CHAPTER F

MODEL DEVELOPMENT

7 MODEL DEVELOPMENT

In the Inception Report (Ref. 1), *Test and Adapt TRRL/MIT Highway Cost Models* was identified as one of the major activities of the project. Envisioned was the direct adaptation of relationships developed in the project to the latest version of the Highway Planning Model. In the last half of 1976, the TRRL Model was seriously studied and flow charted by the project staff. Planned was the testing of the construction subroutines using data from recently completed construction projects. These tests were designed to check the suitability of the Kenya construction routines in the Brazil environment.

Work with the Kenya model ceased early in 1977 when the World Bank announced that the TRRL model had been outdated by a new combined TRRL/MIT model entitled the Road Investment Analysis Model. A number of modifications were made to this new model by the Bank before it was made available to the project in mid 1977. With assistance from personnel of the World Bank, our Computer Group attempted to make operational the recent investment model in Brazil. Although the program has been compiled it has not yet been successfully run.

Thus far, we have made very little progress toward actually putting together a Brazil Road Investment Analysis Model (BRIAM). The reason is that we have assigned higher priority to other research activities. Each of the three study groups have marshalled considerable resources to generate information from which interrelationships on highway construction, maintenance and utilization are to be developed for Brazil. Without these relationships, the development of a planning model is meaningless.

However, the Brazilian Government has insisted that the final product of this research project be an operational Highway Investment Model that incorporates the relationships developed during the study period. Also it is mandatory that the model be programmed and documented so that it can be readily modified and updated by users in Brazil after the project is complete and the research team is dismantled. This means that all of the coding must be oriented to a Brazilian interpretation, use FORTRAN variable names that are based on the Portuguese language and have appropriate Portuguese comments to clarify each of the steps in the programming.

Given the need to produce an operational model before the termination of the project in November 1978, it becomes necessary to set forth at this time a work program to achieve this objective.

Before detailing a workplan, the research team reviewed anew the Requirements for a Brazil model and the current efforts of the research team to develop inputs for such a model. There was no commitment to adopt exactly any of the existing investment models, so it was considered within the prerogatives of the project staff to establish the shape and scope of the Investment Model to be developed for Brazil.

The model being developed for Brazil could be directed to any one of a number of planning levels. To illustrate, a subjective scale of sensitivity is shown in Figure 57 . At the top end of the scale we show network planning. At this level, the planner wants to establish the character of the links in a state or countrywide analysis. Considered are traffic patterns and benefits resulting when links are added to or improved within the existing network. The number of combinations requiring examination is large, and therefore only the most general evaluation of individual link costs are feasible.

Next we have the selections of alternates, from where it is possible to examine any number of possible paths and roadway standards between two points and select an alternative based on the optimization of a specified value function. In this situation, one expects to evaluate different length routes over different terrain. A moderate level of sophistication is warranted such as predicting earthwork as a function of maximum grades and contour line crossings.

At the project link analysis level, essentially one path is considered. The geometry may be optimized to minimize either construction or total transport costs over the link. One expects a reasonably good description of the terrain, and accuracy sufficient for feasibility estimates of cost.

Finally, a model can be developed to produce essentially final design details suitable for construction plans.

During the conceptualization of this study for the Inception Report, the TRRL Model was examined as a guide. The level of detail varied considerable within that model, but the construction subroutines were far more sophisticated than either the pavement performance maintenance routines or the user costs routines.

The major thrust of the Brazil study is to develop improved relationships on pavement performance and vehicle operation costs.

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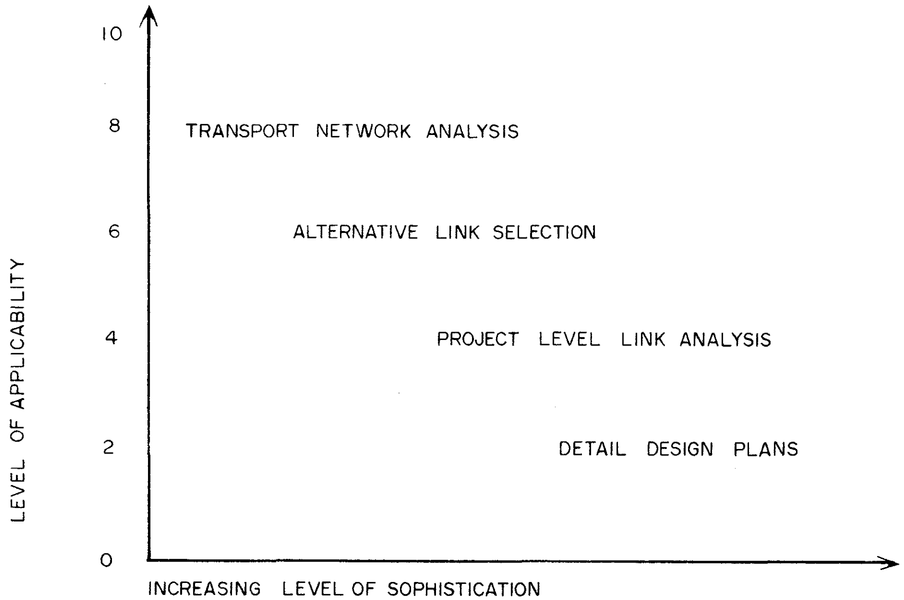

FIG. 57

RELATIONSHIP BETWEEN LEVELS OF APPLICABILITY AND SOPHISTICATION

Further, the study has been formulated so that it will be possible to develop routines with details comparable to those used in the TRRL construction subroutines.

Instead of a generalized rise-and-fall index for vertical geometry, plans were formulated to evaluate the influence of individual grades on vehicle operation cost. The same was true for horizontal curves. The entire inference space on each experiment was made as wide as possible. A detailed program was outlined to monitor the behavior of pavements receiving two extreme maintenance responses. The objective was to have information at hand to develop relationships which would improve on the sophistication of the maintenance and pavement performance subroutines and the vehicle operating cost routines of the TRRL model.

Therefore, it seemed clear that the output of this study would be relationships more detailed and sophisticated than those used in the TRRL pavement and user costs routines, and comparable in detail to the TRRL construction routines. On our planning level scale shown in Figure 57, the TRRL model would be rated at level 4.1. The model being envisioned for Brazil will be more detailed and so might receive a 3.8 rating.

The option to generalize the detailed relationships being developed is always available, and therefore they can be used in a broad level analysis at some future time. However, if the relationships were generalized now, it would not be possible to work back to the detail and sophistication feasible with the data being developed.

Therefore, the model to be developed will be limited to a link analysis where variations in design standard can be studied for a single corridor. The model will be designed to permit construction, maintence and user cost to be evaluated for alternate surface types, maintenance policies and construction and maintenance methods.

a *Approach*

As a result of the work being pursued it is expected that major modifications to some of the relationships used in the existing models will be made. Foremost will be the manner vehicle speeds and fuel consumption are to be handled. Instead of using a single predictor equation for a link or section, we propose to simulate the behavior of a vehicle on the study link and develop a continuous speed profile reflecting the impact of changes in vertical and horizontal alignment by vehicle class for given different levels of volume and various vehicle compositions.

Fuel consumption also will be computed in increments and accumulated for every change in speed or mode of operation defined by the speed profile.

The greater number of different classifications of vehicles over a range of loading being studied is expected to produce relationships covering a wider spectrum of the vehicle stream. Therefore,more classifications of vehicle types will be handled in the model than is currently possible.

A high priority item in this study is the development of information on the utilization rates of vehicles on different roadways. This will have an important impact on determining depreciation rates where almost no information has been developed historically on the influence of the road itself on vehicle utilization.

A completely new set of equations are expected to be developed for vehicle maintenance and repair, tire wear and oil consumption, based on the user cost surveys.

New and improved relationships, permitting the impact ov various maintenance levels on future pavement performance, are expected to be developed from our pavement performance and maintenance studies.

Modifying the existing World Bank Model to incorporate these new relationships being developed during the study was originally considered as an option. This model is made up of 88 different subroutines, and it was thought that three or four new subroutines could be developed to replace or interface with an equal number of the existing routines to make use of this model.

Closer examination showed that many of the input routines would require major modifications.

A construction routine that outputs a description of the roadway link in terms of each grade and horizontal curve is not part of the existing model, yet the project approach to developing vehicle speed and fuel consumption requires this detail. To handle volume and composition effect on traffic congestion, hourly distributions of traffic by vehicle class are required.

Finally, documentation on the Road Investment Analysis Model (RIAM) is currently incomplete, so it does not appear feasible to in corporate within the existing coding stream the new relationships deve loped from this study. Further, before the current model could be ado pted, it would need to be recoded in its entirety to satisfy the documentation requirements neeeded for Brazil. Therefore, we do not believe it is feasible to attempt to directly adopt RIAM within the remaining study frame. Rather, it has been decided that the more practi cal course will be to code a new model from scratch. The conceptual framework already exists from the first MIT study the subsequent TRRL model and the current version of RIAM. We propose to adopt the concepts used by TRRL for their construction subroutine, recode the program in FORTRAN with all variables and coments based on Portuguese.

Further we propose to adopt the input documentation format presently used for RIAM and use the current ouput formats of RIAM as a guideline. We expect to develop completely new modules for pavement and maintenance and user cost, based on the new relationships being developed.

b *Model Workplan and Schedule*

It is proposed that work begin on the development of the Brazil Roadway Investment Analysis Model (BRIAM) in November 1977,at which time the conceptualization phase would commence. The first task of this phase would be to:

- Establish the desired outputs of the final model;
- Establish those paramenters to be generated by the model;
- Define the necessary inputs to satisfay these needs.

Concurrently, the relationships between each of the program modules would be defined. The general structure of the module interfacing shown in Figure 58 would be detailed to establish common areas and transfer variables between modules. Also to be identified will be the required input and output requirements of each module. Defining these input and output requirements for each module provides the analyst with the necessary quidelines to develop each of the modules independently. This will permit a more detailed design of both the modules and BRIAM at an early stage and enable programming efforts to be carried out independent of actual development of useable relationships. Into this last category fit the input/output subroutines. Once the inputs are

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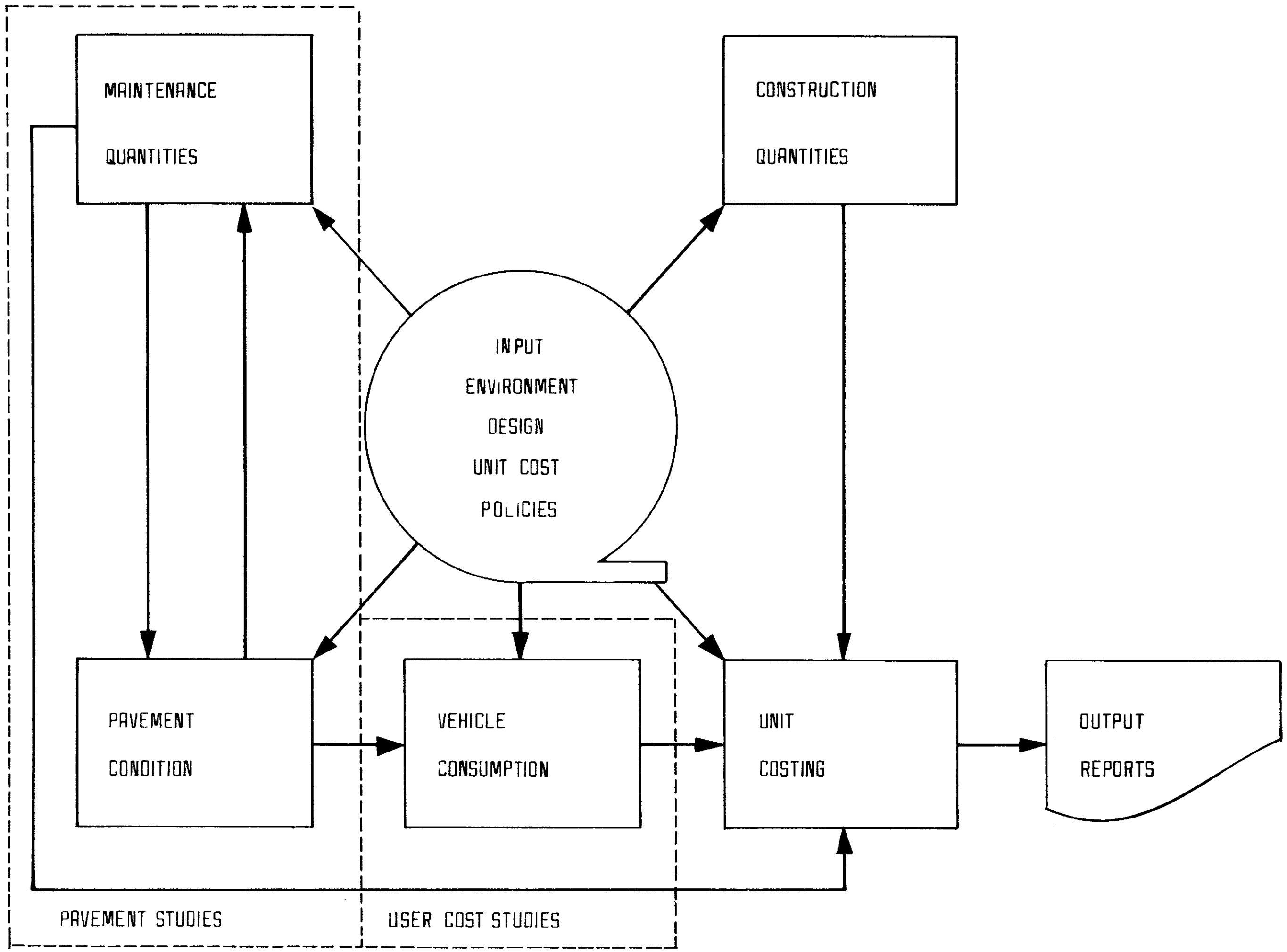

FIG. 58

CONCEPTUAL FRAMEWORK OF BRIAM SHOWING MODULE INTERFACING known, even if specifications must be made for the maximum input possible, appropriate subprograms can then be written to read data, to generate reports on input information, and to generate output reports.

The documentation in these first two phases will involve the writing of specifications on the I/O routines and of documentation of the overall model system.

Work on the construction module will begin as early as possible. The data requirements for the various construction routines, i.e., earthwork, drainage, etc., and for the Time and Fuel Algorithm (TAFA) will establish the inputs for the early phases. Detailed study of the TRRL model construction routines will be reinitiated to permit flow-charting of a modified routine to be used by BRIAM. Once a flow chart is available, programming will proceed as quickly as possible to permit more time for model validation.

Documentation will consist of program specifications, input-card layouts, and flow charts. The effort to be expended in this phase will be a major part of the total.

The vehicle-performance module consists of two major tasks: programming, debugging and testing of TAFA, and development of the routines to calculate user-cost quantities. TAFA is currently in the process of being defined. Before being programmed it will be reviewed and structured to fit the overall model requirements.

Once the maintenance activities to be included in the model are established, much of the programming for this module can start. The key element will be the establishment of workload, an input determined from a definition of maintenance levels interacting with the condition of the pavement in the pavement condition mudule. The establishment of pavement deterioration relationships is a very time-dependent study, and final relationships are not expected to be available until mid 1978.

Analysis work on unpaved roads will start in 1978, so the general structure of parts of this model will start as soon as these relationships are available. The conceptualization relating maintenance to pavement condition can begin earlier and will be developed in conjunction with the maintenance module.

The last phase, model synthesis, should not require extensive time, providing care is taken from the beginning to ensure that all of the modules are compatible. This will leave more time for sensitivity studies and final documentation. Providing each module is documented as it is developed, this final documentation should consist of consolidating existing documents into a user's manual, final model documen tation, and presentation of the results of the sensitivity studies an example applications of the model.

The Workplan with a Time Schedule for development of BRIAM is shown in Figure 59 .

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WORK PLAN AND SCHEDULE

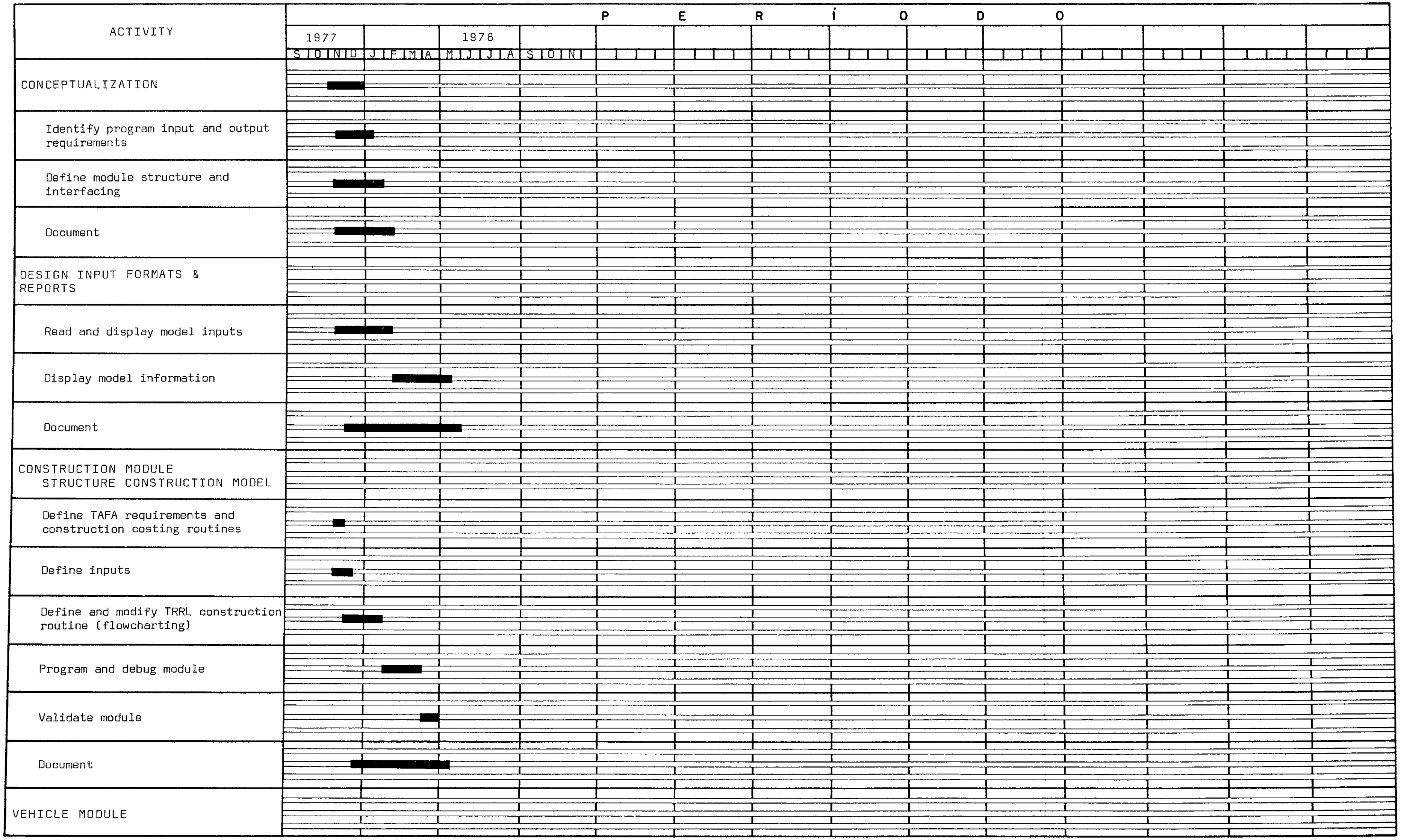

FIG. 59

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WORK PLAN AND SCHEDULE

ACTIVITY
Program and debug TAFA
Define vehicle operating costs relationships
Program and debug module
Document
MAINTENANCE MODULE
Define maintenance activities
Program and debug module
Document
PAVEMENT CONDITION MODULE
Define pavement deterioration relationships
Relate pavement condition to maintenance workload
Program and debug module
Document
MODEL SYNTHESIS
Integrate modules
Make sensitivity studies

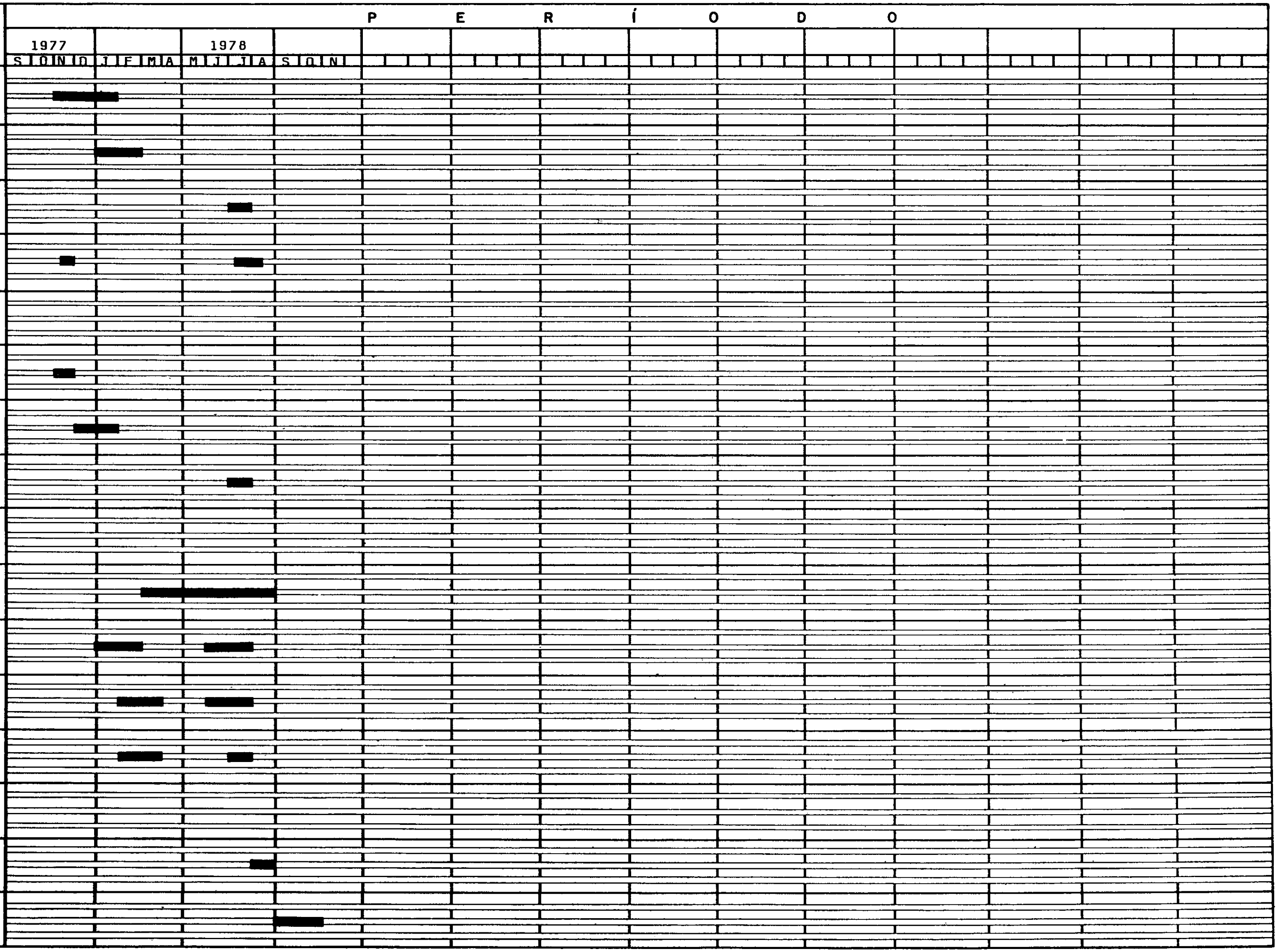

FIG. 59 (CONT.)

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WORK PLAN AND SCHEDULE

ACTIVITY	PERÍODO														
	1977								1978						
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Develop example application of model															
Document															

FIG. 59 (CONT.)