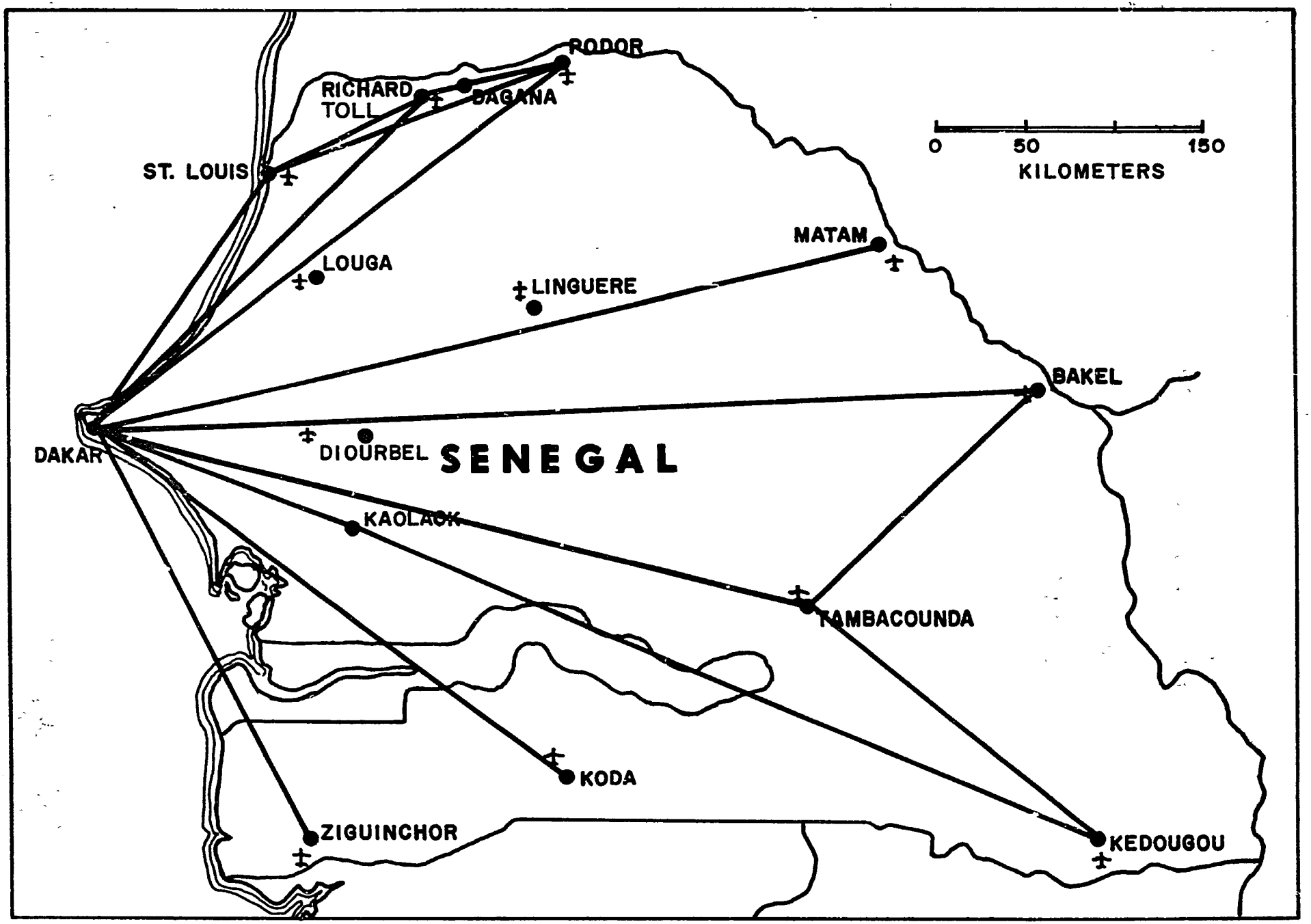
St. Louis: Radio, meteorological and refueling facilities, customs, air-traffic control and lighting system, control tower, two main runways of 1,600 m.

Siminti: Main runway: 1,200 m.

Tombacounda: Radio, meteorological and refueling facilities, air-traffic control system, customs, control tower, lighting system and two main runways: 1,350 m.

6. Upper Volta

The main airport is in Ouagadougou. Latitude: 12-21N, longitude: 01-31W, elevation: 316 m. It has a refueiling station, radio and meteorological facilities, control tower, air-traffic control and lighting system, and customs, with a main runway of 2,600 m.



MAP 13. Air Transport in Senegal

The other airport is Bobo-Dioulasso which has radio, and meteological facilities, lighting system, air-traffic control system, control tower, customs and the main runway is 2,050 m.

B. Airlines

1. Treaty of Yaounde (Air Afrique)

Air Afrique, which operates under the articles of this treaty, is a joint airline of the following countries: Centeral African Republic, Chad, Congo, Dahomey, Gabon, Ivory Coast, Mauritania, Niger, Senegal, Togo, and Upper Volta. Its headquarters are in Abidjan, Ivory Coast. The equipment of the Air Afrique fleet includes: one DC-3, four DC-8-50, one DC-8-63, three DC-10-30 (on order), six DC-4, two Sud-Caravelle 11B, and two Namco YS-11A-300.

2. Air Tchad (Chad)

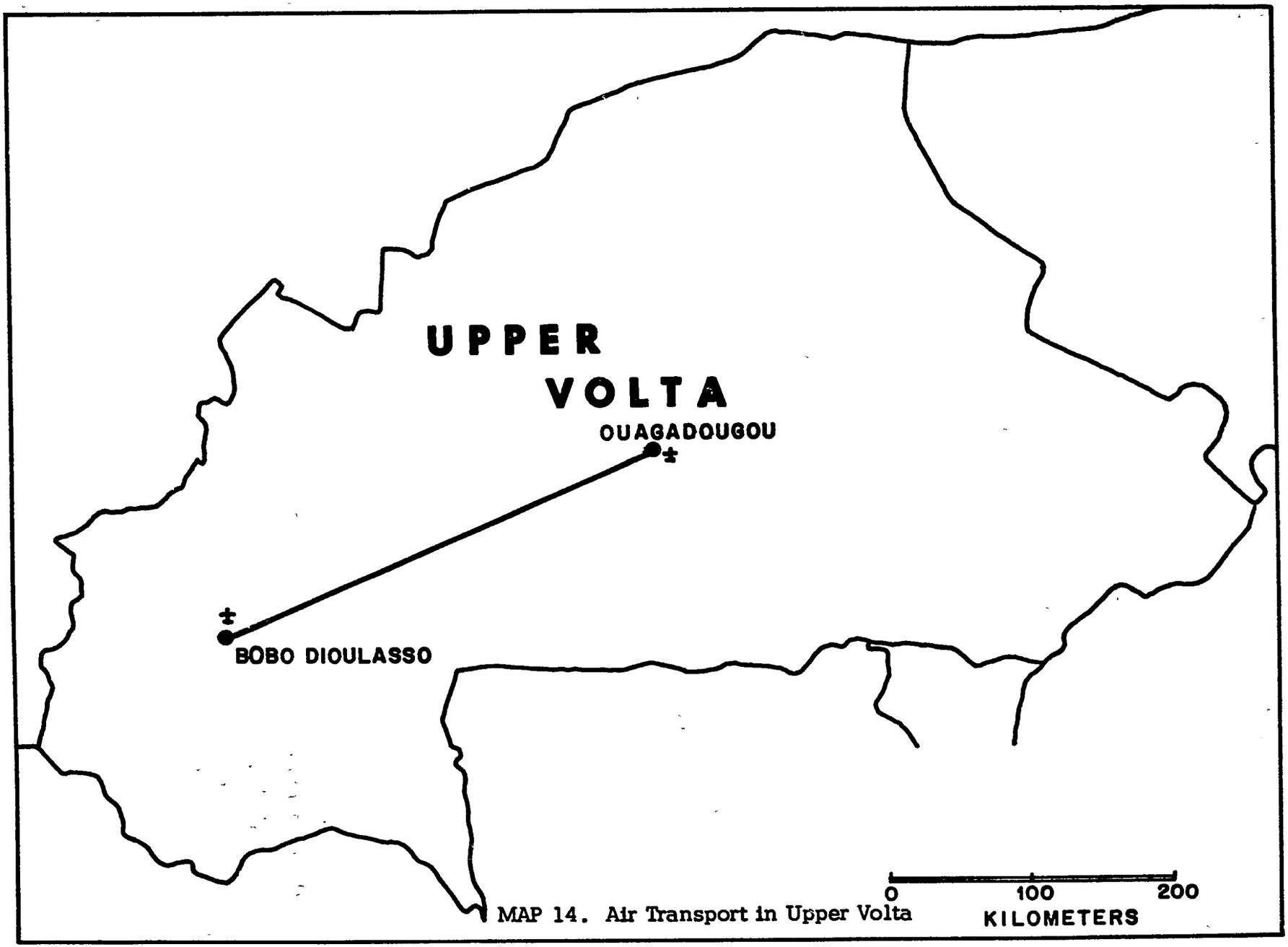
This is the domestic airline of Chad with headquarters in N'Djamena. Its equipment consists of one DC-4,Two DC-3, one Beechcraft Baron, and one Piper Cherokee 6-300. Air Tchad network serves 18 domestic points, and was formed in 1968 under a joint agreement between the government and UTA.

3. Air Mali

Air Mali is the domestic and international airline of Mali, since Mali is not a full participant in Air Afrique. Air Mali's headquarters are loacted in Bamako. The fleet consists of: one B-727, two IL-18, two AN-24, three DC-3, and one AN-2.

4. Air Mauritanie

Air Mauritanie was established in 1962 and covers all domestic and some international routes. The headquaters are located in Nouakchott. The fleet consists of: one IL-18, one DC-4, three DC-3, and



MAP 14. Air Transport in Upper Volta

one Piper Navajo.

5. Air Niger

This airline was established in 1966 under government supervision, mainly to provide service for domestic traffic, with headquarters in Niamey. It has a small fleet consisting of two DC-3s.

6. Air Sonatra (Senegal)

This was formed in 1962 by the Senegal government to serve the domestic and some international routes. Its fleet includes one DC-4 and one DC-3.

7. Air Volta (Upper Volta)

Organized in 1967, Air Volta operates several local services based at Ouagadougou including a frequent service to Bobo-Dioulasso, using a fleet of two Piper Cherokees and one Piper Navajo.

The above information has been obtained from the following sources:

1. World Air Transport Statistics, No. 14 year 1970 IATA.
2. World Aviation Director, Vol. 34, no.1 (summer 1973). Ziff-Davis Publishing Co.