

CHAPTER 2 - GENERAL STUDY ORGANIZATION

OBJECTIVES OF THE PROJECT

The long-range objective of this Project is both to assist the Government of Brazil in minimizing the total cost of their highway transport system and to provide the results to other countries to achieve the same benefits on a world-wide basis.

This will be accomplished by better defining the interrelationships between the three components affecting road transportation costs: 1) construction, 2) maintenance and 3) road user costs. The individual relationships for these three costs may be used separately in road analysis and/or may be combined in a mathematical model. Using such a model, it will be possible to indicate construction and maintenance strategies leading to the minimization of the sum of these three cost components, i.e., minimum total road transport costs.

The objective will be accomplished through four immediate sub-objectives which are:

- (1) to establish the relationships between a) road user costs, b) road geometric standards and c) surface conditions for rural roads;
- (2) to measure the relationship of road deterioration and maintenance costs as a function of pavement and geometric design standards and traffic for rural roads and climatic conditions typical of Brazil;
- (3) to develop mathematical models or modify and adapt those existing for Brazilian use with parameters developed in (1) and (2) above, and
- (4) to establish a capability for continuing applied highway research in Brazil.

SCOPE OF THE STUDY

A project to accomplish the desired objectives could be undertaken at many levels. The scope of the present study is the largest yet undertaken in the field to define highway cost relationships. Funding will total approximately eight million equivalent US dollars.

Scientific and Analytical Scope

The project will develop primary data which can be used to determine the required cost relationships. These data will be obtained both by controlled experimentation, measurements, and through a well organized and documented survey procedure. Sound experimental design and survey design techniques will be established for the separate studies. This is to insure that in so far as possible, quantitative statements of accuracy can be made about the resulting models and coefficients.

Geographic Scope

The basic research will be conducted on rural highways in central Brazil, in the states of Minas Gerais and Goiás and the Federal District with sufficient satellite studies in other areas of Brazil as needed and economically feasible to provide full coverage of the factor space and variables involved. Where possible, the data and results will be presented in terms of basic variables which can be defined for and translated to rural highways anywhere in the world.

Scope of Application

The primary data, the direct analysis and the resulting models will have direct and immediate applicability in Brazil. In addition every attempt will be made to combine the results of this study with those of previous studies as indicated in

objective 3. The models will have primary applicability in the pre-feasibility and feasibility studies of rural highway development in Brazil and many developing countries.

The data itself will be recorded and preserved in such a fashion that it can be made available to others for further analysis, testing of models or other useful applications.

Time Scope

Following three years of planning, the project began on 1 July with an initiation phase of 6 months. The primary data collection and preliminary analysis phase will last 30 months, and 6 months have been designated for final analysis and reporting. Continuation of many of the studies on road user costs and road deterioration is desirable and will improve them significantly. The project structure and equipment will be adequate to continue, and it is hoped that a means can be developed to extend certain of the data observations and reanalysis to 1982, in accordance with objective 4. At present no firm plans exist to continue past 1 March 1979.

RESEARCH APPROACH

A study of this magnitude could be approached in many ways. Our approach has been 1) to take full advantage of background information and work done by others particularly the study in Kenya, and 2) to obtain valid primary data on those important areas which need further study.

The basic research approach will be to develop and conduct an integrated research project covering relevant aspects of the highway cost interrelationships problem. Basically these involve the relationships between road user costs, pavement performance, road geometric characteristics, and pavement maintenance. Past experience and current study of the problem have shown that a judicious combination of experimental measurements and "survey" techniques will be required to

obtain the required relationships. Measurements alone are inadequate. Certain variables such as depreciation, driver behavior and realistic costs of vehicles in actual operation do not yield to direct measurements. Yet these must be related to characteristics of the road and the pavement which are variable and measurable. Pavement performance and the effect of various maintenance strategies are measurable if care is taken and proper instrumentation is available.

All of the major factors to be determined in this study are functions of time. Thus great attention must be given to the time stability of measurements on the study such as pavement roughness or serviceability and pavement maintenance. Likewise, road user costs must be collected over a period of time and these data records must be kept in a uniform fashion for a period of 2 or 3 years.

To accomplish these tasks effectively within the project resources the user costs survey problem is being critically examined. Needed is an effective survey design which is as economical as possible in terms of resources expended per unit of information. Statisticians, experimental designers and survey economists have been called in as consultants to assist in this phase of the Project.

In terms of measurable variables we have undertaken to cover the factor space effectively and economically by using experimental design techniques which provide economical use of sample distribution and experimental units. The analysis of these statistical experiments will be complicated and require effective statistical help and computer support.

The magnitude of the study and the large number of data items generates a need for effective data management techniques. These data processing needs together with the complex statistical analysis requirements, the obvious need for computer modeling and the presentation of the final results dictate the need for strong computer support on the project.

In order to perform the measurements needed and to maintain the equipment effectively, a qualified instrumen-

tation group is required on the project staff. They will be active in mechanical as well as electrical instrumentation and must develop instrumentation on the job as needed.

Research Flow Chart

Figure 2 was developed to summarize a picture of the proposed research approach to the Project.

First, the general project objectives are defined. Then, the basic model needs, to be addressed during the project, are identified. These include major sub-component areas of the project planning model 1) construction, 2) maintenance and 3) road user modules. The principal variables to be addressed in each module are also identified.

Based on these basic modules and variables a general research methodology has been developed. This results in three branches, one for road construction and maintenance costs, another for road user costs and a third indicating the need to interface with and improve the existing state of the art models.

Under road construction and maintenance two functions are shown. The maintenance expenditure information will be collected from existing studies in Brazil. The major pavement studies will be experimental as shown. Under road user costs two major functions are also shown: user costs surveys and user costs experiments and traffic studies.

Finally, all the results from the Project will be brought together to produce a project planning model which will then be tested and refined to produce the best model possible. The dashed lines are proposed extensions of the work by the Brazil research team, to be carried on if possible after the end of the current study.

Literature Review

Initially, background literature was drawn from surveys

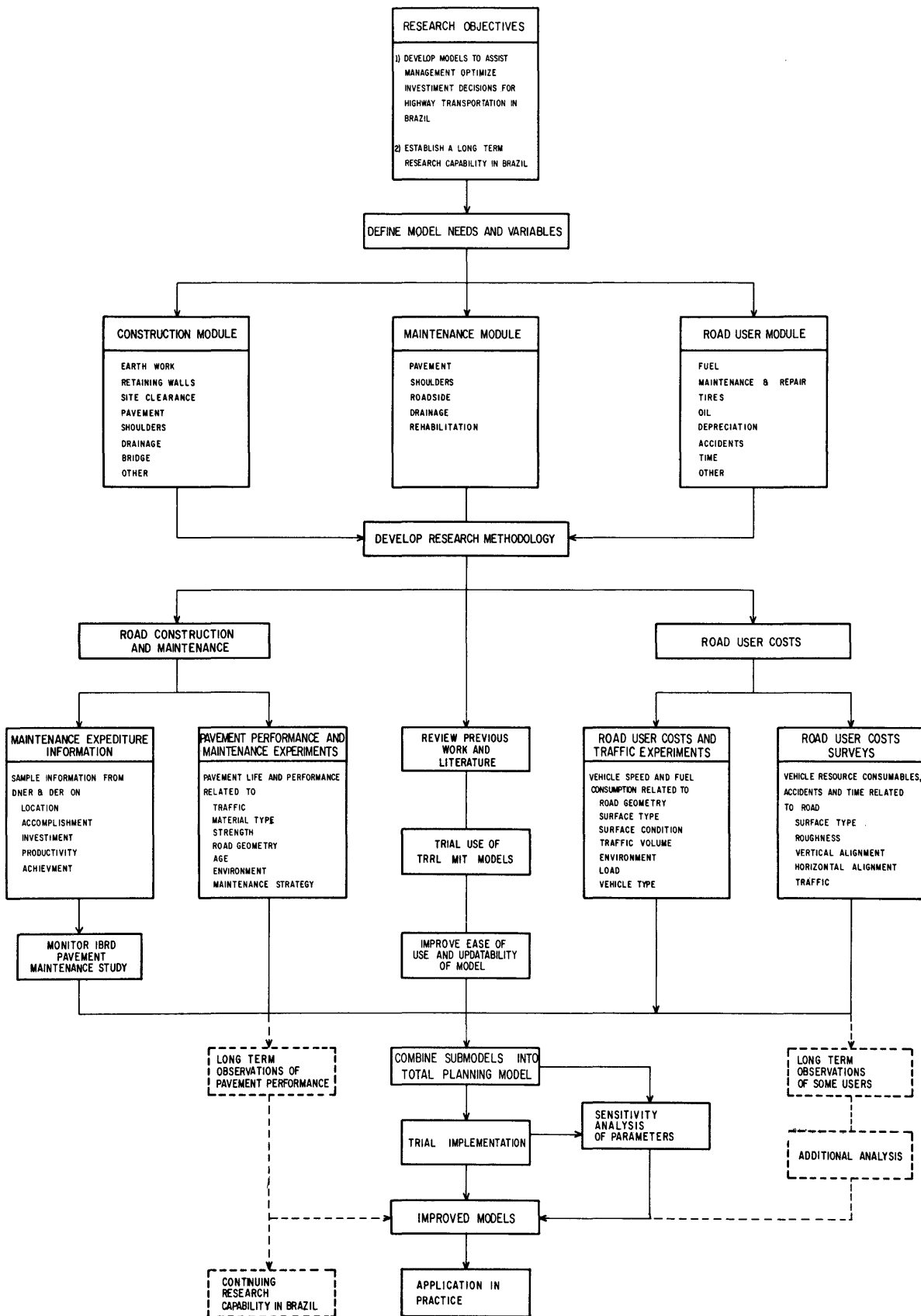


Figure 2 System Flow of the Organization of Research for the Project

done by the World Bank, the MIT Group, and by TRRL in the Kenya Study. References to this work are presented where appropriate herein. The basic history of these developments has been presented in Chapter 1. Finally a large number of related references have been obtained also from the British Transportation and Road Research Laboratory. Likewise, a thorough search has been made through the Highway Research Information Service and up-to-date information on related topics from this source is still being received. In future project reports a complete bibliography of relevant documents will be listed for permanent reference.

The study international Director visited several relevant research laboratories all over the world in March 1975 to discuss the study, related on going research and potential personnel for the project staff. These contacts have yielded considerable literature and information for the project.

Instrumentation and Equipment

To support the research effort, available instrumentation has been studied and \$ 500,000 worth of the latest and best equipment available has been purchased to carry out the required measurements programs. It was also necessary that a complete instrument development and repair shop be created to maintain the equipment. A separate chapter in this report treats the available instrumentation in detail.

In order to accomplish the measurements of road user cost variables a fleet of 8 test vehicles varying from a Volkswagen 1300 automobile to a 27-ton Scania Vabis truck has been purchased. These are discussed in detail in chapter 4.

RESEARCH ORGANIZATION

The Project is being conducted directly by a team involving input from several groups: 1) sponsors, 2) Brazilian staff, 3) expatriate staff, 4) Expert Working Group, 5) spe-

cial consultants, and 6) cooperating international agencies.

All of these groups are important to the project and each contributes in a special way.

The sponsors

This project is the result of an agreement signed in January '75 between the Government of Brazil and the United Nations Development Program (UNDP).

According to this agreement the Ministry of Transport of Brazil is the Government Cooperating Agency through "Empresa Brasileira de Planejamento de Transportes - GEIPOT," and the International Bank for Reconstruction and Development (IBRD) is the executing agency for UNDP.

GEIPOT is cooperating with the "Departamento Nacional de Estradas de Rodagem" (DNER) through its "Instituto de Pesquisas Rodoviárias" (IPR), and both have received grants from the "Instituto de Planejamento Econômico e Social" (IPEA) and from the "Secretaria de Cooperação Econômica e Técnica Internacional" (SUBIN), respectively. The other sponsors include the United Nations Development Program (UNDP) and the International Bank for Reconstruction and Development (IBRD). This sponsorship includes financial, physical and technological support.

Brazilian Staff

The Brazilian staff consists of professional, technical, clerical and administrative employees drawn from several government agencies and state highway departments in Brazil. They are being assembled and organized in GEIPOT offices in Brasilia under the leadership of Messrs. Jair Lage de Siqueira and Theodoro C. Lustosa. The members of the Brazilian staff are shown in Appendix 2.1

Expatriate Staff

The non-Brazilian project staff was formed by the Texas Research and Development Foundation (TRDF) under the leadership of Dr. W. R. Hudson, technical director of the Project. The team will include ten professionals drawn from all over the world, whose talents fill a special need on the Project. Staffing details are covered later in this chapter and in Appendix 2.2. The team serves under contract to the World Bank, the executing agency for the UDNP portion of the Project. World Bank contact representatives for the Project are Drs. Clell Harral and Per Fossberg.

Expert Working Group and Special Consultants

To provide advice to the Project in technical areas of special concern we established a working group of expert advisors in statistics, economics, pavement performance, pavement maintenance and rehabilitation, vehicle operating costs, and low-cost roads. This group has met twice and is expected to meet as needed once or twice annually throughout the Project. Special consultants including both individual members of the EWG and other experts will be retained as needed to provide assistance in any Project study area.

Cooperating International Agencies

A large group of research agencies around the world have expressed interest in this research project. At present the project staff is corresponding informally with this group to keep them apprised of the project research efforts. Of primary importance of course is the TRRL group who conducted the work in Kenya, led by Henry Hide and S. W. Abaynayaka. These two men have worked with the staff on preliminary visits to the project offices in November, 1975. There have been

several suggestions that this group be organized into an international project committee to correspond with the project staff and exchange publications, ideas and information relative to the research activity. Such a group could also be an excellent mechanism for early and rapid implementation of the results of the Project.

Project Coordination

An important part of a large complex research project such as this is coordinating it among all the agencies involved. In particular we will be dealing with existing highways which involve several Brazilian state highway departments (DER) and several districts of the federal highway department (DNER). Other government planning agencies in Brazilian and international agencies will be involved in the research and additional coordination will be required here also.

STRUCTURE OF THE PROJECT STAFF

The study approach and background dictate a staff organization which can function in three major research areas with several support functions. This basic organization was set forth by GEIPOT, UNDP and the World Bank in the original Project documents (Ref 13-15) and has been clarified further during the first 90 days of work on the project.

Three basic research units have been set up to deal functionally with the major areas of concern (figure 3).

1. Road user costs surveys group
2. Road user costs and traffic experiments group
3. Pavement performance and maintenance group

These research groups are assisted by five support functions

1. Project management and coordination group
2. Statistics and analysis group
3. Computer and data management group

4. Instrumentation and equipment group
5. Administrative support group

For each of these eight functions, leadership is shared by the expatriate staff and the Brazilian team except in the administrative support unit which is totally Brazilian and supplied by GEIPOT.

Professional Disciplines

In assembling the research team careful attention was given to the selection of the disciplines and skills required. Ten senior professional slots were specified in the UNDP expatriate budget. These ten persons and their Brazilian counterparts must be carefully selected. Additional supporting professional staff is available through the Brazilian staff group.

Disciplines deemed essential to the study are as follows:

- | | |
|--------------------------------------|---|
| 1. Technical Director | - Civil engineer or economist with transport research experience on large multidisciplinary projects. |
| 2. Asst Technical Director | - Same general qualifications as Director. |
| 3. Vehicle Operating Cost Specialist | - Transport experience preferably with operating companies. |
| 4. Statistician | - Training in experimental design. |
| 5. Pavement Engineer | - Research experience on pavement maintenance and performance. |
| 6. Traffic Engineer | - Experience on vehicle flow and traffic studies. |
| 7. Transport Economist | - Advanced degree with research experience. |
| 8. Computer Specialist | - Experience in data management and program adaptation. |
| 9. Instrumentation Engineer | - Electronic Engineer with both digital and mechanical experience. |

10. Analyst - Model Builder - Advanced degree in Statistics with training or experience in computer and/or Economics.

Each of these jobs is filled by two persons, an expatriate and Brazilian counterpart. In this way input is made from both sides of the team and leadership is provided to the Project supporting staff which is all Brazilian.

Supporting Staff

To support the senior staff and to carry out the detailed research program a group of younger professionals, technical assistants, computer programmers, secretaries and clerical assistants are available. It is expected that this support group will total approximately 150 persons at the maximum research effort.

Some of these personnel such as civil engineers, computer programmers, and soils technicians are available. Many of the personnel however must be hired and carefully trained to carry out their particular job on the project. This is particularly true of technicians to measure speed fuel consumption, and traffic flow, and the clerks required to carry out field surveys of vehicle operating costs and other user costs.

We feel that an important part of this research as outlined in objective 4 and as emphasized in the Project document signed by the Brazilian Government, the UNDP, and the World Bank is to develop a trained pool of research manpower which can continue this type of research work in Brazil in the future. All staffing efforts will be carried out with this in mind.

Functional Organization

As a result of the studies and requirements outlined above an organization has been set up as shown in Figure 3. The detailed organization chart is shown in Figure 4 as of March

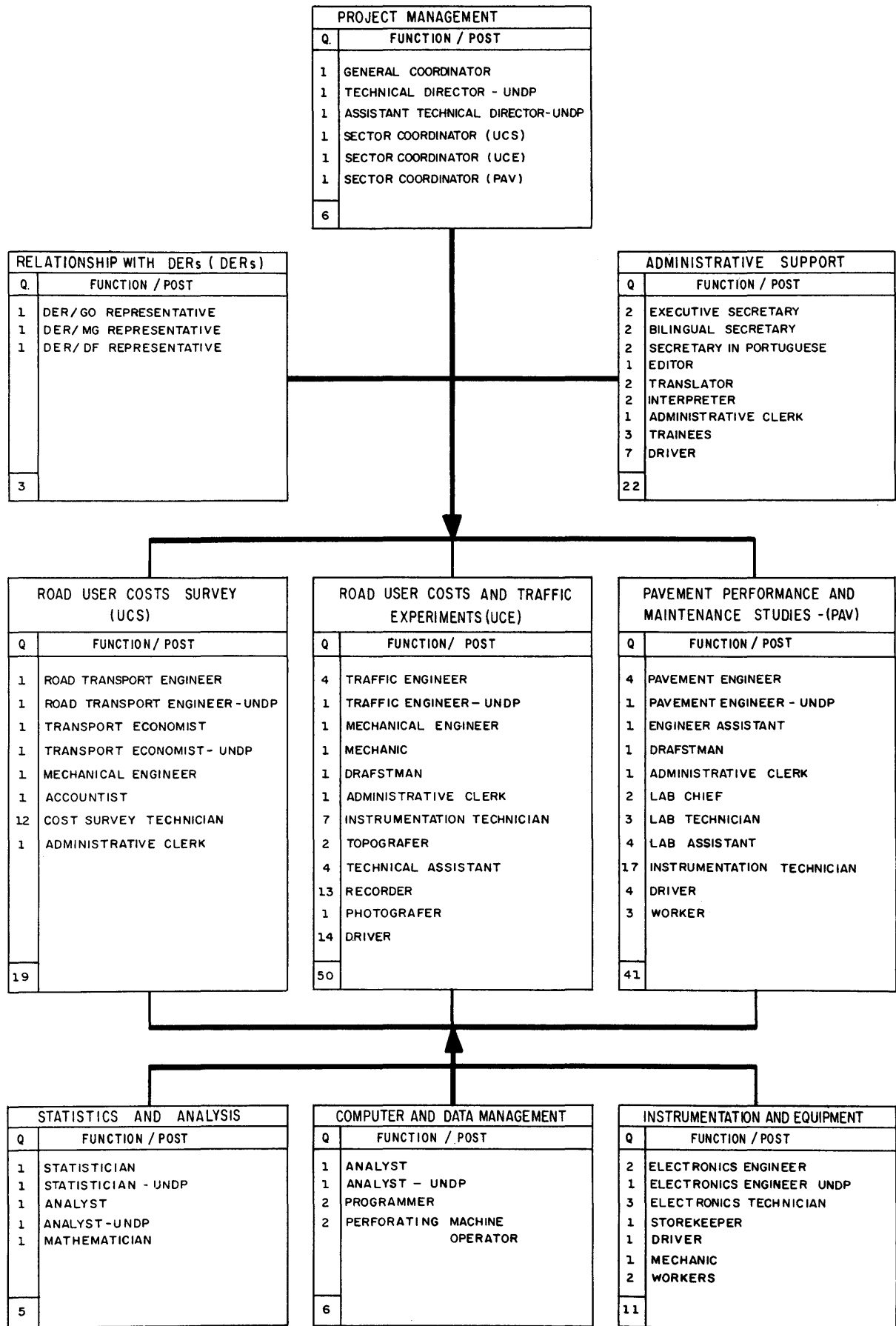


Figure 4 Detail Organization Chart Showing Number and Title of Personnel Required for Project

1976. This will of necessity be modified from time to time as the actual progress of the work dictates. A total of ten expatriate professionals, 18 Brazilian professionals and approximately 120 other technical staff and workers will be involved in the Project. The senior professionals are shown in Figure 5. Eight expatriates, 13 Brazilian professionals and 40 staff are on the job as of March 1976.

Road User Costs Surveys

This group will carry out one of the major functions of the Project. Their objective will be to develop realistic and analytically sound surveys for determining vehicle operating costs for all types of vehicles on a variety of Brazilian roads. They will analyse the resulting survey data for input into the overall project cost model. This work will be closely coordinated with the user costs experimental studies. The details of this work are discussed in Chapter 3.

Road User Costs and Traffic Experiments

This group will design, carry out and analyse experiments related to vehicle operating costs, speed and road characteristics. This will include operation and experimentation with the 9 test vehicles previously discussed. Tests will be conducted to determine parameters and costs for calibration and correlation with the user costs survey data, thus close coordination will be required with the user survey group. The details of this part of the Project are discussed in Chapter 4 of this report.

Pavement Performance and Maintenance Experiments

The pavement studies are aimed at determining the pavement design requirements and the construction costs for various traffic flow and load conditions. The related effects and

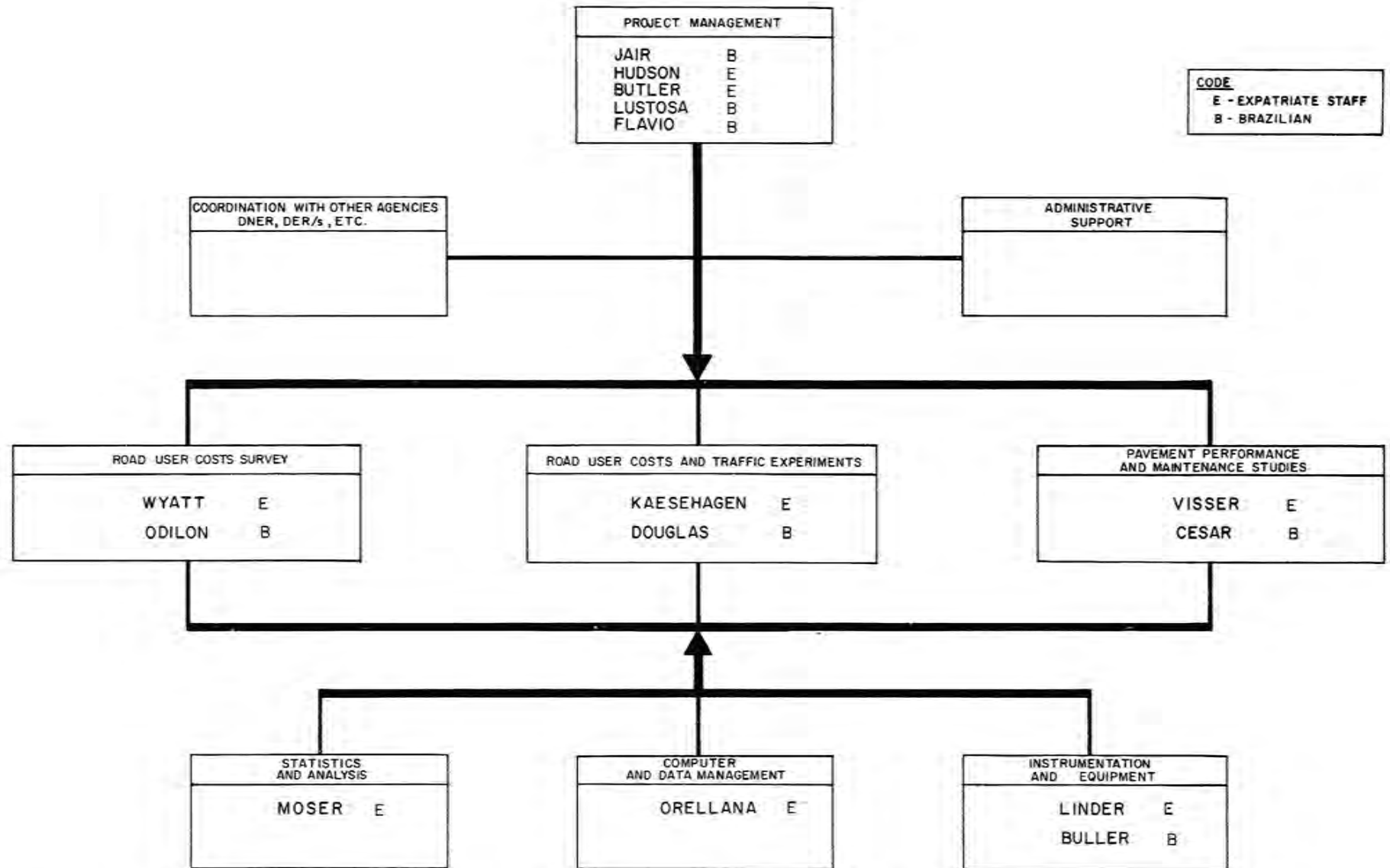


Figure 5 Senior Personnel Assignments for the Research Project

costs of maintenance and rehabilitation will also be studied to obtain relationships and inputs into the overall highway cost models. Instrumentation related to pavement measurements will also be used to measure pavement inputs for the user costs surveys and user cost experiments. The details of these pavement studies are presented in Chapter 5.

Support Functions

In chapter 6 are discussed the support functions, particularly instrumentation, computer, and statistics-analysis group. Little additional attention will be given to the management and administrative group which will be structured as required to keep the Project functioning effectively. The coordination group is made up of engineer representatives of the DNER and the state highway departments in the States of Minas Gerais, Goiás and the Federal District, the primary study area of the Project. These men will assist in coordination of the research with field units of their respective states.

GENERAL WORK PLAN

It is difficult to consolidate a specific work plan for a project of this size which does not become long and tedious. However, it is valuable for understanding of the overall Project to present a summary plan of the work to be accomplished. This gives a general impression of the major work items to be accomplished and their relationships to each other. Detailed work plans for the major studies are presented in their respective chapters with detailed time schedules and associated information. Table 1 presents a summary work plan which conveys the overall aspects of the work in a functional way. No time schedule is shown there but the overall time flow is indicated in the arrangement and statement of the work items.

A general work flow diagram is presented in Figure 6 to convey the approximate time phasing of the Project.

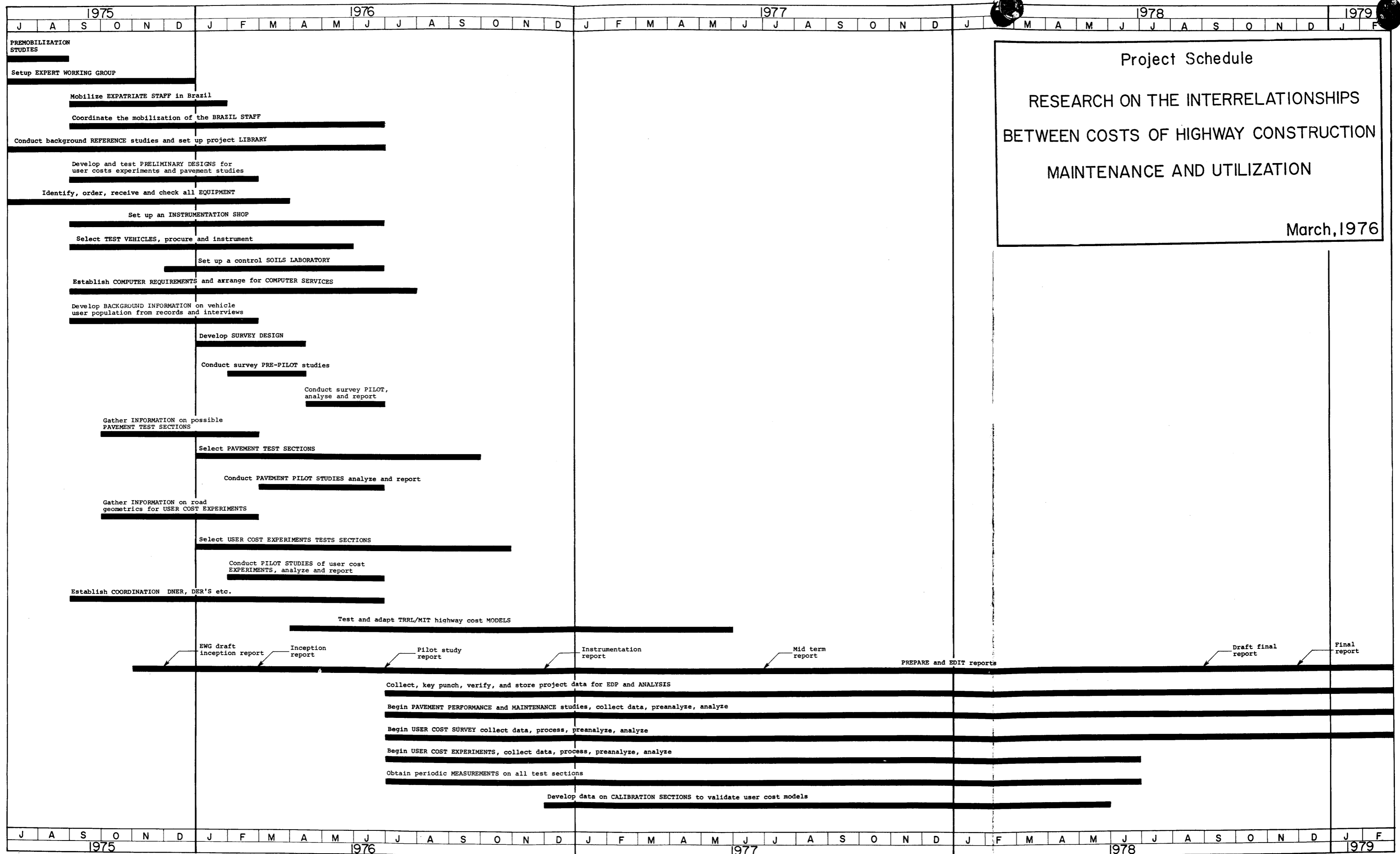


Figure 6 - General Project Work Flow Diagram and Schedule

TABLE 1 - SUMMARY WORK PLAN PROJECT ON INTERRELATIONSHIPS OF HIGHWAY COSTS

A - MANAGEMENT AND ADMINISTRATION GROUP

1. Mobilize expatriate staff in Brazil
2. Set up Expert Working Group and consultants
3. Mobilize Brazilian staff
4. Coordinate among the research and support groups
5. Provide liaison with sponsors and visitors
6. Administrate budgeting, hiring, purchasing, etc.
7. Prepare and publish reports
8. Coordinate Project in Brazil with transport agencies
9. Supervise final analysis, reporting and implementation

B - ROAD USER COSTS SURVEYS GROUP

1. Gather background information
 - a) On national vehicle population
 - b) On vehicle operators
 - c) From vehicle manufacturers
 - d) Develop good will and interest from vehicle-operators
2. Conduct pilot studies
 - a) Conduct pre-pilot study
 - b) Select pilot sample of vehicle operators, prepare forms and collect data
3. Set up final survey design
 - a) 300-500 vehicles from
 - 10-30 individuals
 - 10-30 companies
 - 1-3 visits each per month
 - 15-25 data itemsTotal 10-37,000 items per month
 - b) 100-300 separate routes
Measure roughness, geometry, traffic flow
 - c) Match vehicle to route
4. Coordinate with user costs experiments
5. Process data
 - a) Collect, check and compare
 - b) Key punch, verify, computer process
6. Analyse data
 - a) Pre-analyse data during the study
 - b) Make internal checks for accuracy

- c) Test Kenya - TRRL data
- d) Final analysis

7. Prepare reports as required

C - ROAD USER COSTS AND TRAFFIC EXPERIMENTS

1. Study available roads for test sections
2. Establish the preliminary experimental designs
3. Select 100-150 test sections on plans
4. Mark & survey test sections in the field
5. Conduct pilot studies to establish procedures
6. Analyse results and prepare report
7. Conduct speed studies (500-600,000 measurements)
8. Conduct acceleration tests (3-5,000 measurements)
9. Measure free speed (200 sites, 100,000 measurements)
10. Conduct fuel consumption study
 - a) Buy test vehicles
 - b) Design loads and arrange for loading/unloading equipment
 - c) Measure fuel consumption and speed (6-7,000 runs)
11. Conduct traffic surveys at 144 sites
12. Classify vehicles at 144 sites
13. Check and computer process all data
14. Pre-analyse data during testing
15. Test MIT-TRRL models
16. Conduct final analysis and build models
17. Prepare reports as required

D - PAVEMENT PERFORMANCE AND MAINTENANCE STUDIES GROUP

1. Gather information on existing roads (paved, gravel, and earth)
2. Determine maintenance policy and design standards
3. Design experiments (pavement, gravel & earth, maintenance overlays)
4. Conduct pilot studies, analyse and prepare report
5. Set up calibration course for roughness equipment
6. Assist with instrument calibration as needed
7. Set up control soils laboratory
8. Study road maintenance policies and procedures
9. Set up final experiment designs (150-250 sections)
10. Select and mark test sections in field
11. For each section define or measure
 - a) Material properties
 - b) Traffic data and loads
 - c) Roughness and serviceability
 - d) Deflections
 - e) Distress surveys
12. Process, check and pre-analyse all data
13. Test MIT and TRRL - Kenya Models

14. Conduct final analysis and build models
15. Prepare reports as required

E - STATISTICS AND ANALYSIS GROUP

1. Select statistical analysis programs for computer
2. Develop preliminary designs for all major experiments (about 20)
3. Test each design with dummy data
4. Set up pilot and pilot experimental designs
5. Advise total project on statistics
6. Assist with pre-analysis
7. Lead final analysis and model building
 - a) User costs surveys (4-8 studies)
 - b) User costs experiments (10-14 experiments)
 - c) Pavement performance and maintenance (6-10 experiments)

F - COMPUTER AND DATA PROCESSING GROUP

1. Study computer needs for the Project
2. Determine computer availability
3. Arrange for computer services and facilities
4. Hire and train personnel for data processing
5. Adapt computer statistics library for use
6. Adapt pavement analysis program for use
7. Set up data system for profilometer
8. Develop computer programs as required for project
9. Set up data management system for project
10. Check and process data for all project activities
11. Provide computer support for pre-analysis, analysis and model building

G - INSTRUMENTATION GROUP

1. Create an instrument shop and soils laboratory
2. Purchase all equipment listed
 - a) Surface dynamics road profilometer system
 - b) Mays road roughness meters (4 each)
 - c) Road geometric survey vehicles (2 each)
 - d) Dynamic scales
 - e) Static scales (2 each)
 - f) Traffic counters (25 manual and 10 automatic)
 - g) Fuel consumption meters (5 each)
 - h) Tachographs (20 each)
 - i) Vehicle speed meters (4 each)
 - j) Lapsed time Cameras (2 each)
 - k) Dynaflect deflection device
 - l) Benkelman deflection beams (6 each)
 - m) Rain gauges (10 each)

- n) Stop watches (several types - 50 total)
 - o) Resilient modulus repeated load test machine
 - p) Splitting tensile test machine
 - q) Soils laboratory
3. Set up, test, and calibrate all equipment
 4. Hire and train crews to operate equipment
 5. Repair and operate equipment during 3-year study
 6. Select and operate 8 dynamic scales weighing locations
 7. Develop and modify equipment as required
 8. Establish permanent instrumentation group for Brazil

BUDGET TABLE

Table 2 shows the distribution of resources planned for each of eight project activities. The man/months shown reflect the total commitments of GEIPOT, UNDP and DNER. The percent total budget is based on a four-to-one professional-support ratio.

TABLE 2 - BUDGET ALLOCATION FOR BRAZIL RESEARCH ON THE INTERRELATIONSHIP BETWEEN COST OF HIGHWAY CONSTRUCTION, MAINTENANCE AND UTILIZATION

Activity Description	Professional Man/Months	Support Man/Months	Equipment US Dollars	Percent Total Budget
Administrative Coordination	189	-	-	8
Administrative Services	-	729	-	8
Computer Services	72	132	-	5
Analysis Services	172	-	-	8
Instrumentation	99	245	-	7
User Costs Surveys	239	590	208,000	19
User Costs and Traffic Experiments	227	1,172	382,000	25
Pavement & Maintenance	197	897	292,000	20