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AN INTERNATIONAL RESOURCE SHARING SYSTEM FOR CONSTRUCTION PROGRAMS IN THE SOUTH PACIFIC COMMISSION AREA

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF FINE ARTS

IN ARCHITECTURE

SEPTEMBER 1970

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(Chairman)

1. PREFACE

When working in the tropical developing areas, one becomes very involved with the problems of getting the most for the least. These are problems of resource management.

In areas where needs are great and resources are specialised and of a limited nature, the situation demands maximum efficiency in the utilization of these resources to gain maximum benefit, with least resource absorption into the management process. That is, the greatest spiritual and material benefit for the Island People and least resource dissipation into the mechanism of utilization.

In the construction field, including building programming, design and construction, similar problems are encountered in areas of similar needs and resources. The South Pacific Commission area is made up of islands with these similarities. Because of the isolation of the South Pacific area and the many separate administrative groups, the solutions to developmental problems also tend to be isolated. The potential benefit from the effect of coordination and sharing is not utilized.

Where similarities exist in conditions for development, great benefit is likely to accrue from sharing resources. In recognition of this fact the South Pacific Commission was formed in 1947 and through the role of advisor and researcher, has assisted member Governments in "improving the conditions of life of the island people." (South Pacific Report 1967 - 1968)

As seen in the islands the work has made some contribution to development efficiency, however the degree of this role may be realistically questioned. Would individual island groups benefit from greater coordination, cooperation and resource sharing? Would the benefit be of sufficiently direct advantage to make financial contributions proportionately rewarding? Would it be more advantageous to have some operations politically independant?

Because of the existence of the South Pacific Commission (see Appendix 1) and some experience working in the area, it was decided to make the study relevant to the South Pacific Commission area as a whole.

The limitations of isolation are experienced when working in the islands, particularly in certain aspects of the construction activity. It is however, obvious that problems of one area are similar to problems of adjacent areas and that solutions may be similarly related.

In studying the situation holistically, it was clear that the typical nature of the problems being studied was not unique to the construction activity, but was relevant to all aspects of physical development. In recognition of these implications it became practical to restrict the study to the housing sector of construction since it is the most pressing problem and, in terms of process operations, is representative of other sectors of the construction field.

Particular though this study is, the implications may be of a more general nature.

2. ABSTRACT

The purpose of the thesis is to prove the hypothesis that a resource sharing system for construction programs in the South Pacific Commission area could deal more effectively with the existing constructional problems to the mutual benefit of the island peoples and the administrations involved in the area.
The study was carried out by analyzing the existing construction program operations covering building programming, financing, design, costing, construction and evaluation. A computer simulation model (CONPROG) was developed to represent one typical sector of construction. The model simulates the housing activity in twelve of the island territories over a twenty year period.
Accurate data of the type required was not available in all cases --data used was obtained from the South Pacific Commission, the Pacific Library Collection at the University of Hawaii, or was derived from personal experience in the area. Since the comparative potential benefit of sharing was the measure of performance, realistic simulation of the processes involved was relatively more important at this stage than accuracy in the statistical data.
Alternate models were developed to represent different intensive and extensive sharing strategies.
Extensive sharing included:
1. CONPROB: Sharing independently within six similar administrative areas.
2. CONPROC: Sharing in six similar administrative areas with coordination through the South Pacific Commission.
3. CONPROD: Complete sharing throughout all South Pacific Commission areas.
Intensive sharing strategies included sharing individual process stages within the above framework--these include programming, financing, designing, construction and evaluation.

Comparative sensitivity tests were carried out on the four basic models to determine which stages within the processes produce greatest potential benefit from sharing. These tests were directly related to practical implementation considerations.

Analysis of the results proved the hypothesis to be valid.

Further analysis of results evolved a set of recommendations for incremental implementation of a realistic strategy with the aim of increasing benefits to the people utilizing existing resources.

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4. INTRODUCTION

a. Hypotheses

1. That a resource sharing system for construction programs in the South Pacific Commission area could more effectively deal with the existing constructional problems, to the mutual benefit of the island peoples and the administrations involved in the area.
2. That construction programs are one representative component in the total development process of the South Pacific area, and that principles established for this subsystem may be applicable to other components of the developmental process.

b. Aims

1. To study the construction program component of the total development process of the South Pacific Commission Area.
2. To model the housing sub-system of this component to enable evaluation of alternate resource sharing strategies.
3. To determine recommendations that could be beneficial as a guide for future planning, firstly in the construction field and secondly in the total development process.

c. Terms, Concepts and Scope

Terms

Resource: A resource is a factor utilized in the productive process. In this thesis it includes manpower, finance, knowledge, experience, organization, facilities and natural resources.

Sharing: Sharing is a collaborative process of mutual assistance.

System: A system can be defined as a complex of interacting elements (von Bertalanaffy. 20)
A system is a set of components that interact to accomplish a set of goals.
A system is an arbitrarily demarcated section of the real world which has some common functional connections. (von Bertalanaffy. 20)

Construction Programs: Construction programs are the total activity of construction. It includes the processes of programming, design, bidding and actual construction.

Model : Aconceptual tool describing an observed phenomenon in a consistant and accurate manner. The representation in this case is a computer model.

Model Operation : The dynamic functioning of a model.

Model Construction : The process of modeling, testing and evaluating a process or system.

Holistic: Consideration of the whole system rather than its individual components.

Simulation : A technique utilizing dynamic models to represent a phenomenon of the real world.

Benefit : To accrue advantage or gain improvement from a particular sharing strategy.

Concepts and Scope

The South Pacific Commission area is regarded as a total dynamic system. The system environment includes many sets of interrelated components each interactive within a subsystem and within the total system.

The South Pacific Commission area system may be analysed in many ways, geographic analysis would reveal an easily defined area of island components with similar attributes. When analysed as an economic system, vital links from the artificially defined administration area groupings to the mother country, would make the system relevant in many parts of the world. As an ethnic system three main overlapping areas of island people would be the major components. The area could also be analysed as a social system, a political system or an ecosystem.

This thesis studies one segment of the total system of physical development, the segment of construction programs. Within this subsystem the computer model simulates the housing component only. Other components in the construction subsystem include educational and health facilities, commercial, industrial, administrative and public amenities. The housing component has been selected because it is generally regarded as the most vital need of the construction activity, and also because it is generally representative of the other components.

The study covers twelve of the South Pacific Commission territories, namely:

1. American Samoa
2. British Solomon Islands Protectorate
3. Cook Islands
4. Fiji Islands
5. Gilbert and Ellice Islands Colony
6. New Caledonia
7. French Polynesia
8. New Hebrides
9. Territory of Papua and New Guinea

10. Kingdom of Tonga

11. Trust Territory of Micronesia

12. Western Samoa

After researching the operations of the other South Pacific Commission areas they were excluded from the study for the following reasons :

1. Guam. The majority of the population is of military origin and the economy is similarly based. The situation is unique and not representative of the other island territories.

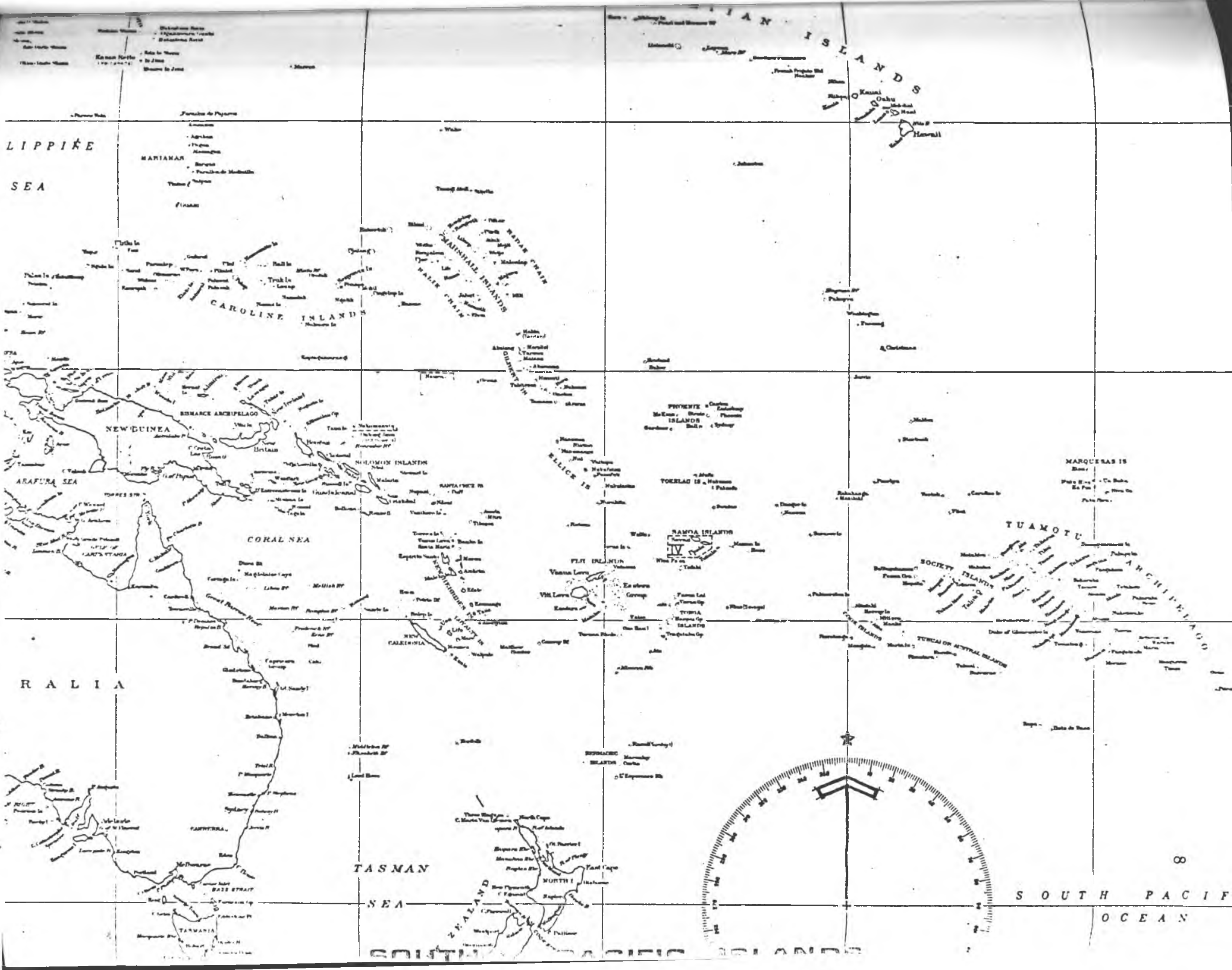
2. Niue, Norfolk Island and Pitcairn Island. These islands have relatively small populations--an assumption could be made that while not affecting seriously the study, their inclusion would increase the effectiveness of the hypothesis and the benefit to the small areas would be great.

3. Nauru. Very small area and population. The island is comparatively wealthy and able to meet their own needs through economic stability dependant on natural resources.

4. Tokelau and Wallis and Futuna Islands. Avery small population and island area. A fair proportion of the population leave to work in other territories of the Pacific and support the economy and needs from exterior sources--the majority of housing is indigenous.

In the territories considered, very limited data are available. The data that are available is for the capital town of the particular territory concerned. Since the majority of the housing demand results from an increase in the town population, the data from these capital towns are used. Many smaller towns and centers do exist throughout these territories, the situation in these could be assumed to be similar and their inclusion would serve to increase the potential of resource sharing.

From experience and knowledge of several territories in the study, a representative general system of construction operation has been formulated. It is assumed that this process is similar if not exactly the same, in other areas. It is a basic premise that although this study concerns itself with the housing construction component of the general construction subsystem which operates within the total system of development, the findings will be directly related to the other components of the construction programs and will also be applicable to other subsystems within the system of physical development in the South Pacific Commission area.



IAN ISLANDS
Kauai
Oahu
Hawaii
SEA
MARIANAS
CAROLINE ISLANDS
MARSHALL ISLANDS
RALIK CHAIN
RATAK CHAIN
GILBERT IS
BISMARCK ARCHIPELAGO
NEW GUINEA
Britain
SOLOMON ISLANDS
Guadalcanal
ARAFURA SEA
CORAL SEA
NEW HEBRIDES
NEW CALEDONIA
ELLICE IS
PHOENIX ISLANDS
TOKELAU IS
SAMOA ISLANDS
FIJI ISLANDS
Vanua Levu
Viti Levu
TONGA ISLANDS
COOK ISLANDS
SOCIETY ISLANDS
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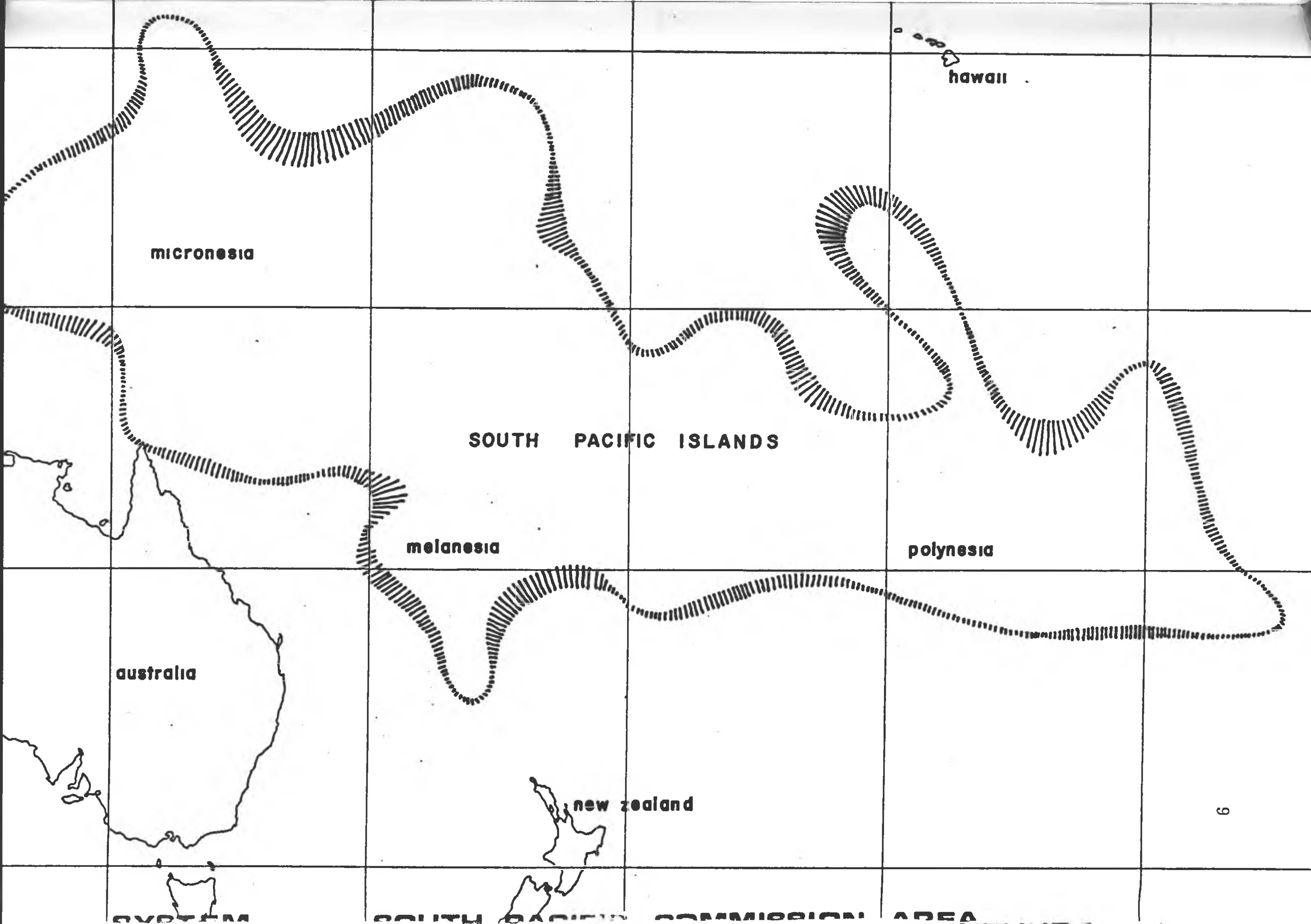
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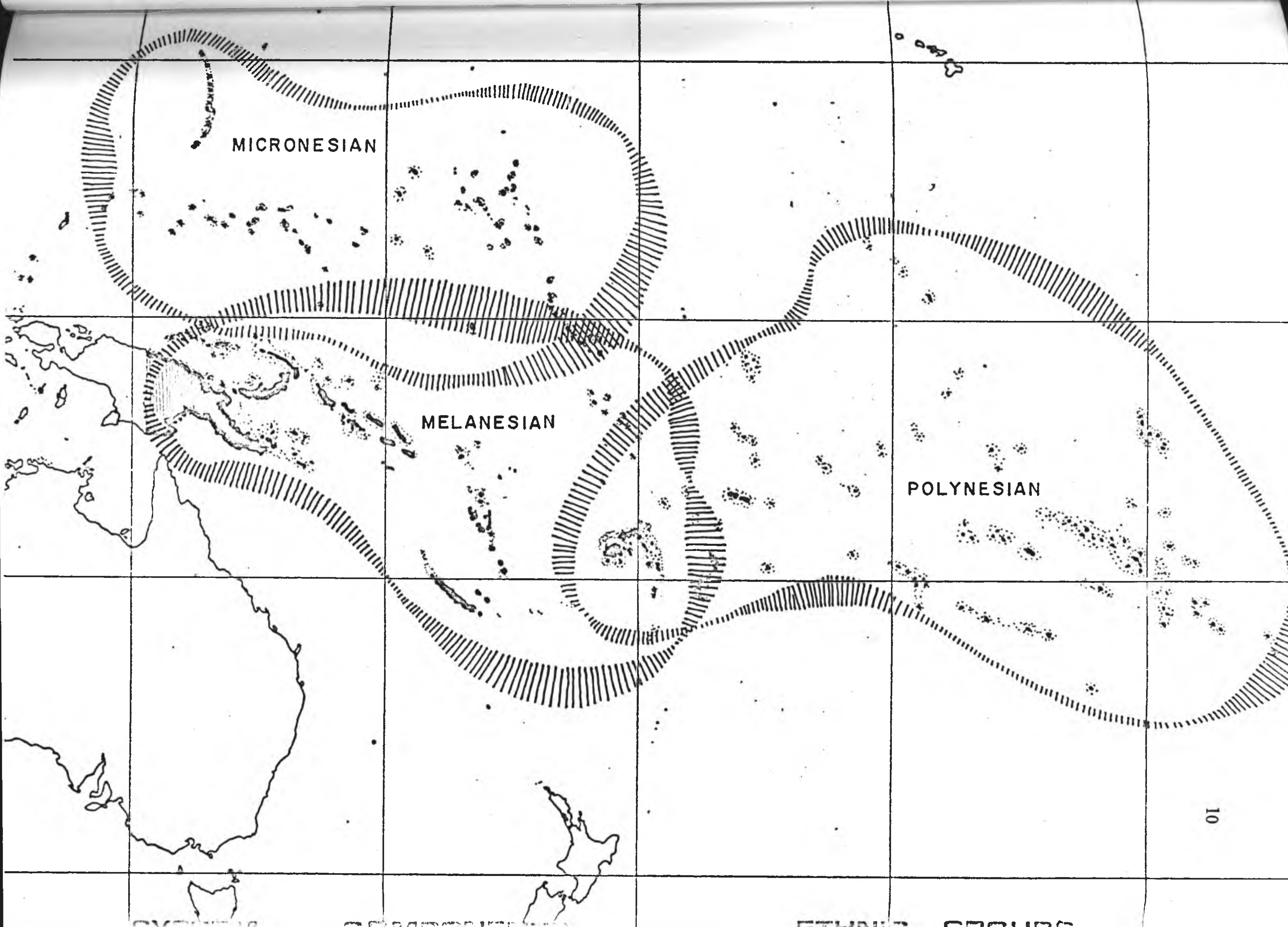
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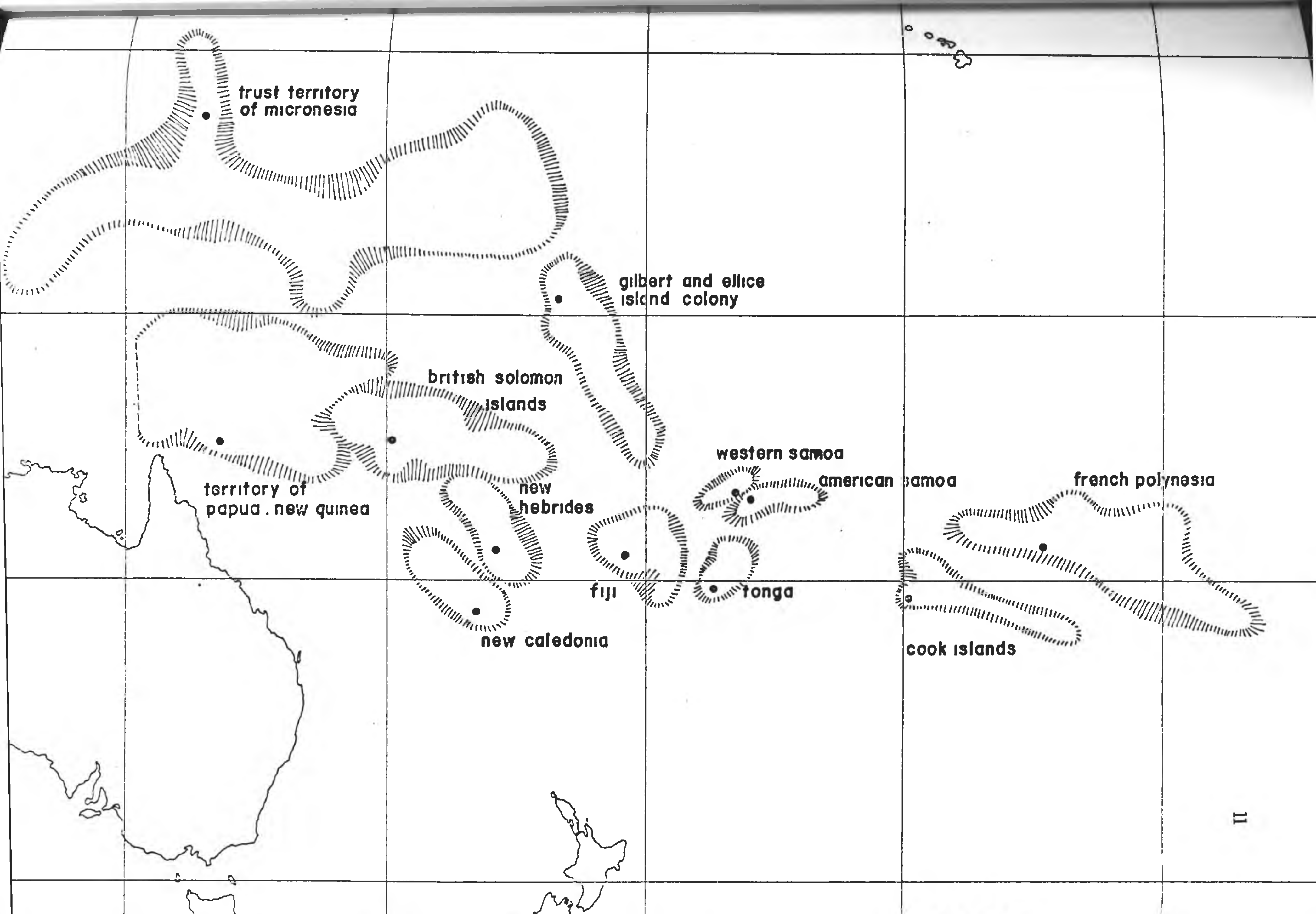
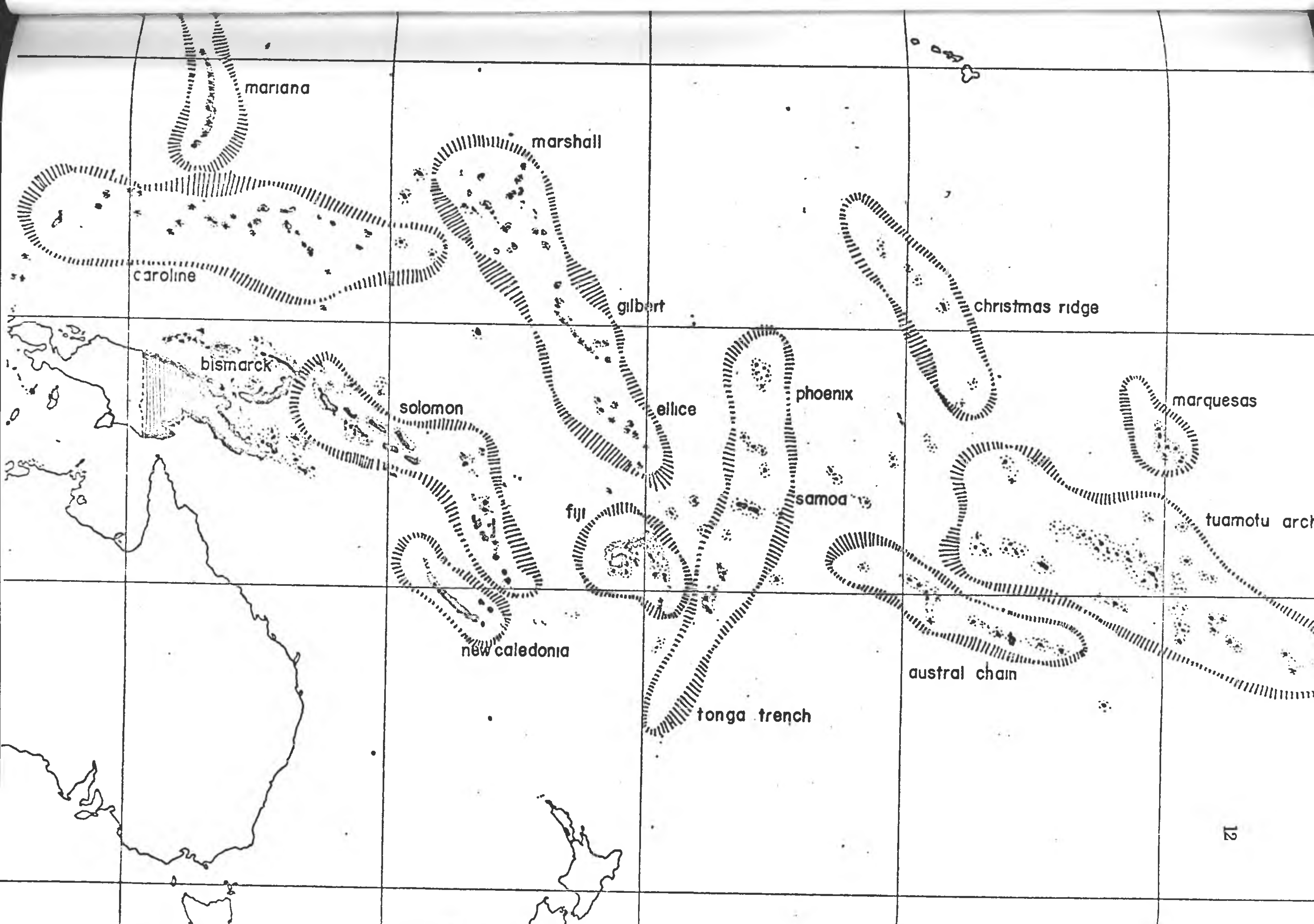


SYSTEM COMPONENTS — ADMINISTRATIVE ISLAND GROUPS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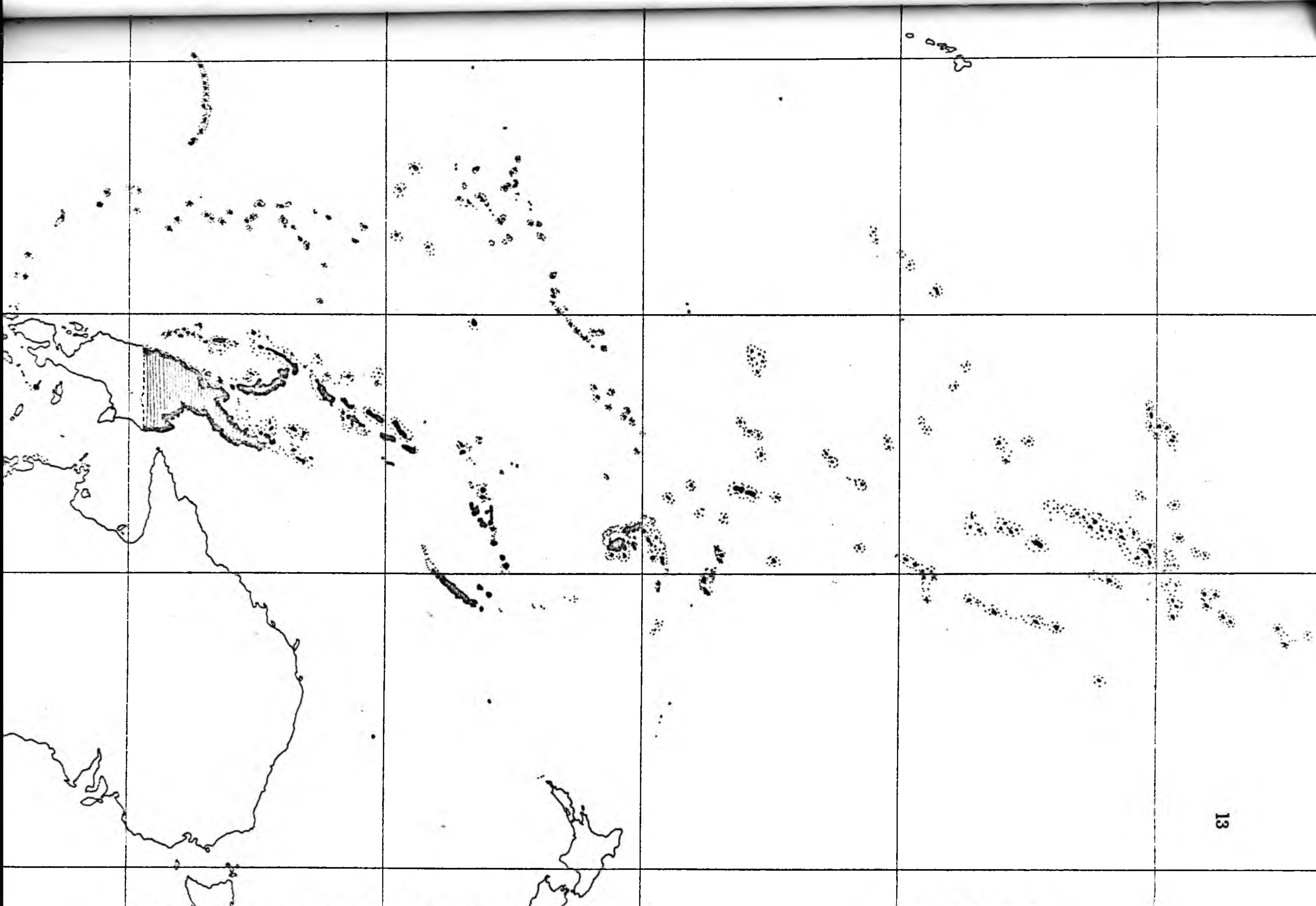
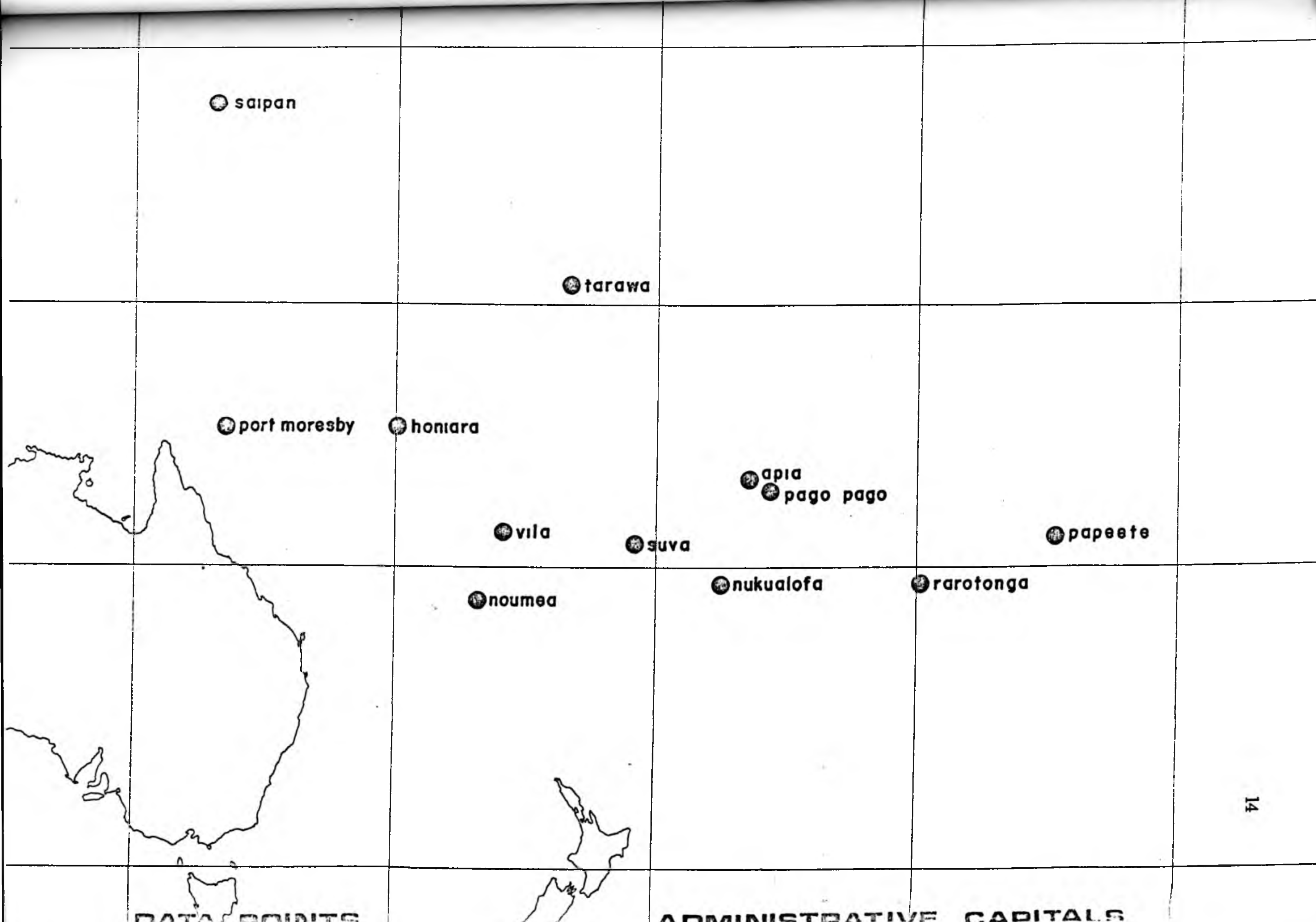


SYSTEM SUBCOMPONENTS ISLANDS


saipan
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pago pago
vila
suva
papeete
nukualofa
rarotonga
noumea
DATA POINTS
ADMINISTRATIVE CAPITALS

d. Planning Systems and Systems Planning

Planning has been defined in many ways.

United States Federal definitions of urban planning from the Executive Office of the President (1967) include :

Development Planning : Planning covering the whole or components of the physical, economic, or human resources development of a geographical area.

Comprehensive Development Planning : The process of (1) assessing the needs and resources of an area; (2) formulating goals, objectives, policies and standards to guide its long range physical economic and human resource development; and (3) preparing plans and programs therefore which (a) identify alternate courses of action and the spatial and functional relationships among the activities to be carried out thereunder, (b) specify the appropriate relevant factors affecting the achievement of the desired development of the area, and (d) provide an overall framework and guide for the preparation of functional and project development plans.

Ecological studies regard planning as the economization of scarce resources.

Business management sees planning being a multistage decision making concern which studies the "decision maker who chooses among alternative courses of action in order to reach certain first stage goals, which lead to other stage objectives." (Churchman. 7)

Practically speaking "planning is what planning does." (Shelly Mark. Honolulu)

From a spatial orientation planning is concerned with the ordering of human activity in space.

It can be seen that planning has many notions, ideas, implications, meanings, consequences and involvement to different people and their orientations.

In order to facilitate communication about such a broad field it is necessary to establish functional definitions of the total field. Because these definitions are attempting to order an already existing state of affairs, they consequently will also be broad in scope.

In addition to the numerous varying, yet specifically appropriate planning definitions, there are also numerous planning problems and planning environments, as well as many ways of describing and defining them.

This section deals with a particular set of planning approaches, it deals with those related to systems planning. The systems planning approach can imply computer utilization, this is often the case, but it is not a necessary prerequisite.

It is important to describe this study in terms of planning approaches in general, and this section is developed with the following intentions :

1. To describe the systems planning approach used in this study.
2. To relate this approach to the general field of problem solving techniques.
3. To systematically show how the problem and its environment interact to determine the planning approach.
4. To facilitate description of the problem and its environment.
5. To provide an adaptable basis for planning in different situations, because international cooperation would be facilitated by a generally applicable approach to problem solving.
6. To provide a conceptual framework to which the study components can relate.

i. Planning Systems

The Planning System is the overall functional consideration of planning, it includes all components of the planning problem and the planning environment that are responsive to change in any other component.

Planning problems exist in a planning environment and the interrelationships of the attributes of these indicate a particular appropriate planning approach. It has been pointed out (Bolan. a) that for each planning problem there exists a set of circumstances which make one course of action or one approach more applicable. This leads to the importance of defining the problem and its context in relation to each other. The attributes of various planning approaches can be linked to this relationship and an appropriate approach adopted. Planning is involved with the adaption of the problem or its environment to produce an harmonious relationship, that is one with least friction and maximum complementarity in the interaction and the least disruption to either the problem or the problem environment.

The level of friction, complementarity and disruption are performance measures capable of being valued in various quantitative and qualitative ways. Measurement is important in terms of the performance or utility values, and for predicting the effect on the whole system. Quantitative analysis is used in planning systems as a measure of standards, as an evaluation process and in terms of system operation.

Because of the difficulty in quantifying many of the components in the planning system, it is often necessary to use qualification as the value criteria. In this case the planning approach becomes more probablistic rather than deterministic because it is utilizing relative rather than absolute measures. The determination of the planning approach is never a defined clear cut operation, however when dealing in qualitative system variables, it may be necessary to apply a number of selected appropriate planning approaches, evaluate their performance and conclusions, thereby evolving more meaningful problem solving techniques. Implementation factors and decision making procedures often cause most friction and disruption because of the high content of the qualitative influences, for example in fact there is rarely one "right" choice in decision making, rather there exists an hierarchy of choices, some more right than others.

The choice of appropriate planning approaches is a vital link in the problem solving process since the actual approach may imply certain predictable conclusions irrespective of the system attributes. That is the application of different approaches to the same problem may produce different solutions. Using a multiple approach method would also largely alleviate this potentially dangerous situation.

As mentioned previously, and because of the diverse and complex problems that planning is required to deal with, there will rarely be one most appropriate approach--more realistically there will be a series of more appropriate approaches relative to those more inappropriate. The selection criteria then, becomes one to obtain the best qualities of each and to dispense worst qualities of each approach i.e. a comparative selection of appropriateness at various stages in the planning process.

A planning problem exists through the perception of wants, desires and needs, both explicit and implicit. Having too much of the wrong thing or not enough of the right thing, are both problem situations. Planning attempts to resolve this situation, but it goes further in its theory in that it attempts to define what is the "right" thing and the "wrong" thing for a particular situation and also how much is wanted and how much is needed. These considerations also involve quantitative and qualitative evaluation.

The planning environment is the situation in which and around which the planning problem exists.

It includes all relevant internal and external influences acting on and affecting the planning system.

The planning environment is often random and seemingly unpredictable but the planning approach must consider and adjust to the existance of this context, in which all plans must eventually be implemented. Comprehension and understanding of the relation between the planning approach, implementation, environment and the decision making process is important to the viability of any planning attempt. It determines the degree of realism and practicality in any planning attempt.

The planning approach is the methodology or technique used to relate the planning problem to the planning environment with the aim of establishing a compromise solution by adapting and changing one to the other. In this adaptation process we usually only consider changing one component (the problem) to fit the other (the environment) this is generally the easiest way because of the inertia and large scale of the planning problem environments. It is important to realize that it is possible to produce a solution by mutual adaptation--we could require changes in the planning problem environments as a necessary requisite to supplement a certain planning solution. For example the problem of delays and crowding while commuting daily to the central business district of a city, may be solved by the introduction of a rapid transit system which requires that at least a certain percentage of commuters use the system. This requirement implies that a change in the habits, voluntary or involuntary, of some commuters will be a prerequisite to the solution of the problem. Other adaptations of the problem environment may also be implicitly or explicitly involved in the planning solution.

The planning process is the activity of a planning system and must be evaluated in terms of its measure of performance and its advantages and disadvantages to the operations and functions of the system within its own environment.

In organizing planning approaches in a systematic manner, the actual activity of planning must be studied in its component parts and the parts interconnections. These activities relate to the methodology or technique of the approach. Planning is concerned with a sequential process of decision making by the planner and others.

The planning process is an interactive, cyclic activity concerned with decision making relative to various alternate actions, to exogenous and endogenous criteria and in the overall direction of established goals and objectives. The process may be regarded as the problem identification and analysis, solution synthesis and implementation phases and a recurring evaluation stage.

Planning then is a process and an activity. It is closely tied in its relationship. Both process and activity are dynamic operations, they are changing in time and space. Process refers to the developmental stage of problem solving techniques, and activity relates to problem recognition, strategies, techniques and tactics within the planning environment.

Planning approaches need to be simultaneously precise, accurate and general in their application. We need to approach problems holistically, scientifically, logically and well informed.

In addition to the process and activity functions of the planning process, the considerations of time and space or scale are also relevant in the determination of an appropriate approach.

For a particular study or problem, there exists an optimal time period, and optimum space scale for which planning should be carried out. These are determined by the particular attributes of the problem and its environment, but should be realistic to the purpose of the planning. They must be inclusive enough to cover all meaningful information of relevance, yet defined enough to be practical and not to produce theory only.

The environmental characteristics or attributes effect in varying proportions, the characteristics of the planning approach, i.e. process, activity, time and space.

ii. Systems Planning

A system is a set of entities or objects with interacting relationships between the objects and their attributes. The universe is a system, the atom is a system. In between exist an hierarchy of systems within systems. In order to differentiate one system from within the hierarcy, an interface must be established. This interface defines the internal and the external environment of the system. Each system is artificially isolated by the interface. The real situation is an interactive whole with external influences on the system, and also internal components, both shared and unique. The flows through the interface, between internal and external environments, may also be regarded as assumptions, influences or input/output of the system--their existance and importance should be noted.

The urban environment, for example, may be regarded as an activity system, organized around establishments, and carried on through linkages, by its demands for space and location. The urban spatial pattern may be stratified into social, physical, economic and political patterns.

Systems planning is a planning system within the preceeding analysis. It has unique identifying characteristics which serve to define the approach as a particular broadly based planning system.

The systems approach is a way of thinking of the whole system as an interactive set of components.

Systems analysis is a way of studying a complex system by identifying its components and their interactions.

Systems analysis is an attempt to formulate a system, utilizing the most appropriate components and linkages, to achieve a certain performance in the achievement of goals.

Systems planning is the application of systems analysis and systems design to the planning approach. The approach attempts to analyse the cause/effect relationships from a view of their relation to the total system structure. Plans are formulated by defining the aims of the system and designing to produce a set of components that interact to accomplish these goals. The systems planning approach can incorporate a multiple approach utilizing other planning tools, these tools can be an aid at various appropriate stages in the planning process.

Systems planning is important because of its holistic view which is able to include and study possible relationships within the complex situations that invariably occur in planning problems. The approach itself is also a great aid for the designer in the comprehension and understanding of these complex situations. This understanding in some depth is a prerequisite for any design or planning approach. Systems thinking facilitates a more meaningful understanding of the planning phenomena, their causes and effects, costs and benefits, by analysis methods that include quantification and modeling. The analysis facilitates description, prescription and prediction which clarifies the consequences of alternate possible actions. The clarification allows more informed and effective decision making which has the potential to produce practical planning solutions. The approach usually includes the quantifyable components like economics and physical qualities, however it need not exclude the more qualitative aspects of social values, life quality, politics etc. For example interest groups can be identified, defined and their relationships established within the planning environment.

Performance in the operation of the system can also be measured in terms of these quantifyable and qualifyable variables like economic stability, physical input, social output, political conflicts and satisfaction of physical needs. The relative importance of each of these measures is directly related to the goals and objectives of the whole system.

In order to create a viable identification for the systems planning approaches we can examine the attributes of systems, then relate the planning approaches to these qualities.

System Definition

Systems may be defined by their external and internal attributes.

System attributes are the characteristics or qualities of a system.

Internal attributes are the characteristics or qualities of the system components.

and their interactions.

External attributes are the characteristics or qualities of the system and its relation to the system environment.

System attributes

(a) Stability or instability.

(b) System objectives and goals. Goals being short term attainable states of the system defined to exist at a point in time. Objectives are the long term direction or guidance for the total system function, not necessarily attainable at a particular point in time.

(c) System environment, its constraints, influences and input/output relationship.

(d) The system may be open or closed, an open system accepts input from the system environment, processes it and distributes it as output. A closed system is a totally internal process which may attain equilibrium.

(e) Adaptability and flexibility relate to the degree of the system's capacity to adapt to changes in the system, its components or the system environment.

(f) Dynamic systems change over time and/or space. Static systems involve no structural or functional change.

(g) Systems may be stable or unstable.

(h) Homeostatic systems contain mechanisms for self regulation, self adjustment and control of input and output in terms of quantity and quality. It includes the ability to adjust the process, components or interactions to control the directions and goals of the system.

(i) Systems may be simple or complex.

(j) A cybernetic system has feedback mechanisms which relate the rate and directions of changes within the system to cause response in other components.

(k) System growth is the ability to multiply and produce new systems, or to generate growth within the system. Systems may also decline.

These attributes describe the characteristics of a particular system by their existance as qualities in a unique combination. Through analysis of their attributes, an appropriate planning approach can be selected to cope with the particular problem. System design is also formulated from these attributes which act as design criteria.

(iii) Conceptual Systems Planning Framework

The system planning approach utilizes the general systems attributes and their interrelations by defining the planning problem and the planning environment in these terms. This establishes the common links and control nodes through which the most effective planning can be actuated.

As mentioned previously, the most important thing about systems planning is that it is holistic in its approach, this implies that all relevant considerations can be successfully included into its field. Thus systems, and their attributes, form their own framework within which many more traditional, and also the newer innovative approaches to planning can be classified. These planning approaches are then regarded more as tools for analysis or design of the system within the overall systems approach, each tool being utilized as and where appropriate in the planning process and activity.

All planning problems can be approached with the systems way of thinking and so the procedure becomes one of identifying useful tools as a support for the application to the various stages in the systems planning approach. Systems planning is concerned with the structural design of the system itself and so is involved at all stages of the planning activity. It is an extensive approach with the ability to develop intensity as needs arise. These needs are determined by the particular characteristics of the planning problem and the planning environment.

In applying the systems approach to the activity of construction programs in the South Pacific Commission area, it is a necessary prerequisite to define the scope of the system being considered, to identify the interface (which has been artificially established for this particular study) between the system and its environment, and to note the links between the system and environment which flow through the interface making the system open.

Identifying this scope, together with the intensity and the extensiveness of the study, allows relevant system adjustments to be made with known considerations and limitations, and also determines when system manipulation is outside the scope of its definition.

e. Computers and the Systems Approach

As previously stated, the systems approach is a way of looking at problems of all scales. The approach will vary for problems of different scale and complexity however the total process of systems approach can be illustrated as follows :

1. Orientation to problem.
2. Analysis.
3. Organization of elements.
4. Research and development.
5. Synthesis.
6. Implementation.
7. Evaluation.

This is a very general list of the process activities. Actually the process is not directly sequential by cyclic in its operation--evaluation for instance occurs at all stages.

i. Man and the design process

The human mind has certain characteristics which are particularly relevant when considering the design process. Man approaches the process with an intuitive approach--he is able to analyse, synthesise and evaluate a problem systematically to arrive at a solution. The competence and ability of a designer is relative to the perception and the acuity of his intuition and thinking capability. This capability determines the problem complexity that can be readily solved by conventional means. In today's society many complex problems exist which often go beyond the capabilities of the most competent thinkers, we are constantly finding it necessary to consider larger problems, and so efficient tools of assistance may be employed to augment the human capability.

By utilizing augmented problem solving techniques we are able to approach complex problems of a scale hitherto impossible to handle--we can look to the larger system and its environment rather than narrowing a problem to our human capability at the expense of possibly disregarding relevant components.

ii. Computer, man and the systems approach.

The computer has unique characteristics which may be utilized in the system approach as an extension of the capabilities of man and his thought process. Some of the characteristics are large memory, very fast calculator, performs monotonous tasks, variety of input/output devices, great accuracy, requires perfection and does exactly as instructed.

There are parts of the design approach being performed by man that may be more efficiently given to the computer to perform. There are parts of the process in which the computer can effectively augment the human ability to give greater advantage and more insight into the problem and its implications. There are also parts of the process that only the human mind can carry out efficiently. In considering the advantages of the man/computer symbiosis we must look at the characteristics of both man and the computer and their efficiency in carrying out parts of the process. To optimize the process we can allocate each function to the most efficient operator. Both man and computer have unique attributes and by utilizing the best of each in a coordinated way, a synergetic advantage will result. One of these man/computer combinations used in planning is a technique called simulation.

iii, Simulation

Simulation as a complete process is anything that is pretending to be something else. The total scope includes such things as space simulation, driving simulation or even drawings. Considerations in this discussion apply to simulation as an aid in the system approach. Here it is the technique for modeling, testing and evaluating a process or system.

Simulation involves :

1. The creation of a mathematical, computer or graphical model of the system or process to be studied.

2. The use of the computer as a means of manipulation of the model to obtain the desired information from the process.

Simulation objectives are :

1. To obtain a better understanding of the principles involved in the design and operation of a system.

2. To allow an inexpensive and speedy means of observing the response of the system to varied inputs and to progressive time cycles.

The simulation process consists of the following procedure:

1. Creating of a mathematical or graphical model representing the system under consideration.

2. Modification of the model following initial evaluation.

3. Manipulation of the model by varying the parameters or controls by computer /man interaction or by variable input.

4. Evaluate the simulation process and create alternative models.

Simulation is useful as an analytical or graphical tool where the system components are complex and require isolating and ordering. It is also useful because it allows a large number of variations to be made and tested within the parameters of the problem scope, with the objective of obtaining representation of an optimal system. The ability to simulate a number of alternate plans or systems in a short period of time gives the designer an informed basis upon which to make decisions.

The value of simulation depends on the ability to produce a model which will realistically and adequately represent the system or process under consideration , so models play an important role in the technique.

iv. Models

A model is a conceptual tool describing an observed phenomena in a consistent and accurate manner.

Models may be mathematical, graphical, computerized or three dimensional, in fact any representation of a real situation may be regarded as a model. Each is derived from the designers perception of the patterns in the process being modeled. Identification of the relationships is developed within the system framework to represent the elements of the system and these elements are related in a prescribed way.

A model consists of variables within a structural framework and an operation process. As described previously--a model represents a system in an environment--the system does not exist in isolation. External factors may be allowed to influence the model or they may be assumed to be constant. In the latter case they may be explicit or implicit assumptions. Variables may be exogenous where they affect the structural relationship of the model externally and are not themselves changed, or they may be endogenous where they change and are changed within the structural relationship.

Models may be descriptive, predictive, planning, process or evaluation models. Within a given situation there exists an appropriate degree of aggregation and complexity of a model to successfully represent the system and to provide the required information.

A successful model requires the integration of mathematical accuracy and informed professional judgement. Both qualities are required. These model components or attributes should be defined, and where judgement is involved this should be explicitly stated.

Lowry (c) describes three types of models:

1. Descriptive: An orderly description of a situation. This type is an aid in understanding relationships within the system being modeled.

2. Predictive : A descriptive model developed to include casual sequences. Dynamic simulation enables prediction of variables. These predictions are however conditional on the assumptions of the model framework.

3. Planning : A prescriptive model with the added attribute of evaluation with respect to stated goals or objectives.

All models have three basic characteristics of representation: reality, accuracy and generality. Mathematical models emphasise accuracy and generality. Biological models are realistic and accurate but are not usually general.

It would appear that the three properties cannot be simultaneously optimized. The planning model including the vital considerations of social values, opinions and stochastic processes may be of the third possible variety. Absolute accuracy may have to be reduced in order to optimize realistic representation and generality. For instance a process model emphasizes process relationships without the need for absolute numerical accuracy. When modeling social values and other non quantifyable variables the model becomes probablistic rather than deterministic. In this case the qualitative contrasts are the important factors. Hierarchies of values in order of relative importance may be weighted to contrast with each other. Comparisons and relative positions of the variables are the important factors--not absolutes.

"Above all the process of model building is educational. The participants invariably find their perceptions sharpened, their horizons expanded, their professional skills augmented. The mere necessity of framing questions carefully does much to dispel the fog of sloppy thinking that surrounds our efforts at civic betterment." (Lowry.c.)

5. METHOD

a. Problem Orientation

An ecosystem is a "functioning interacting system composed of one or more living organisms and their effective environment, both physical and biological." (Fosberg . 10)

The Pacific Island ecosystem exists within the hierarchy of systems. For analysis purposes we consider it as an identifyable unit, however in fact the ecosystem is part of an interactive whole earth, with unique and shared components. The system is open and responds to external and internal stimulii.

The Pacific Island ecosystem has a relatively obvious identifyable interface geographically, ethnically and politically, however the defined isolation is an artificial one.

The Pacific Island ecosystem is characterized by a large expanse of water with small isolated land areas. The sea is generally large in scale and open, but some islands have enclosing reefs and sheltered water.

The island land is of small scale and is classified as high or low, volcanic island or atoll formation. The land is <u>limited</u> while the sea is relatively <u>unlimited</u>. The majority of the system is in the tropical area where heat and humidity are the major controlling climatic elements. While varying micro climates do exist the macro climate is of a tropical marine nature--moist trade winds (some cyclones and doldrums), high insolation and illumination, wet seasons, clouds and moderate to high temperature and humidity. The natural resources of matter and energy (marine and terrestrial) are sparce, which necessitates efficient utilization. The majority of the Pacific Islands are underdeveloped with a lower standard (but not necessarily lower quality) of living than the surrounding continents. Traditionally the South Pacific Islands have changed slowly and have maintained stability. As development and modernization penetrates the area, changes are created which have the potential to disrupt the balance of the system, possibly causing more harm than good to many individual components. Consequently it is advantageous to view development as a force acting on an existing functioning system tending to simultaneously change its separate components. The effect of these individual changes may be beneficial or disruptive on the system as a whole.

If we regard development ideally as being beneficial for the ecology of the area (the people and the place) then it is vital that holistic consideration of the system be established - the new dynamicism may cause instability in the place of the existing static stability.

There is at present no organization existing that monitors the changes in this developing area, or that projects systematically the future consequences of individual developmental decisions. It has been shown that the Pacific Islands are unique within their basin environment and that they share many similarities. It is also relevant that many territories are isolated, in one form or another, and are also too small to effectively contribute individually to planning for the area as a whole.

Developmental planning for the South Pacific Islands should be carried out at an appropriate scale by an agency capable of perceiving problems at the large scale but also not unresponsive to the small problems of individual territories--the only agency with this potential capability is the South Pacific Commission.

It is within this context that the study is undertaken--planning for construction programming within the whole South Pacific Commission area. One subcomponent of the total developmental system is studied as it exists, and projected to obtain results from alternate extensive and intensive sharing strategies. The results can be used to evaluate the alternate benefits from such strategies.

b. Problem Definition

Existing within the Pacific Island environment, the problem of development is a problem of how to make available to the island peoples the technical advances they are lacking without destroying the balanced and unique culture already existing. Development should not be imposed but it should be available for evaluation. Progress for the sake of progress is retrogress. There is a right time to develop and a right rate to progress to obtain maximum advantage and benefit for the people--this cannot be measured entirely in economic terms. Any deviation from this optimum stage means disadvantage, inefficiency and waste to varying degrees.

Without entering into the question of whether these territories should or should not be developed--we must accept that there will be pressure from the developed territories and that development will take place to some extent.

If this assumption is accepted then the problem is how to best utilize the resources of the area to give maximum benefit, a problem of resource utilization efficiency or resource management. Within the problem environment previously outlined, various physical facts can be established--the land areas are small and isolated, they are underdeveloped relatively, there is a population increase and a trend to urbanization, and there are great needs in many ways.

The problem is not how to most efficiently develop the areas but rather how to most effectively meet the needs, of the area utilizing the most appropriate resources both indigenous and exotic. This need not necessarily imply modernization or development per se, but will utilize these components within the total development process to produce a balanced harmonious transition over the period of vast change.

It is a problem of mutual adaptation and modification of contrasting life styles and technology--each component of the two systems must be evaluated in relation to its true environment and accepted, rejected or alternatives developed in this context.

It is through this constant monitoring and evaluation of the changing situation that we can control development in a balanced and sympathetic way.

Controlled and balanced development is facilitated by the application of the systems approach. Solutions to particular problems in the system may well be found outside what appears to be the problem environment--by looking at the whole system of development relevant answers to the real problem are more likely to be found. Housing problems for instance can be solved by means other than constructing more houses more quickly and economically. The problem here is defined, within this larger hierarchy of problems, as determining the potential benefit of various sharing strategies in the construction field. It can be seen that being a component in ever larger systems, the implications of the findings could reasonably be related to other components in the same system.

c. Organization

The approach combines two powerful scientific procedures--those of simulation and comparative method--to produce and evaluate a computer model.

The model was developed by perceiving the elements that make up the processes involved in the determination of housing needs, the allocation of funds and the actual construction of houses.

The total process operation has been organized into the following sectors:-

1. Programming
2. Financing
3. Design
4. Costing
5. Construction
6. Evaluation of the situation

The factors that preceed actual construction determine the amount and type of buildings produced. Although varying in degree from a norm the process operates along the following lines.

Needs and desires for construction are felt by various consumers, administrators, officials, architects etc. These needs are quantitatively determined and screened by developmental priorities previously established. The needs are programmed into a development plan for a certain time period and this plan provides the framework for future development priorities and policies. This investigation and selected quantification comprises the programming phase.

As the development period evolves, more detailed quantification of needs produce an estimate of costs. The estimate is evaluated within the priority for financial resources and a budget is established. This budget becomes the actual amount of funds available for a particular project and hence determines the quality and quantity of the design. In the case of housing this may be a bulk sum or a sum allocated to each unit.

The operation of applying predetermined space and quality standards to the established needs within the budget is the design process. In the South Pacific area, where resources are limited, this usually involves getting the maximum building for the minimum cost. Standards are determined by previous experience into costs, needs and established standards--they are adjusted relative to these factors also.

Building design is carried out by architects, draftsmen and tracers and one design may be standardized and used many times.

In the developing territories where Government involvement in progress is great there are at least two ways of constructing buildings. One is by direct labor using the materials, labor, administration and facilities of the Government. The other is by contract with a private building contractor. There are also various combinations of these methods, for example a labor only contract may use material supplied by Government. The process of costing is the determination of contractors bids, comparison of these with the budget and if necessary the estimation of direct labor costs. It is usual, because of low overheads and lack of profit, that direct labour costs are lower than contractors bids, it is also usual that Government policy favors the encouragement of private enterprise.

Once the construction method has been selected then the actual production of the building takes place utilizing the allocated budget. In broad terms this is the functional opera tion of the construction process in the developing territories of the South Pacific. The model is designed to simulate quantitatively this total process as a cyclic sequential operation representative of an annual cycle. The process occurs consecutively in all areas of the study and this also is simulated.

Basic assumptions have been made which in the presence of more detailed information may prove to be invalid in some detail. The most important of these is that the broad construction process is similar in all territories.

The assumption is not as idealistic as it first seems, since detailed variations can be simulated through information input and factors such as the proportion of local funds to overseas development aid are not relevant to the process of construction-- only the budget limitation effects building output.

More detailed discussion of the components of the process will follow.

d. Presentation

The basic model simulating the construction process for territories in the South Pacific Commission area is called CONPROG. The model simulates the process network by producing alternate procedures following decision points. These points or control nodes simulate the factors which in reality influence and allow a decision to be made.

Basic statistical data of many kinds is processed and used to aid in decision making. By producing a model which contains a number of alternatives at each process stage and simulating the factors by which decisions are made, a large number of alternate processes are represented and these alternatives are utilized through time and for different territories.

In reality while broad construction operations are similar through time, their detail varies. This process has been produced in CONPROG. The process details are determined individually but interdependantly through sequential computations of relevant data and identifiers.

The model uses cybernetic and homeostatic mechanisms throughout to produce information feedback and interaction as it occurs in real life.

Three dimensional array matrics are used for memory throughout to enable all information to be available at all stages of the simulation. This information storage also allows output or graphs to be produced, other than those already given, without major alteration to the model.

All exogenous variables have been identified as input data items and can be changed easily. As more accurate data becomes available this also can be very easily substituted. Thus the model is very general and has potential to accept new or varied information without major alteration.

Conceptually the model simulates the six process sectors previously described. There are a number of alternate ways of computing each sector, a decision node preceeds each sector, and others exist within the sectors.

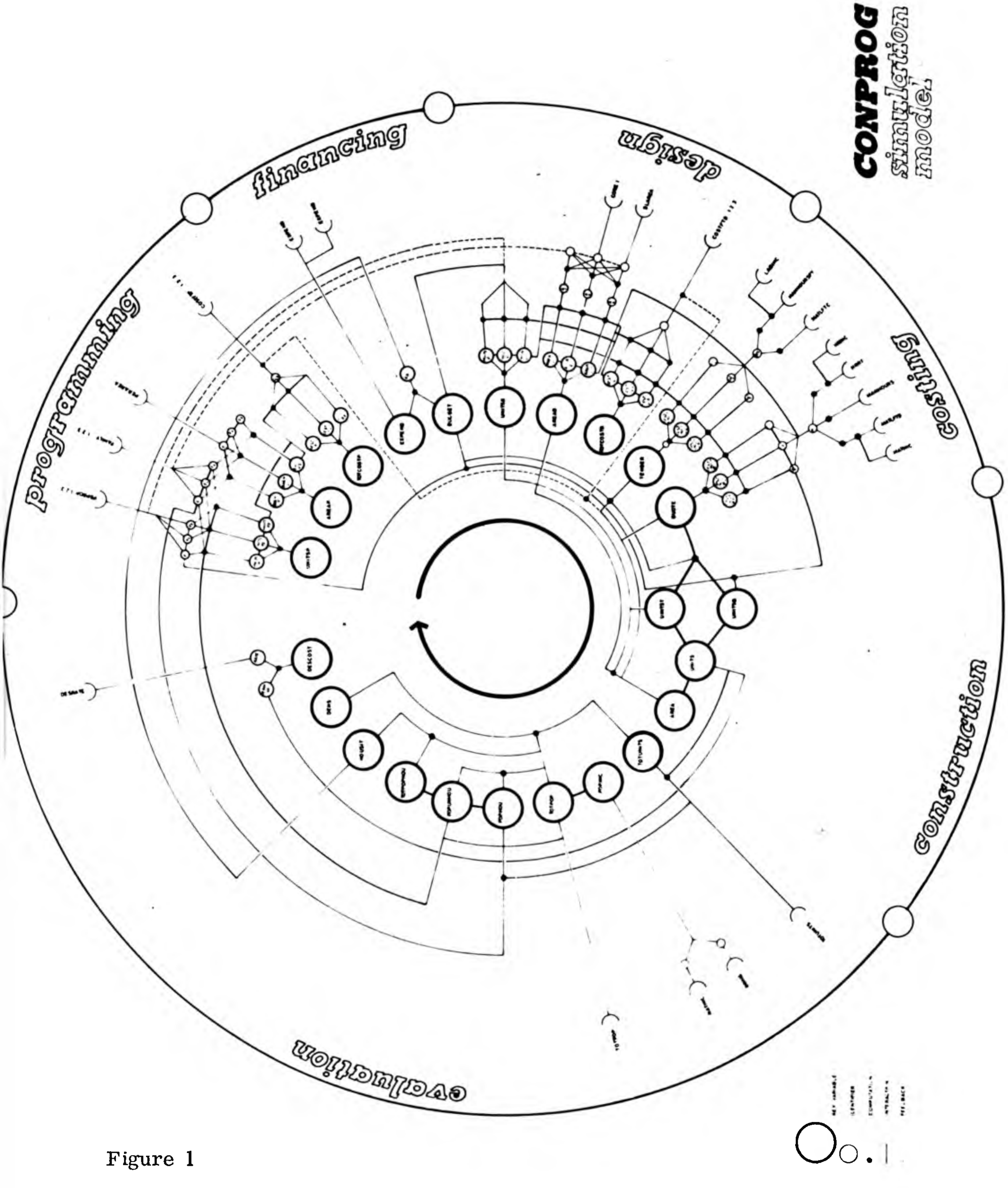

CONPROG
simulation
model
programming
financing
design
costing
construction
evaluation

Figure 1

At the completion of a sector, information relevant to future decisions is stored and other information is fed back to previous sectors.

The sectors simulated are programming, financing, design, costing, construction and evaluation. CONPROG simulates this total process for each of twelve island territories for each of 23 years--1967 data is used and output commences at time 1970. At the end of each year the model sums several identifiers through all territories for that year--for instance the total number of houses constructed for a particular year is given for each territory and then the total for all territories is given for the same year. Other variables are averaged for all territories.

In detail CONPROG simulates three sizes and qualities of house for each territory. Briefly, programming consists of determining the population without adequate housing, the proportional breakdown of this population into family sizes, determination of living, sleeping and service space standards for these families and the allocation of appropriate house size. An estimation of the average costs of these houses is based on previous experience. The key variables of the programming sector are :

1. Total number of houses at predetermined standards to meet the actual unsatisfied need.
2. The total area of the same housing , and
3. The total cost.

The other sectors have output key variables as follows :

Financing
1. Total expenditure of the territory.
2. Actual budget allocated to housing construction.

Design
1. Total number of various housing types that can be designed at the set space standards within the budget.
2. Total area of the same housing as designed.
3. The total cost estimate at conclusion of the design sector.

Costing
1. Bid or tender as submitted by the building contractors.
2. Quote for cost by Government direct labor.

Construction

1. The number of housing units that can be built by contract or by direct labor.
2. The number of various housing types that are actually constructed.
3. The total area of housing built.

Evaluation

1. Total inventory of units.
2. Population increase in the urban area.
3. Total urban population.
4. Population that is satisfactorily housed according to the set standards.
5. Population that is not satisfactorily housed.
6. Population that is housed by the newly completed construction.
7. Percentage of the population housed satisfactorily.
8. Average number of people to each house on the total inventory.
9. The annual cost of design of the housing production.

Another example of the process within one sector of the model is in the costing sector. In order to compute the TENDER and QUOTE figures CONPROG accepts basic data of hourly labor costs (which increase through time), material costs for each of the three house types (these also increase through time), and the average rate of labor/supervision time for each house type (this figure reduces with the number of housing units to be constructed). These are used to calculate a cost per square foot for each house type. Predetermined information on house areas, as designed, is used together with these square foot rates to produce the cost per unit of each house type. The total basic estimate is then determined by these costs and also the numbers of each unit as designed. In the case of TENDER, to this figure is added the contractors profit to determine the final bid.

The TENDER and QUOTE are then compared with each other and with the allocated BUDGET. The decision on whether to build by contractor or by direct labor is related to these comparisons. If the TENDER is less than the BUDGET or is less than 10% above the BUDGET the Government policy dominates and the job goes to contract by private enterprise. If the TENDER is too high then Government direct labor is selected. In this case the number of house units actually built is altered to conform to the BUDGET restrictions.

Other details of the internal operations of the model can be followed on Figure 5.

Basic conceptual Assumptions:

1. The concept of the scale effect is utilized throughout the model--basically this assumes the following

   a. As unit output increases the opportunity for and utilization of research and development also increases and benefits accrue.

   b. Standardization and technology are also increasingly utilized at output increases.

   c. Overall costs will decrease as quantity increases.

2. A degenerating housing situation will produce more urgent concern and will result in a higher priority for housing and a higher proportion of funds will result.

3. Design is carried out by teams comprising an Architect, draftsmen and tracers. Each team is capable of a certain work output. Design costs change over time in team units rather than in small increments.

4. Actual financial aid grants for each territory were determined over the period 1957 to 1967 and the rate of increase in aid over this period was projected to the future--large changes in this figure would produce large changes in the output--however if more information was obtained then this could be easily incorporated into the model.

e. Development

From the basic model CONPROG, alternate models were developed to represent sharing strategies defined here as extensive. These are illustrative of strategies that share the total construction process in varying degrees throughout the South Pacific Commission area.

CONPROB : This model simulates construction activity with territories having similar parent administrations, that is all British administered areas group to share and operate together in construction, as do the French, Australian/New Zealand, and American, the two independent territories of Tonga and Western Samoa operate as existing. This extensive strategy would be relatively easy to implement since it would involve no dissolution of political boundaries--it would merely mean coordination and cooperation between territories with similar organizations and policies and would involve no major changes outside present capacities.

CONPROC: This simulation is similar to the CONPROB model however it includes the important factor of a centralized coordination agency--this could be a development of the South Pacific Commission. Sharing takes place on two levels--within the similarly administered areas as above, and also, between these six areas coordinated sharing takes place through the central agency. The agency determines where needs are greatest and allocates priorities accordingly. This strategy while being a little more difficult to implement, would in fact involve little more than expanding the scope of the existing South Pacific Commission to enable it to act as coordinator. The agency would carry out central services such as data collection, investigation of best material supplies from a world market, allocating some funds to areas of most need and measurement of cost/benefit of building types on an area scale. The information would be made available to all territories through the agency and consequently would be an aid in all sectors of the construction operation.

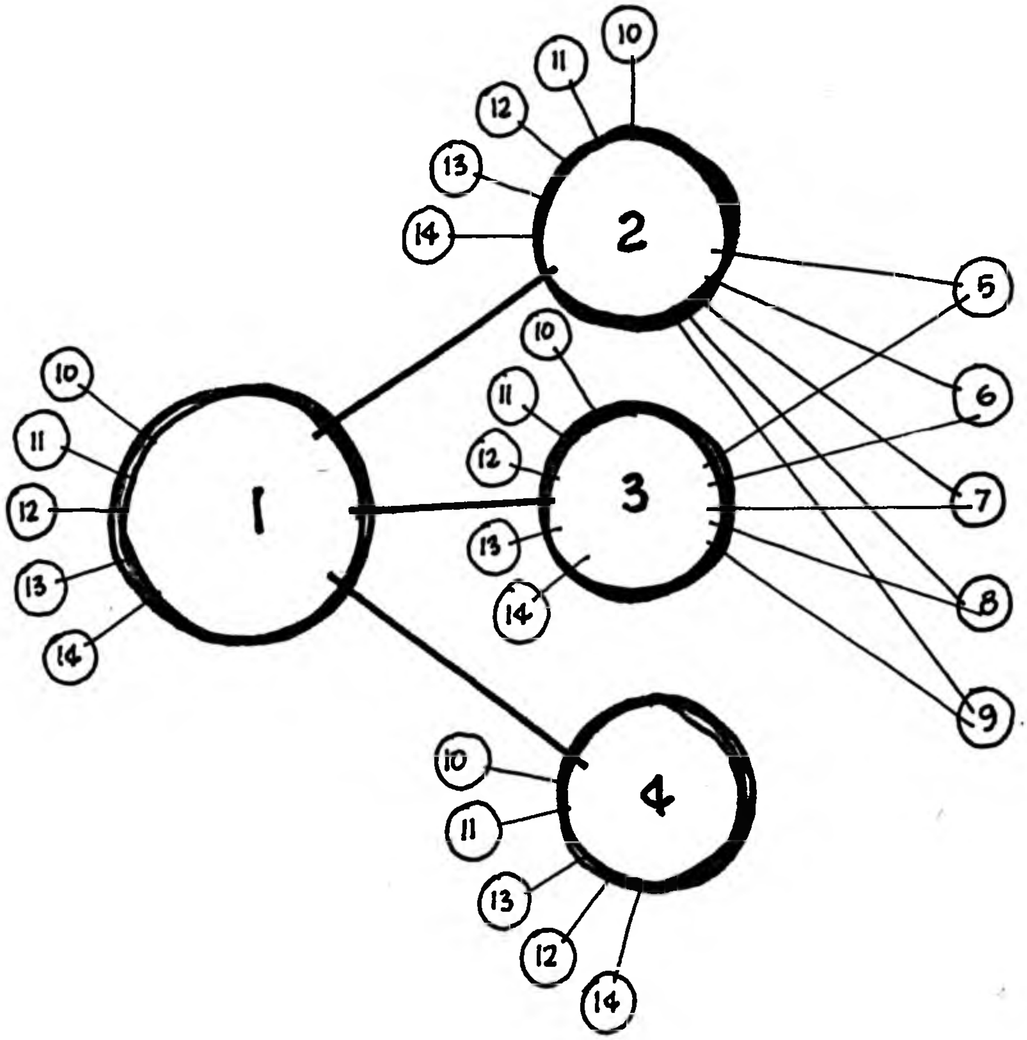
CONPROD : This model simulates the total construction activity as it would operate as a system of total sharing. The whole South Pacific Commission area would function as one territory supported externally by the same nations. The implementation would involve the formation of a strong independent sharing agency whose function would be to receive funds, determine needs and allocate accordingly. The whole area would operate effectively as one unit as far as construction is concerned, contracts could be let on a large scale, materials could be purchased for the whole area and designs, research and development could be increased to produce greater efficiency. The situation would be more difficult to create in reality however it represents the end of the scale of extensive sharing strategies and is the total opposite of the existing situation.

In addition to the above mentioned extensive sharing strategies, intensive strategies have been developed to represent sharing within the above framework, internal to the construction process. For instance the six sectors of the process could each be independently shared in the above fashion i.e. Design services only could be shared within similarly administered areas, coordinated in these areas or one design office could be established for the whole South Pacific Commission area. This produces various degrees of difficulty of implementation in different sectors.

It can be seen that sharing strategy models have been developed from the basic simulation to represent varying degrees of intensive and extensive sharing, each with varying degrees of implementation difficulty and differing benefit potential.

f. Testing

The development of the simulation models representing intensive and extensive sharing strategies enabled the computer to produce comparative results from each model.



EXTENSIVE		INTENSIVE		SENSITIVITY	
1.	CONPROG	5.	Programming	10.	Space Standards
2.	CONPROB	6.	Financing	11.	Population
3.	CONPROC	7.	Design	12.	Costs
4.	CONPROD	8.	Construction	13.	Financing
		9.	Evaluation	14.	Expenditure

Figure 2

In addition to the simulation runs previously described the models were tested for sensitivity of certain key variables. The data input effecting each variable was changed by a fixed known quantity to determine the proportional sensitivity of other variables. The key data selected were for

1. Space standards
2. Population
3. Material costs
4. Budget/Finance
5. Expenditure

These five standard tests were carried out for each of the four basic models. Those results for CONPROG were regarded as the norm for the existing situation. Comparative benefit resulting from these sensitivity tests was measured to determine the most sensitive variables i.e. those that change most with the least change in the relevant data. These variables can then be related to implementation difficulties and the most overall effective variables determined.

The whole testing procedure was designed to be a link between the simulation models and the real life situation--each model and each test was developed to represent actual possibilities for resource sharing in practice. In this way the computer has been used to develop relative quantitative relationships that act as a measure of benefit. While these quantities cannot be used outside the particular study, they are realistic within its scope and serve to determine the relative effectiveness of the tested sharing strategies.

g. Evaluation

Models can be evaluated in terms of their realism, generality and accuracy. The method can be evaluated in terms of its appropriateness and its results. It appears from the output data and from experience in the South Pacific that the models do simulate the construction activity realistically. It should be remembered that the models have not been designed for absolute numerical accuracy and consequently the output data cannot be used to forecast such things as the number of houses built in a particular year. The information is relative within the whole model structure and as such is useful for comparative analysis--this type of analysis has been used in the testing procedure as outlined. The basic CONPROG, CONPROB, CONPROC and CONPROD models have been developed in very general terms--they are applicable to territories of different sizes and can easily accept variations in data. They are particular, however, to the South Pacific Commission territories, since a somewhat unique system of construction operates.

The method of system analysis, computer simulation and comparative method has produced vast quantities of information that can be processed in many ways. The models, together with their output have potential far greater than that utilized in these results, here a particular aim was established and the information produced fulfills this aim, however other analyses would reveal information relevant to a different problem. A further stage in the holistic study, though beyond the scope of this thesis, would have been the application of computer techniques of multi regression and stepwise regression and the use of factor analysis--these would allow the large quantity of information to be ordered into a comprehensible form.

The advantages of utilizing the selected method is that relative quantitative benefits have been produced. As distinct from an intuitive approach, this method has scientifically indicated the areas of the system that will give most benefit for least effort and where effective sharing can increase problem solving capability.

Within the scope of the thesis the method of approach has been most efficient and especially beneficial as a study.

With respect to the aims of the thesis, as mentioned, the method has enabled complete fulfillment, in fact the problem solving technique clearly has great potential in studies of this kind and it is hoped that more work can be done with the data produced by the models. These models combined with a data processing program could provide a coordinating agency with the necessary information to plan and program future development in the South Pacific to give maximum benefit for the island peoples.

6. RESULTS DISCUSSION AND CONCLUSIONS

a. General

The results of the study are measured by the twenty three key variables as represented in the model diagram and some of these are shown graphically in the following pages as graphical output from the computer. The British Solomon Islands Protectorate has been selected as a case study.

The results may be discussed in three categories, those from extensive sharing, intensive sharing and those from sensitivity testing.

Other graphs have been produced from the computer output data and are grouped for comparison purposes.

Generally the results have proved the hypotheses to be valid. The models represent the construction activity realistically as a system and the output is very varied as can be seen from the charts. Through an understanding of the operation of the model sectors, a clear insight can be gained into the cause/effect relationships of certain results. This clearly reveals that in many cases a problem may be more effectively controlled by working on a factor seemingly unrelated to the problem. For instance when considered as a system, the housing problem may be more efficiently solved by population management.

Efficiency, in solution means an improved housing situation with minimum effort. Population management need not necessarily mean population control--policies aimed at curbing urbanization can also improve the quality of housing. These may include increased agricultural development, decentralization of Government centers or encouragement to develop the unique attributes of individual areas.

Thus, with the system dynamically simulated in the form of a model, there is a greater chance of efficient solution to the real problems of the system.

This discussion deals with two of the major determinants of benefit, namely percentage of population housed and the total production of housing. Further analysis of the other key variables will provide further understanding as to the reasons for the changes in this evaluation.

SUNITS

	1970	1975	1980	1985	1990
CONPROG	1648.7	1664.4	1790.2	2966.1	2629.8
1	1776.2	1694.2	2797.7	2380.2	3969.4
2	1746.9	1553.4	1539.7	1492.6	1037.5
3	1977.1	1593.5	1615.4	2757.4	2375.3
4	1696.9	1610.1	2074.7	2523.2	3045.9
5	3043.2	2988.9	2057.6	4078.3	4264.2
CONPROB	2385.3	1515.1	1794.7	1491.0	2751.0
1	2005.0	1318.7	2208.3	2581.5	2993.1
2	2352.1	0991.0	1617.2	2065.2	2526.4
3	2385.3	1541.7	1834.6	1501.6	2762.5
4	2455.0	1636.1	1400.8	1816.9	2269.7
5	3502.1	1704.6	2049.8	2435.5	3214.8
CONPROC	1600.2	1071.6	1265.1	1568.9	1992.8
1	1535.4	0993.5	1297.2	1605.1	2043.0
2	1423.5	0774.4	0915.2	1106.0	1353.7
3	1918.7	1183.1	1494.8	1871.2	2229.0
4	1618.7	1111.1	1291.8	1646.7	2120.0
5	811.3	1035.7	1309.3	1667.6	2122.3
CONPROD	3064.8	2058.3	2415.7	2831.3	3313.8
1	3426.4	575.3	2700.7	3165.3	3704.7
2	3064.8	2058.3	0603.9	0707.8	0828.4
3	3064.8	2058.3	2415.7	2831.3	3313.8
4	3154.0	2221.0	0683.9	0840.9	4129.6
5	8148.8	2098.9	2721.3	3466.5	4415.3

SUMMARY OF SUNITS OUTPUT FOR EXTENSIVE AND INTENSIVE MODELS THROUGH TIME

Figure 3

SHOUSIT

	1970	1975	1980	1985	1990
CONPROG	56.3	58.9	57.9	56.7	55.3
1	57.6	60.8	59.9	58.7	57.0
2	58.1	63.2	63.8	63.1	63.3
3	58.0	60.5	59.5	58.2	56.5
4	56.5	59.6	59.3	58.9	57.9
5	67.0	76.1	78.9	79.3	76.4
CONPROB	56.2	60.2	59.7	59.8	58.6
1	59.1	63.0	62.4	61.6	60.4
2	58.3	63.8	64.1	64.1	63.3
3	56.0	60.0	59.9	60.2	58.9
4	56.5	61.0	60.7	61.6	61.4
5	35.2	34.3	30.2	26.7	24.9
CONPROC	59.8	61.8	59.2	56.3	53.8
1	62.0	62.6	59.9	57.2	54.6
2	61.6	64.9	64.0	63.0	62.1
3	61.9	65.8	64.2	62.0	59.5
4	60.0	62.1	59.8	57.2	55.0
5	67.7	64.4	61.3	58.5	56.1
CONPROD	65.1	78.0	80.4	80.8	79.6
1	69.3	81.1	78.6	78.3	79.6
2	67.0	80.9	81.8	82.2	82.0
3	65.1	78.0	80.4	80.8	79.6
4	65.5	76.4	81.1	81.3	80.7
5	83.1	96.5	96.3	96.1	96.0

SUMMARY OF SHOUSIT OUTPUT FOR EXTENSIVE AND INTENSIVE MODELS THROUGH TIME

Figure 4

SUNITS

MODEL	1	2	3	4	5
CONPROG	50.0	-16.5	-12.0	16.5	16.5
CONPROB	22.2	-11.0	00.0	-22.0	-24.0
CONPROC	05.0	-22.0	08.0	05.0	08.0
CONPROD	12.5	-66.0	-03.0	-66.0	12.0

1. Lowering of space standards 10%

2. Population growth was increased to 4%

3. Material costs were reduced 10%

4. Total expenditure for each territory was increased 1% over and above the actual expenditure.

5. Abudget of 2% of total expenditure was used in each territory.

PERCENTAGE BENEFIT FOR SENSITIVITY TESTS.
SUNITS

Figure 5

SHOUSIT

MODEL	1	2	3	4	5
CONPROG	02.0	04.0	01.0	01.0	20.0
CONPROB	04.0	05.0	01.0	03.0	12.0
CONPROC	00.0	07.0	07.0	00.0	02.0
CONPROD	-02.0	02.0	00.0	1.0	16.0

1. Lowering of space standards 10%

2. Population growth was increased to 4%

3. Material costs were reduced 10%

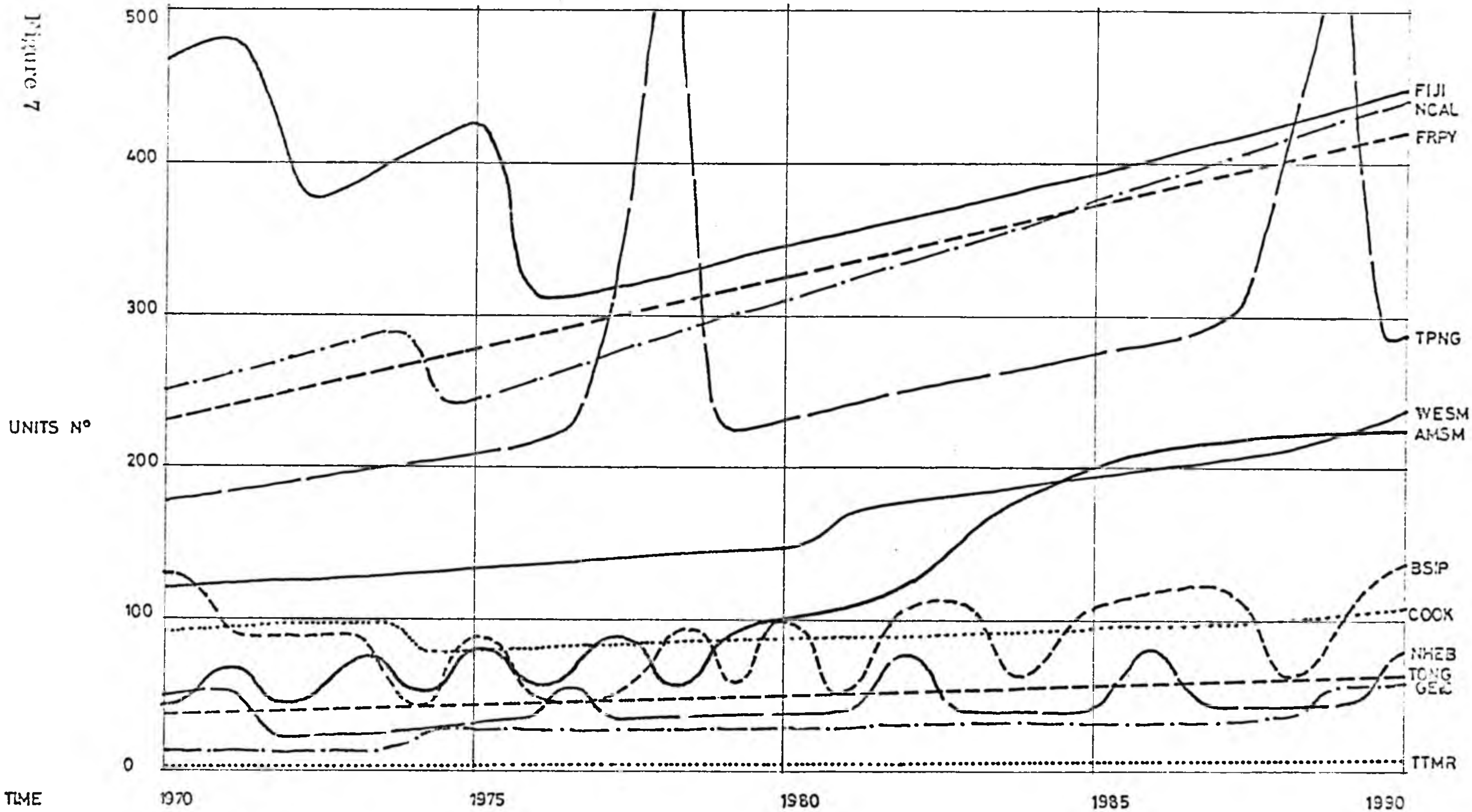
4. Total expenditure for each territory was increased 1% over and above the actual expenditure.

5. A budget of 2% of total expenditure was used in each territory.

PERCENTAGE BENEFIT FOR SENSITIVITY TESTS.
SHOUSIT

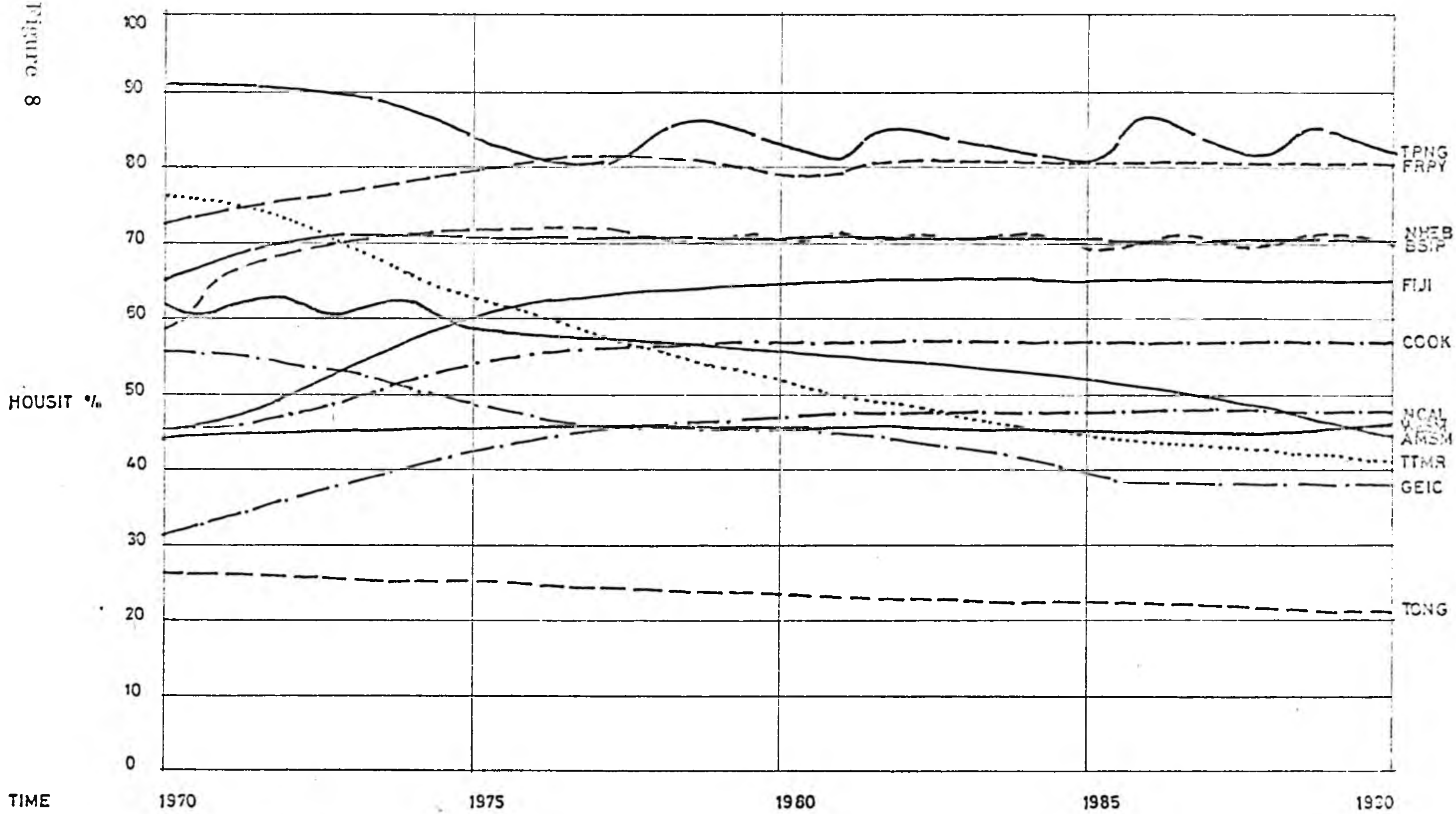
Figure 6

Figure 7



UNITS ANNUAL HOUSING PRODUCTION

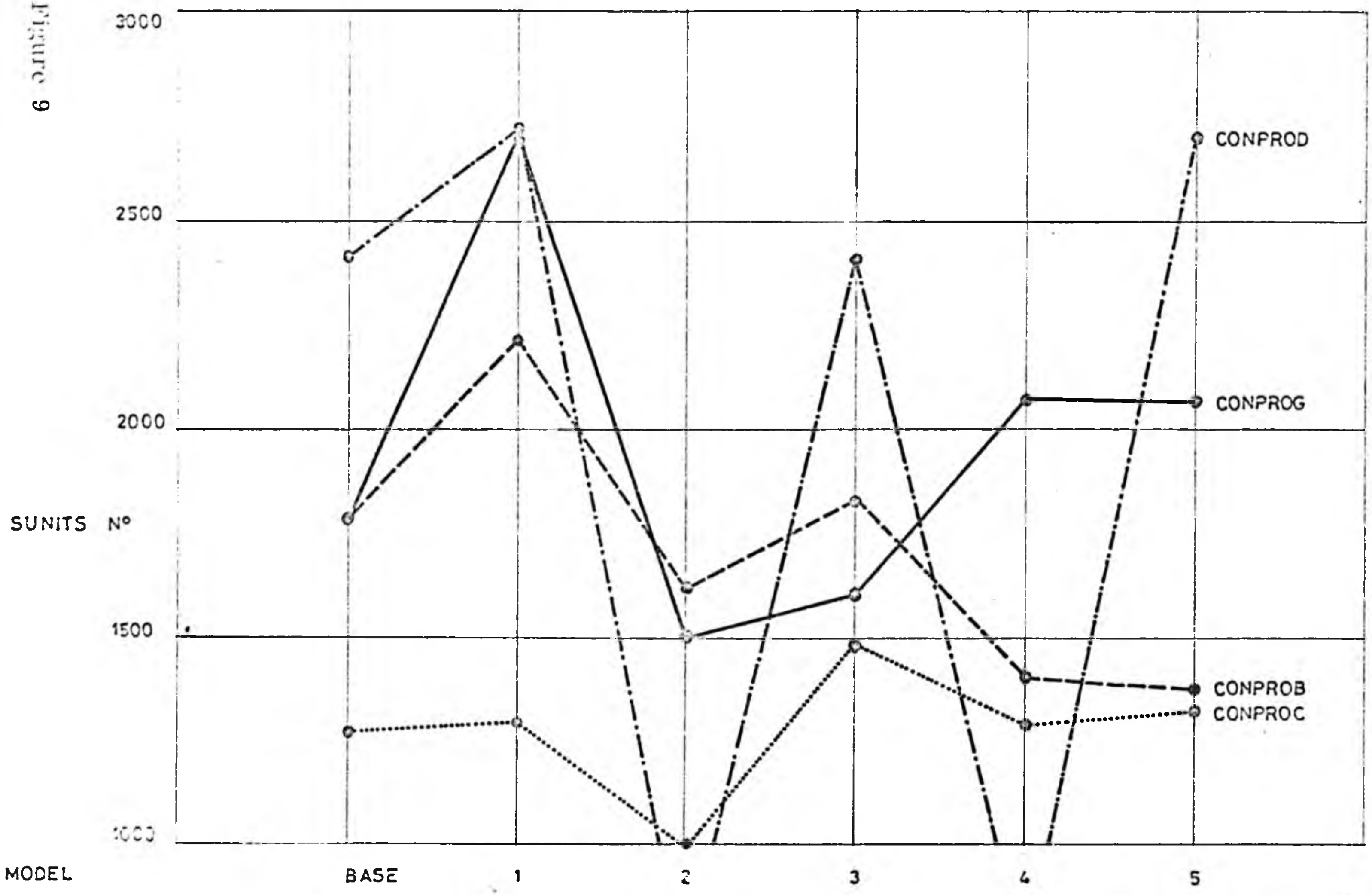
INDIVIDUAL TERRITORIES SUPERIMPOSED



HOUSIT PERCENTAGE OF POPULATION SATISFACTORILY HOUSED

INDIVIDUAL TERRITORIES SUPERIMPOSED

Figure 9

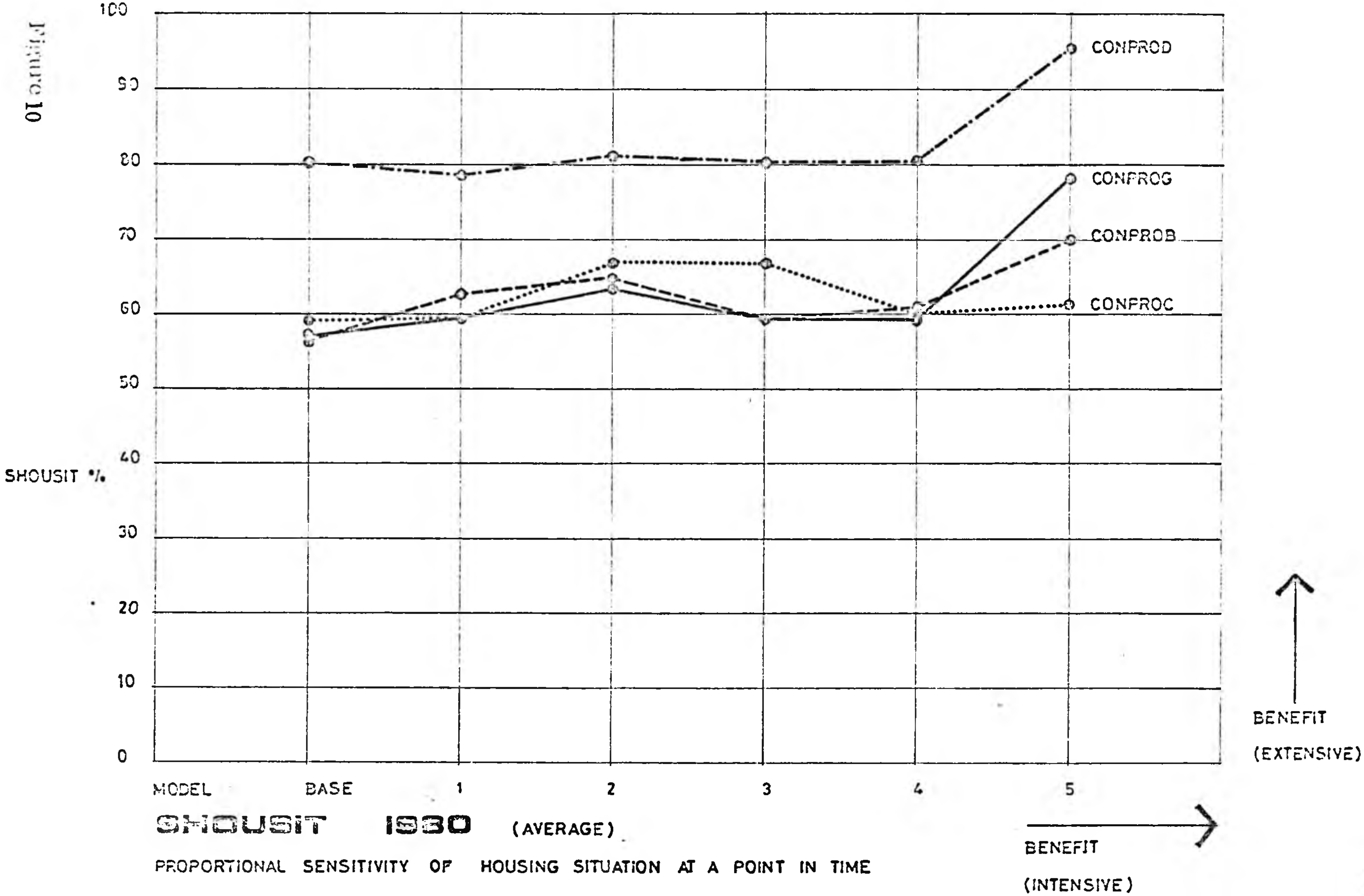


SUNITS 1980

PROPORTIONAL SENSITIVITY OF HOUSING OUTPUT

BENEFIT
(INTENSIVE)

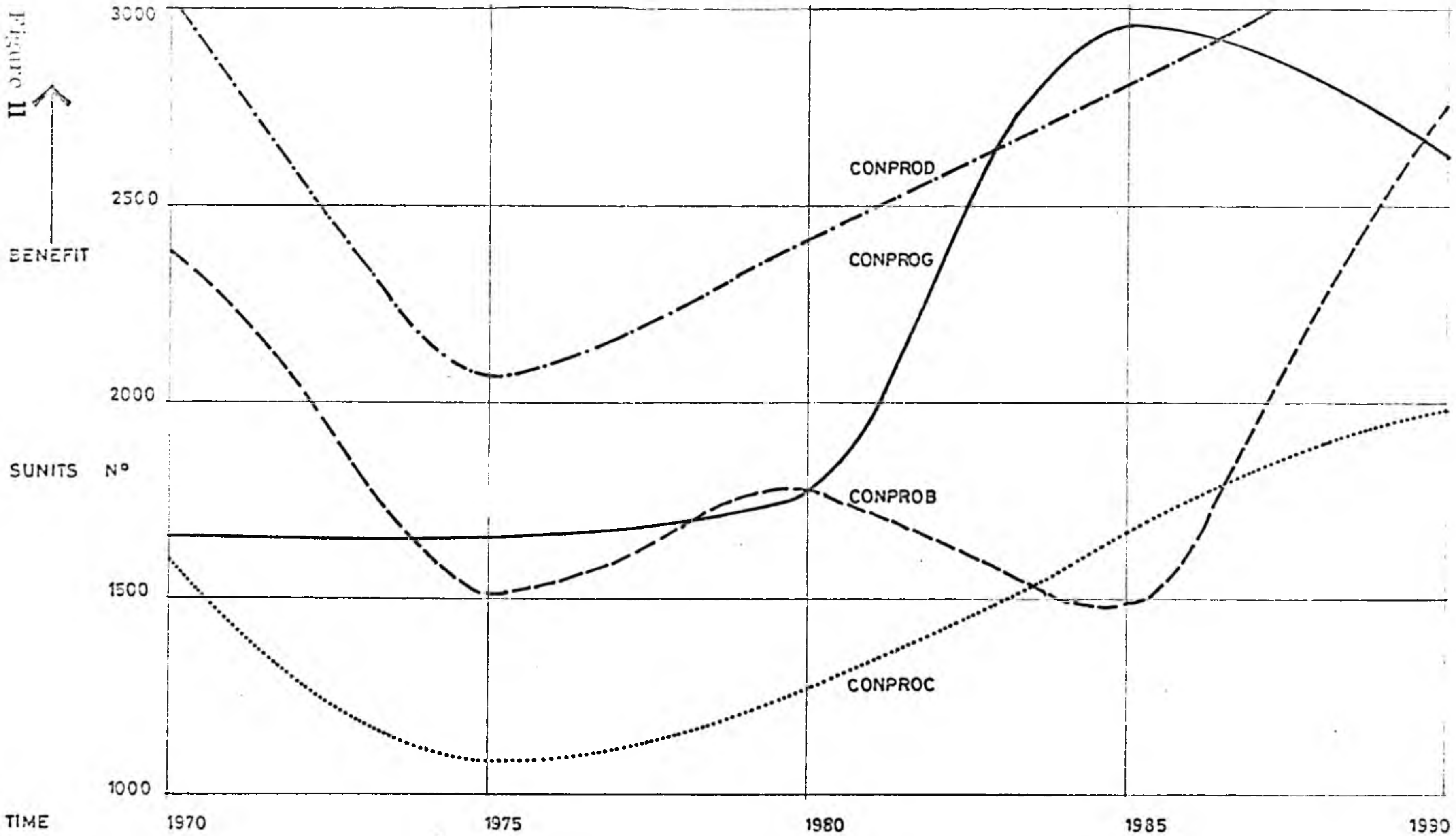
Figure 10



SHOUSIT 1980 (AVERAGE)

PROPORTIONAL SENSITIVITY OF HOUSING SITUATION AT A POINT IN TIME

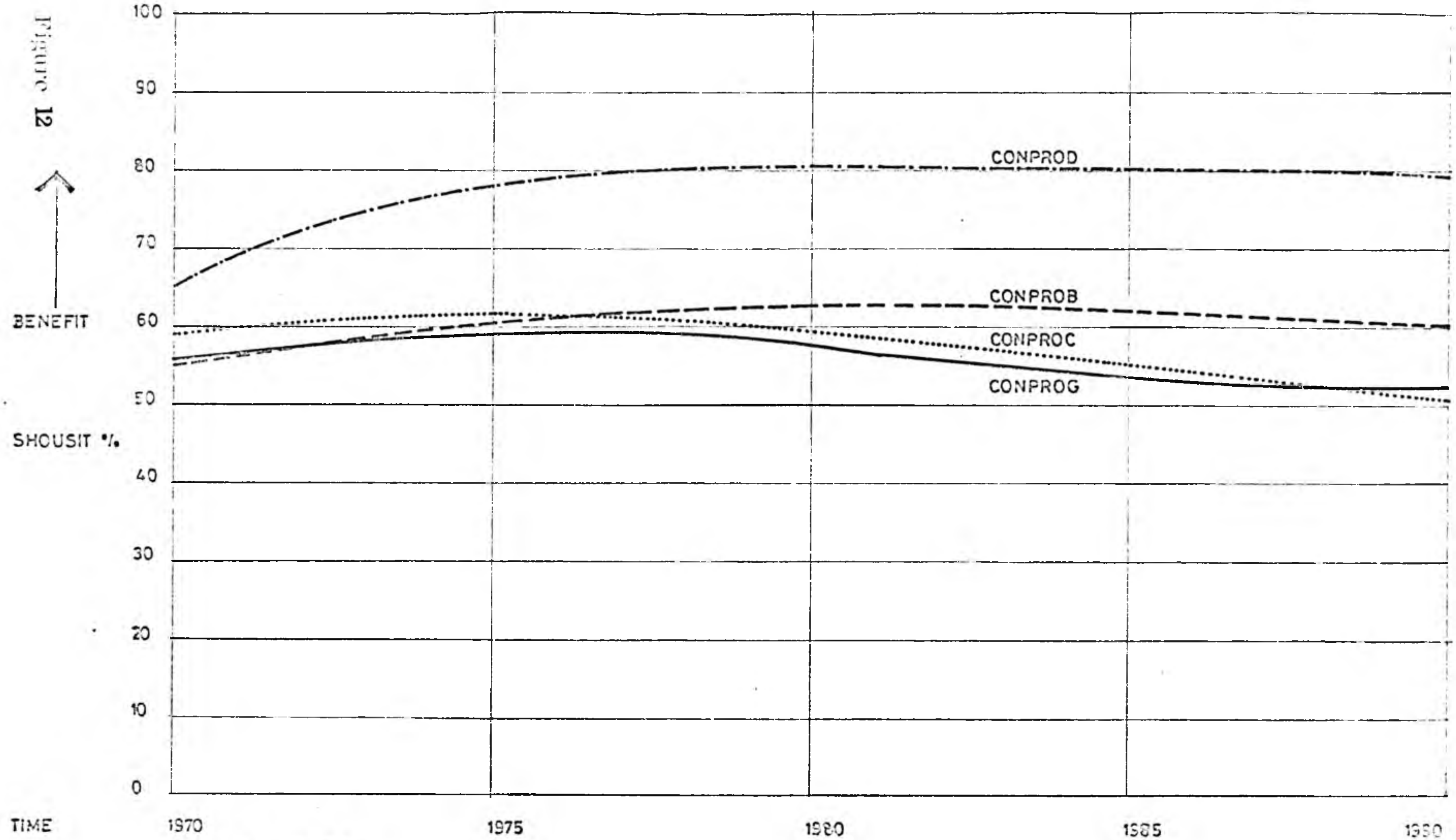
Figure II



SUNITS

PROPORTIONAL SENSITIVITY OF UNIT OUTPUT THROUGH TIME

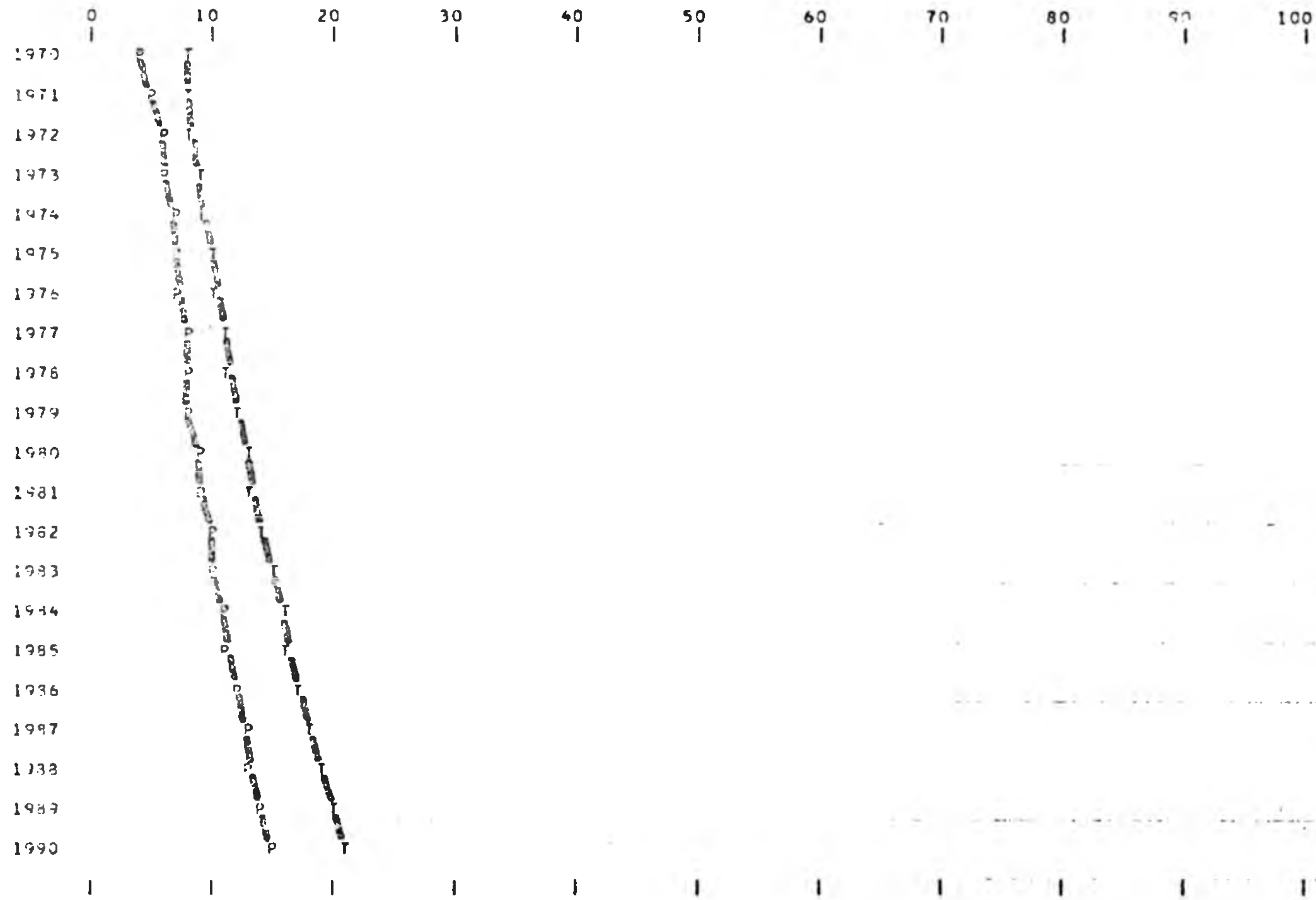
Figure 12



SHOUSIT (AVERAGE)

PROPORTIONAL SENSITIVITY OF HOUSING SITUATION THROUGH TIME

Figure 13

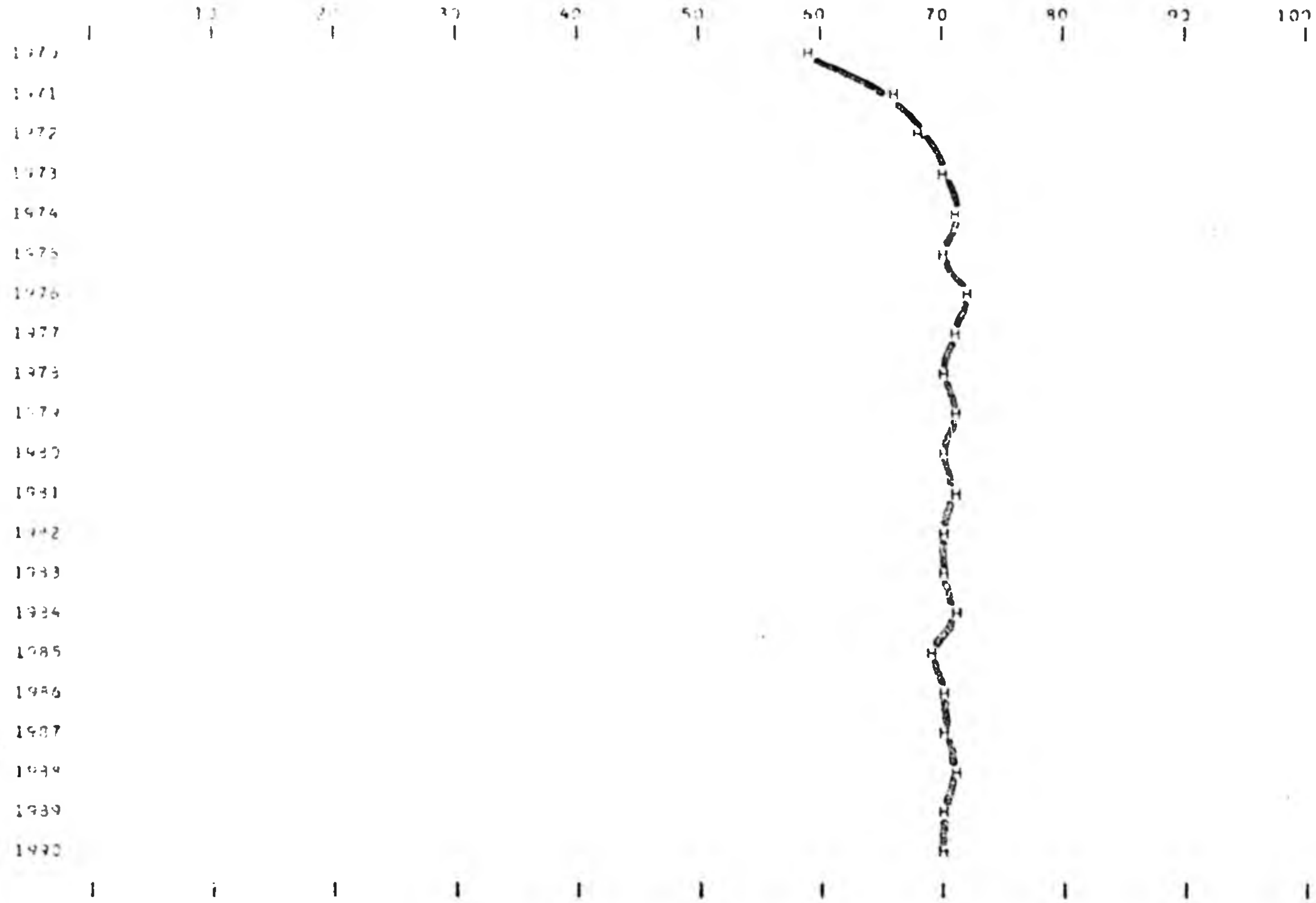


KEY

P = POPULATION HOUSED * 1000, T = TOTAL POPULATION * 1000

BRITISH SOLOMON ISLANDS PROTECTORATE

Figure 14

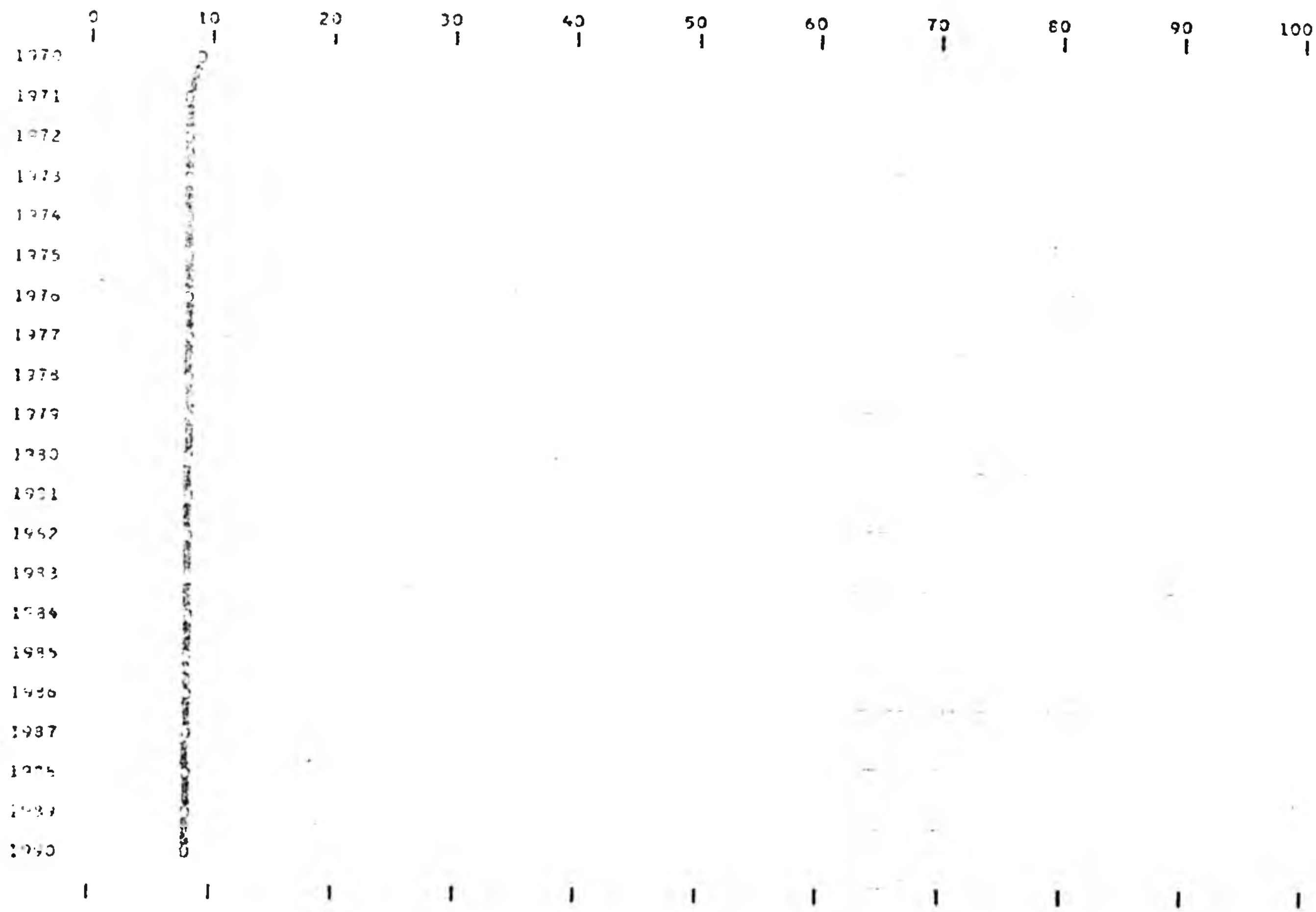


KEY

H = PERCENTAGE OF POPULATION HOUSED

BRITISH SOLOMON ISLANDS PROTECTORATE

Figure 15

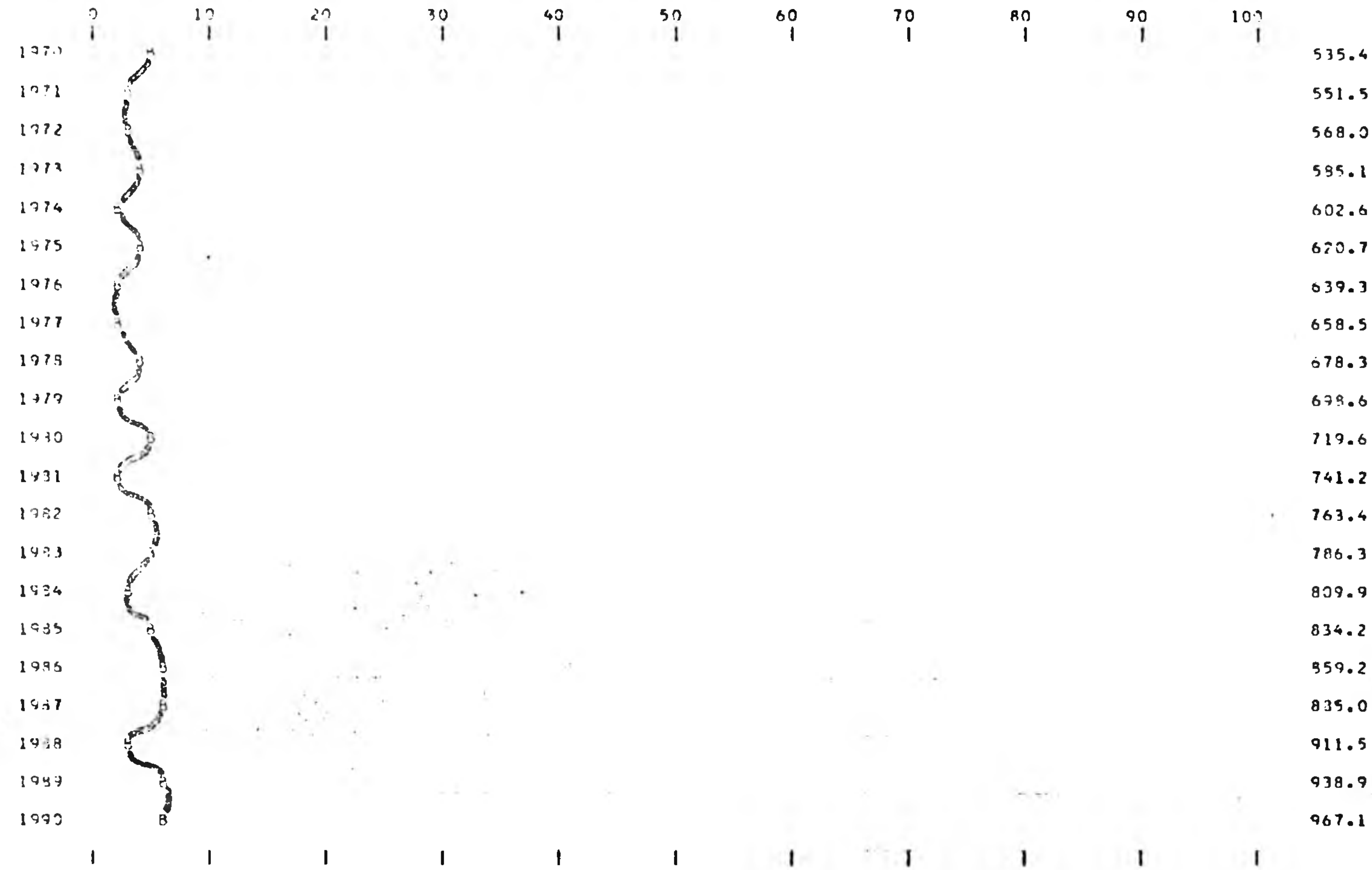


KEY

D = DENSITY (PEOPLE PER HOUSE)

BRITISH SOLOMON ISLANDS PROTECTORATE

Figure 16

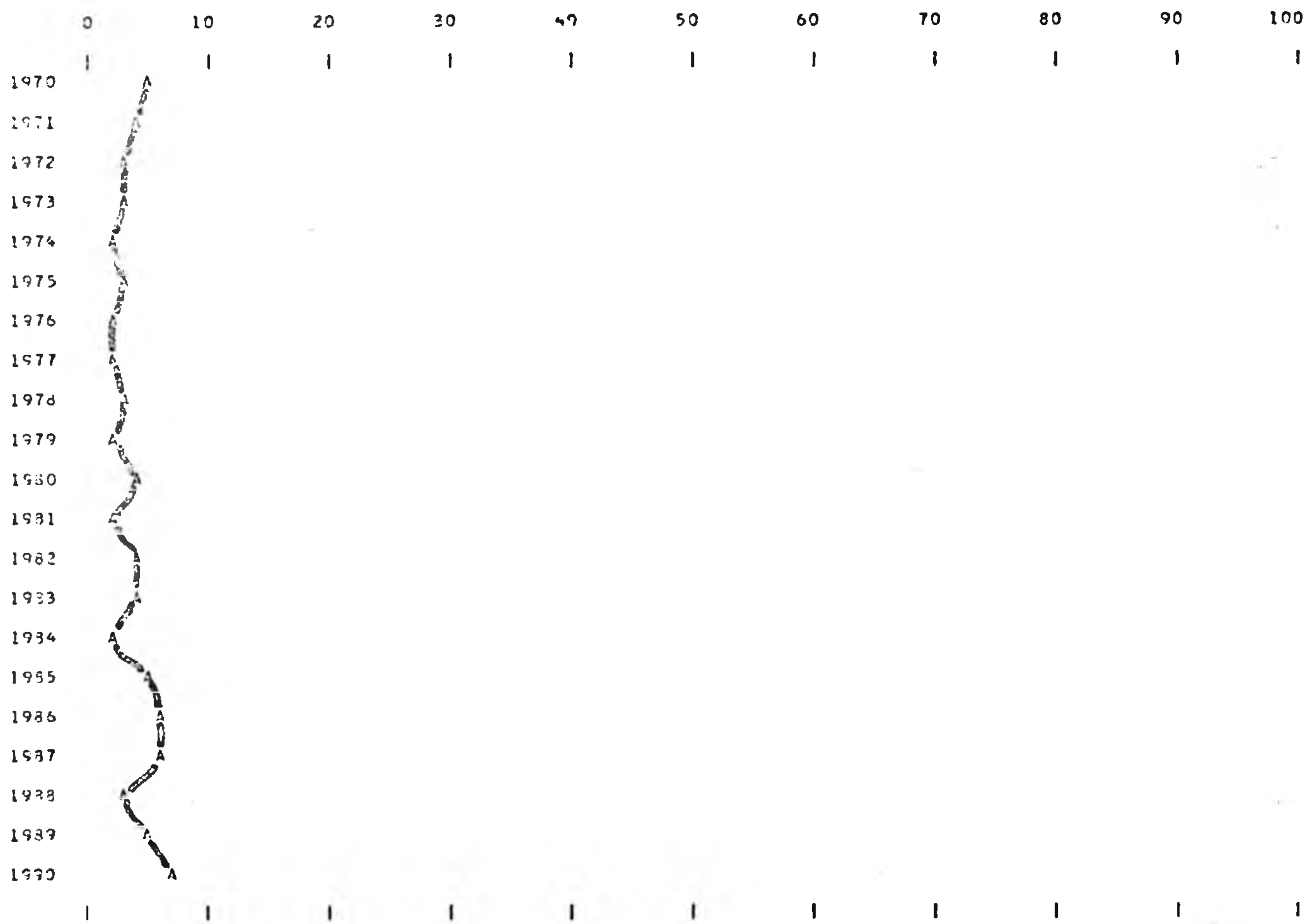


KEY

E = EXPENDITURE * 10000, B = HOUSING BUDGET *10000

BRITISH SOLOMON ISLANDS PROTECTORATE

Figure 17

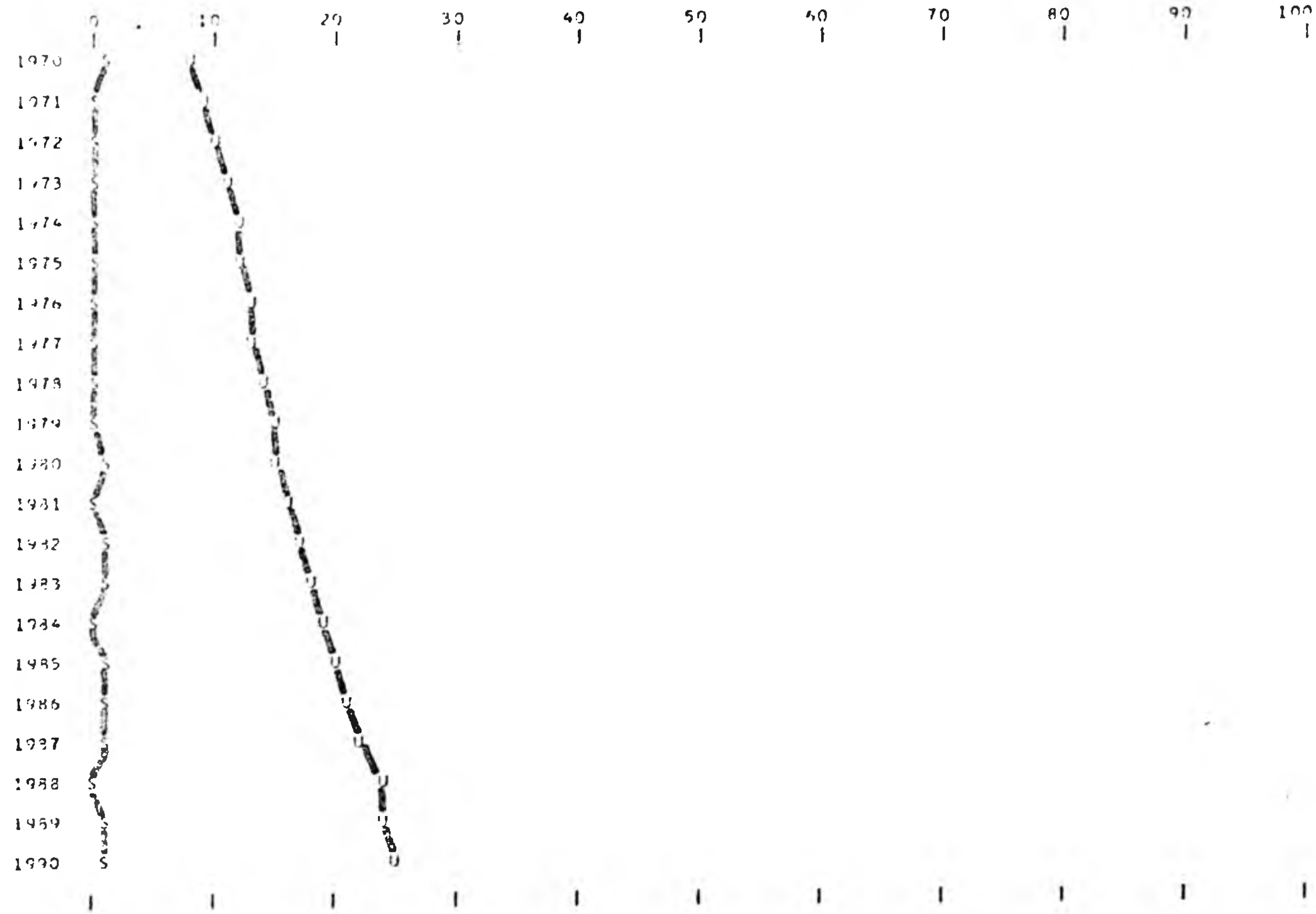


KEY

A = AREA OF HOUSING BUILT • 10000

BRITISH SOLOMON ISLANDS PROTECTORATE

Figure 18



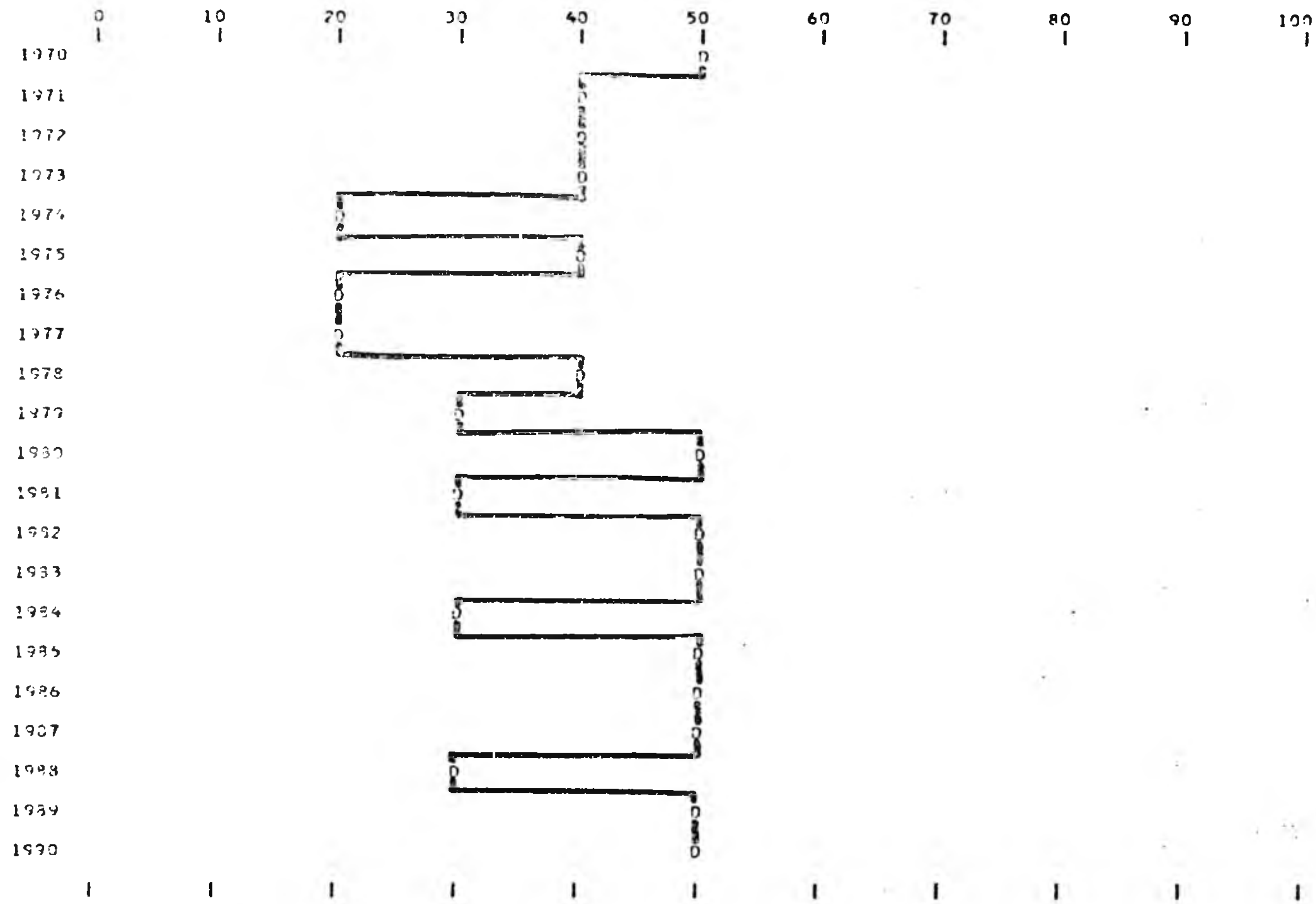
KEY

S = ANNUAL HOUSING UNIT PRODUCTION *100

U = TOTAL NUMBER OF HOUSING UNITS *100

BRITISH SOLOMON ISLANDS PROTECTORATE

Figure 19



KEY

D = ANNUAL DESIGN COST *1000

BRITISH SOLOMON ISLANDS PROTECTORATE

b. Extensive Sharing

The comparisons on the charts between CONPROG, CONPROB, CONPROC and CONPROD, show the benefit of extensive sharing strategies.

In all cases the greatest benefit (as measured by percentage of population satisfactorily housed or the total production of houses) derives from the most extensive strategy--as represented by CONPROD.

It is interesting to note that the benefit is not evenly distributed throughout the four stages of sharing. In fact the coordination offered between the six shared administration areas, as simulated in CONPROG, is not really beneficial. From the charts of SHOUSIT and SHOUSIT 1980 it is clear that some benefit accrues with the smaller scale sharing and greatest benefit from the most extensive sharing as simulated in CONPROD.

The housing production variation is related to actual needs, it is subjected to other limiting forces such as budget and population growth and so is not directly related to the housing situation.

The efficiency of the sharing strategies is seen when comparing the total housing production with the change in the housing situation. In CONPROD more units are able to be constructed with the same budget allocations and hence the housing situation improves.

It can also be seen from the chart SUNITS 1980 that benefit for CONPROD is much more sensitive to variations in policies. The same changes in population, financing, material costs, etc. make proportionally greater changes in housing production output. For each policy change the most extensive sharing has greatest variation. The models here function more evenly in sensitivity.

Comparison of the average housing situation, SHOUSIT and the total housing production, SUNITS with the individual territory HOUSIT or UNITS shows that great variation exists within each territory while averages are a more smooth curve. Each functioning unit is varying according to its individual pressures and limitations and the scale of the South Pacific Commission area as a whole is large enough to change more evenly and is less susceptable to detailed fluctuations. This evenness would be an advantage to holistic planning since benefit, outcomes and policies could be more easily forecasted or projected for planning purposes.

c. Intensive Sharing

Sharing within sectors of the construction activity is of varied proportional benefit. In fact sectoral sharing, because of its inconsistency, is difficult to implement in practice. It is hard to imagine sharing construction activities without some design coordination.

The distinction in intensive sharing is not clear when compared with extensive sharing as defined in this thesis. For instance sharing programming in similar areas of administration has basically the same implications as partial sharing on an extensive basis--similar base systems exist which frequently coincide with each other.

Intensive sharing is also related to the sensitivity of variables. Where the effect of a particular variable is confined to one sector then its sensitivity is directly proportional to the degree of benefit from sharing within that sector.

The results from intensive sharing strategies reveal an hierarchy of sectors of diminishing benefit. From greatest to least benefit the list is as follows :

1. Construction
2. Design
3. Programming
4. Financing
5. Costing
6. Evaluation

In fact where information or action is not physically shared no actual benefit accrues--intensive sharing is not as beneficial as extensive sharing. Where costing is shared without the implementation of construction then potential benefit exists but no actual benefit has been achieved. This factor also exists between other sectors and hence realistic benefit measurement and actual implementation of intensive sharing strategies is unrealistic.

d. Sensitivity testing

Sensitivity testing of variables was carried out to determine where effort can most effectively be exerted to achieve maximum benefit.

Key variables related to space standards, population, material costs, budget and financing were tested. The known change established in these variables affected all other variables to a differing extent. See chart SUNITS 1980 and SHOUSIT 1980.

1. Space standards were lowered 10% in all of the extensive models. In most cases benefit accrued although it was to a varied degree.

CONPROG had greatest benefit and CONPROC the least in housing production. Although housing output increased in all cases, the percentage change in the housing situation was small. Without sharing, efficiency dropped, it took more housing to maintain a similar housing situation.

The efficiency in sharing is revealed through the reduction in the amount of housing required to maintain the same percentage of population housed satisfactorily.

2. The population growth rate was adjusted to 4% for all territories and the results in all cases were beneficial. This adjustment showed that housing production could drop in each sharing strategy, while the percentage of population housed in all cases increased.

In the case of the most extensive sharing the number of units produced could drop by 66% while the housing situation increased 2.0% over and above the existing situation--this is a very substantial increase in benefit from the same resources. Throughout the extensive sharing strategies, increasing benefits result from increased sharing. This benefit is synergetic in that less houses result in a more satisfactory housing situation.

The tests show population to be an extremely sensitive variable in the housing situation--it is directly interactive with the construction system--that is less population means less building workers and consequently it is relevant that less construction is actually required.

3. A reduction in building costs of 10% also brought a benefit to the area as a whole. In all cases the percentage of population housed increased and only in the case of CONPROC did this require an increase in housing output. The reduction in costs automatically meant that more houses could be constructed with the same budget and hence efficiency accrues through the scale effect.

The benefit is not as great as for population variation but it is very relevant in the smaller territories with small housing production.

4. A 1% increase in total expenditure in each territory has mixed effect on unit output while maintaining a similar housing situation. Great efficiency can result in the more extensive sharing strategies, a large reduction in housing output can maintain housing standards. Through increased external aid, great potential exists for solving housing problems. This solution may be a false one in that no demands of efficiency or improved resource utilization are made on the individual territories when more resources are made available externally. The island situation inherently involves limited resources and increased aid is not allowing the real problem to be identified and solved within the system.

5. The proportion of the total expenditure that is spent on housing construction varies for each territory, here a similar proportion has been assumed to be allocated to housing, namely 2%. Once again varying results show benefit increasing with sharing, the housing situation increasing in all cases and requiring a greater housing output in all cases except CONPROB. Similar criticisms as in 4 can be levelled at problem solving by subsidy, but the test does show finance to be a sensitive variable. It would seem appropriate to approach finance efficiency internally by resource management techniques.

e. Summary

Extensive sharing

1. The more extensive the sharing the greater the benefit.
2. The more extensive the sharing the greater the sensitivity to policy changes.
3. Positive policies have synergetic effect on potential benefit.
4. Holistic system planning is facilitated by extensive sharing strategies.

Intensive sharing

1. Intensive sharing is less beneficial than extensive sharing.
2. Sectoral sharing benefit results from the following list in diminishing order.
3. Intensive sharing is an unrealistic strategy.

Sensitivity testing

1. Potential benefit increases with increased sharing.
2. Population and finance are the most sensitive variables.
3. Coordination and cooperation without actual physical sharing is ineffective.
4. Building costs are more vitally important to the smaller territories.
5. Increased external aid may not be a solution to construction problems.
6. Internal efficiency is not increased through increased external aid.
7. Financial efficiency generated internally is of greater benefit to the system.

f. Conclusion

The resources are presently at hand within the total South Pacific island system, to solve many of the problems of the area. Their efficient utilization could lead to economic independance of the island territories while maintaining their unique culture. This would be made possible by the development of the internal system attributes at the exclusion of disruptive external forces.

7. RECOMMENDATIONS

It is not intended that the following recommendations are wholly practical without further investigation and research--however they are a guide to the factors capable of utilizing resources more effectively to produce an increased benefit for the island peoples.

They are the results from investigation into a resource sharing system for construction programs in the South Pacific Commission area and should be treated as such. They are evolved from and limited by the scope of the study, however it is hoped that they are potentially beneficial within this framework.

1. That increased efficiency be generated within the South Pacific Commission area, through resource sharing.

2. That the South Pacific Commission be expanded to cope with the Development of sharing strategies.

3. That coordination and cooperation be developed together with pysical sharing.

4. That interterritory communication be developed in an holistic way rather than on an interdepartmental level.

5. That segmental sharing within the construction activity be discouraged in favor of systematic sharing.

6. That sharing over political boundaries be facilitated by the Administrations of the South Pacific.

7. That investigation into population management be incorporated into South Pacific Commission programs.

8. That a survey be instigated to gather data and make a resources inventory for the islands of the South Pacific Commission area.

9. That further analysis of results of the simulation models in this thesis be undertaken to establish further perception into the operation of the system.

10. That further studies be undertaken to relate the potential benefit established in sharing within construction programs, to the potential benefit sharing could bring in the other components of the total developmental system.

8. APPENDICES

Appendix 1.

The South Pacific Commission

The South Pacific Commission was established in 1947 by the Governments of Australia, France, The Netherlands, New Zealand, the United Kingdom and the United States of America. The Commission was set up 'to encourage and strengthen international cooperation in promoting the economic and social welfare and advancement of the non-self-governing territories of the South Pacific." (from South Pacific Report. 1967-1968)

The South Pacific Commission headquarters are in Noumea, New Caledonia and the present region of concern includes the following territories :

1. American Samoa (U.S.)
2. British Solomon Islands Protectorate (U.K.)
3. Cook Islands (N.Z.)
4. Fiji (U.K.)
5. French Polynesia (Fr.)
6. Gilbert and Ellice Islands Colony (U.K.)
7. Guam (U.S.)
8. New Caledonia (Fr.)
9. New Hebrides (Fr. -- U.K.)
10. Norfolk Island (Aust.)
11. Pitcairn Island (Aust.)
12. Territory of Papua and New Guinea (Aust.)
13. Tokelau Islands (N.Z.)
14. Trust Territory of the Pacific Islands (U.S.)
15. Wallis and Futuna Islands (Fr.)

The following independant countries also participate in the South Pacific

Commission :

16. Independant Western Samoa
17. Nauru Island
18. Kingdom of Tonga

The role played by the South Pacific Commission is one of advising and consulting to the member territories. The activities are determined by the budget which is made up from contributions from the participating Governments and through grants from other organizations and territories.

The main areas of concern are Health, Social Development and Economic Development and to facilitate these operating fields there are two bodies advisory to the Commission: The Research Council and the South Pacific Conference.

"The Commissions purpose is to advise the participating Governments on ways of improving the well-being of the people of the Pacific Island territories. The Commission is concerned with health, economic and social matters." (South Pacific Report 1967)

With such broad terms of reference the coverage must inevitably be extensive rather than intensive, and the importance of the priorities determination to maximize fulfillment of the objectives will be a vital activity.

In carrying out its work the South Pacific Commission operates conferences, meetings, seminars and training courses, it carries on relations with International bodies, as well as its own work program, publications and library.

Within this scope of reference, the physical development and in particular the construction program falls under all three basic concerns as each phase needs physical facilities, hence this area of study is of great importance in the structure of the South Pacific Commission as well as in the actual development of the Island territories.

Appendix 2.

The Simulation Model

The main computer model CONPROG simulates the existing construction operation process in the selected areas of the South Pacific Commission area. It accepts statistical input data, simulates the construction process and projects information to allow monitoring of the model at each cycle which represents one year.

CONPROG Model Statistics

Territories represented

1. American Samoa
2. British Solomon Islands Protectorate
3. Cook Islands
4. Fiji Islands
5. Gilbert and Ellice Islands Colony
6. French Polynesia
7. New Caledonia
8. New Hebrides
9. Territory of Papua and New Guinea
10. Tonga
11. Trust territory of Micronesia
12. Western Samoa

Programming and Computing

All programs were written using PL/1 for the IBM/360 computer.

All computing work was done at the University of Hawaii Statistical and Computing Center.

Statistics

Data points: 12

Input data variables:30

Total data items: 360

Total identifiers: 130

Array variables: 79

Key output variables: 23

Program statements: 524

Computing time : 50 seconds

Input/output computations: 8063

Operation

The model simulates the construction activity of three types of houses sequentially in each of the twelve areas for one time period, it then increments to the next time period and repeats the process. It does this a total of 23 times from 1967 to 1990, this allows utilization of 1967 data, the latest available.

The model is developed with a high level of generality to allow easy adjustment and manipulation of all relevant data items. These can be changed as better data is made available or as a testing procedure to evaluate alternate policies. For instance the population change can be simulated by simple data adjustment of variables such as total population, natural population increase (births over deaths) or migration rate (immigration over emmigration).

The model can also be used as a device to monitor the construction process in operation through time, and to subsequently evaluate alternate strategies progressively.

As explained in the text a total of 19 models were utilized in the testing procedure. The initial model from which all the subsequent models were developed is CONPROG and the program follows. Other major variations were CONPROB, CONPROC and CONPROD.

: PROC OPTIONS (MAIN);


```
CONPROG: PROC OPTIONS (MAIN);
DCL PERAREA1 (12,1967:1990);
DCL FAMILY1 (12,1967:1990);
DCL FAMILY2 (12,1967:1990);
DCL FAMILY3 (12,1967:1990);
DCL COSTFTP1 (12,1967:1990);
DCL COSTFTP2 (12,1967:1990);
DCL COSTFTP3 (12,1967:1990);
DCL CORE1 (12,1967:1990);
DCL SLAREA (12,1967:1990);
DCL COSTFTD1 (12,1967:1990);
DCL COSTFTD2 (12,1967:1990);
DCL COSTFTD3 (12,1967:1990);
DCL MATLFTC (12,1967:1990);
DCL LABFTC (12,1967:1990);
DCL PROFIT (12,1967:1990);
DCL MANHOURSFT (12,1967:1990);
DCL HRRT (12,1967:1990);
DCL MATLFTB (12,1967:1990);
DCL NATINC (12,1967:1990);
DCL IMMIG (12,1967:1990);
DCL TOTPOP (12,1967:1990);
DCL POPROP1 (12,1967:1990);
DCL POPROP2 (12,1967:1990);
DCL POPROP3 (12,1967:1990);
DCL EXPEND (12,1967:1990);
DCL EXPINC(12,1967:1990);
DCL TOTUNITS (12,1967:1990);
DCL MATINC (12,1967:1990);
DCL HRINC (12,1967:1990);
DCL LABINC (12,1967:1990);
DCL HOUSIT (12,1967:1990);
DCL BUDGET (12,1967:1990);
DCL DESCOST (12,1967:1990);
DCL POPHOU (12,1967:1990);
DCL UNITS (12,1967:1990);
DCL QUOTE (12,1967:1990);
DCL TENDER (12,1967:1990);
DCL POPUNHOU (12,1967:1990);
DCL TOTPOPHOU (12,1967:1990);
DCL DENS (12,1967:1990);
DCL TOTCOSTD (12,1967:1990);
DCL AREA (12,1967:1990);
DCL COSTP (12,1967:1990);
DCL UNITSP (12,1967:1990);
DCL AREAP(12,1967:1990);
DCL TOTCOSTP (12,1967:1990);
```

Figure 20

```
...: PROC OPTIONS (MAIN);

    DCL UNITSD (12,1967:1990);
    DCL AREAD (12,1967:1990);
    DCL UNITST (12,1967:1990);
    DCL UNITSQ (12,1967:1990);
    DCL POPINC (12,1967:1990);
    DCL X (23,12,1967:1990);
    DCL NAME (23)  CHAR ( 9);
    DCL TITLE (12) CHAR (40);
    DCL SNAME (23) CHAR (10);
    DCL Y (23,1967:1990);
    DCL SUNITSP (1967:1990);
    DCL SAREAP (1967:1990);
    DCL STOTCOSTP (1967:1990);
    DCL SEXPEND (1967:1990);
    DCL SBUDGET (1967:1990);
    DCL SUNITSD (1967:1990);
    DCL SAREAD (1967:1990);
    DCL STOTCOSTD (1967:1990);
    DCL STENDER (1967:1990);
    DCL SQUOTE (1967:1990);
    DCL SPOPINC (1967:1990);
    DCL STOTPOP (1967:1990);
    DCL SPOPHOU (1967:1990);
    DCL STOTPOPHOU (1967:1990);
    DCL SPOPUNHOU (1967:1990);
    DCL SUNITST (1967:1990);
    DCL SUNITSQ (1967:1990);
    DCL SUNITS (1967:1990);
    DCL STOTUNITS (1967:1990);
    DCL SDESCOST (1967:1990);
    DCL SHOUSIT (1967:1990);
    DCL SDENS (1967:1990);
    DCL SAREA (1967:1990);
    GET LIST (PERAREA1 (*,1967), FAMILY1 (*,1967), FAMILY2 (*,1967),
    FAMILY3 (*,1967), COSTFTP1 (*,1967), COSTFTP2 (*,1967),
    COSTFTP3 (*,1967), CORE1 (*,1967), SLAREA (*,1967),
    COSTFTD1 (*,1967), COSTFTD2 (*,1967), COSTFTD3 (*,1967),
    MATLFTC (*,1967), LABFTC (*,1967), PROFIT (*,1967),
    MANHOURSFT (*,1967), HRRT (*,1967), MATLFTB (*,1967),
    NATINC (*,1967), IMMIG (*,1967), TOTPOP (*,1967),
    POPROP1 (*,1967), POPROP2 (*,1967), POPROP3 (*,1967),
    EXPEND (*,1967), EXPINC (*,1967), TOTUNITS (*,1967),
    MATINC (*,1967), HRINC (*,1967), LABINC (*,1967));
    PUT DATA (PERAREA1 (*,1967), FAMILY1 (*,1967), FAMILY2 (*,1967),
    FAMILY3 (*,1967), COSTFTP1 (*,1967), COSTFTP2 (*,1967),
    COSTFTP3 (*,1967), CORE1 (*,1967), SLAREA (*,1967),
    COSTFTD1 (*,1967), COSTFTD2 (*,1967), COSTFTD3 (*,1967),
```

```
MATLFTC (*,1967), LABFTC (*,1967), PROFIT (*,1967),
MANHOURSFT (*,1967), HRRT (*,1967), MATLFTB (*,1967),
NATINC (*,1967), IMMIG (*,1967), TOTPOP (*,1967),
POPROP1 (*,1967), POPROP2 (*,1967), POPROP3 (*,1967),
EXPEND (*,1967), EXPINC (*,1967), TOTUNITS (*,1967),
MATINC (*,1967), HRINC (*,1967), LABINC (*,1967));
DO I = 1 TO 12;
PERAREA1 (I,*) = PERAREA1 (I,1967);
FAMILY1 (I,*) = FAMILY1 (I,1967);
FAMILY2 (I,*) = FAMILY2 (I,1967);
FAMILY3 (I,*) = FAMILY3 (I,1967);
CORE1(I,*) = CORE1 (I,1967);
SLAREA (I,*) = SLAREA (I,1967);
MANHOURSFT (I,*) = MANHOURSFT (I,1967);
NATINC (I,*) = NATINC (I,1967);
IMMIG (I,*) = IMMIG (I,1967);
POPROP1 (I,*) = POPROP1 (I,1967);
POPROP2 (I,*) = POPROP2 (I,1967);
POPROP3 (I,*) = POPROP3 (I,1967);
EXPINC (I,*) = EXPINC (I,1967);
MATINC (I,*) = MATINC (I,1967);
HRINC (I,*) = HRINC (I,1967);
LABINC (I,*) = LABINC (I,1967);
END;
DO J = 1967 TO 1990;
DO I = 1 TO 12;
/*PROGRAMMING*/
POPUNHOU (I,J) = TOTPOP (I,J) - (TOTUNITS (I,J) * POPROP1 (I,J) *
FAMILY1 (I,J))- (TOTUNITS (I,J) * POPROP2 (I,J) * FAMILY2 (I,J))-
(TOTUNITS (I,J) * POPROP3 (I,J) * FAMILY3 (I,J));
PERAREA2 = PERAREA1 (I,J);
PERAREA3 = PERAREA1 (I,J) * 110/100;
UNAREAP1 = PERAREA1 (I,J) * FAMILY1 (I,J);
UNAREAP2 = PERAREA2 * FAMILY2 (I,J);
UNAREAP3 = PERAREA3 * FAMILY3 (I,J);
UNITSP1 = POPUNHOU (I,J) * POPROP1 (I,J) / FAMILY1 (I,J);
UNITSP2 = POPUNHOU (I,J) * POPROP2 (I,J) / FAMILY2 (I,J);
UNITSP3 = POPUNHOU (I,J) * POPROP3 (I,J) / FAMILY3 (I,J);
AREAP1 = UNAREAP1 * UNITSP1;
AREAP2 = UNAREAP2 * UNITSP2;
AREAP3 = UNAREAP3 * UNITSP3;
COSTP1 = COSTFTP1 (I,J) * UNAREAP1 * UNITSP1;
COSTP2 = COSTFTP2 (I,J) * UNAREAP2 * UNITSP2;
COSTP3 = COSTFTP3 (I,J) * UNAREAP3 * UNITSP3;
TOTCOSTP (I,J) = COSTP1 + COSTP2 + COSTP3;
UNITSP (I,J) = UNITSP1 + UNITSP2 + UNITSP3;
AREAP (I,J) =(AREAP1 + AREAP2 + AREAP3);
```

```
P: PROC OPTIONS (MAIN);

/*BUDGET CONSTRAINT*/
  TOTPOPHOU (I,J) = (TOTUNITS (I,J) * POPROP1 (I,J) *
  FAMILY1 (I,J)) + (TOTUNITS (I,J) * POPROP2 (I,J) *
  FAMILY2 (I,J)) + (TOTUNITS (I,J) * POPROP3 (I,J) * FAMILY3 (I,J));
  HOUSIT (I,J) = TOTPOPHOU (I,J) / TOTPOP (I,J) * 100;
  IF HOUSIT (I,J) > 80 & HOUSIT (I,J) < 100 THEN HOUFAC = 0.1;
  IF HOUSIT (I,J) > 70 & HOUSIT (I,J) <  81 THEN HOUFAC = 0.4;
  IF HOUSIT (I,J) > 60 & HOUSIT (I,J) <  71 THEN HOUFAC = 0.7;
  IF HOUSIT (I,J) > 50 & HOUSIT (I,J) <  61 THEN HOUFAC = 1.0;
  IF HOUSIT (I,J) > 40 & HOUSIT (I,J) <  51 THEN HOUFAC = 1.3;
  IF HOUSIT (I,J) > 30 & HOUSIT (I,J) <  41 THEN HOUFAC = 1.6;
  IF HOUSIT (I,J) < 31 THEN HOUFAC = 2.0;
  IF TOTCOSTP (I,J) >= EXPEND (I,J) * (HOUFAC / 100) THEN DO;
  BUDGET (I,J) = EXPEND (I,J) * (HOUFAC / 100);
  END;
  ELSE DO;
  BUDGET (I,J) = COSTP1 + COSTP2 + COSTP3;
  END;
/*EXPENDITURE ANNUAL INCREASE*/
  EXPEND (I,J+1) = EXPEND (I,J) * ((100 + EXPINC (I,J)) / 100);
/*DESIGN*/
  CORE2 = CORE1 (I,J);
  CORE3 = CORE1 (I,J) * 110 /100;
  UNAREAD1 = CORE1 (I,J) + (FAMILY1 (I,J) * SLAREA (I,J));
  UNAREAD2 = CORE2       + (FAMILY2 (I,J) * SLAREA (I,J));
  UNAREAD3 = CORE3       + (FAMILY3 (I,J) * SLAREA (I,J));
  COSTUNITD1 = UNAREAD1 * COSTFTD1 (I,J);
  COSTUNITD2 = UNAREAD2 * COSTFTD2 (I,J);
  COSTUNITD3 = UNAREAD3 * COSTFTD3 (I,J);
  UNITSD1 = BUDGET (I,J) * POPROP1 (I,J) / COSTUNITD1;
  UNITSD2 = BUDGET (I,J) * POPROP2 (I,J) / COSTUNITD2;
  UNITSD3 = BUDGET (I,J) * POPROP3 (I,J) / COSTUNITD3;
  UNITSD (I,J) = UNITSD1 + UNITSD2 + UNITSD3;
  AREAD (I,J) =((UNAREAD1 * UNITSD1) + (UNAREAD2 * UNITSD2) +
  (UNAREAD3 * UNITSD3));
  TOTCOSTD (I,J) = (UNITSD1 * COSTUNITD1) +
  (UNITSD2 * COSTUNITD2) + (UNITSD3 * COSTUNITD3);
/*SCALE EFFECT*/
  IF UNITSD (I,J) >   0 & UNITSD (I,J) <   6 THEN FAC = 90;
  IF UNITSD (I,J) >   5 & UNITSD (I,J) <  11 THEN FAC = 90;
  IF UNITSD (I,J) >  10 & UNITSD (I,J) <  21 THEN FAC = 80;
  IF UNITSD (I,J) >  20 & UNITSD (I,J) <  51 THEN FAC = 70;
  IF UNITSD (I,J) >  50 & UNITSD (I,J) < 101 THEN FAC = 60;
  IF UNITSD (I,J) > 100 & UNITSD (I,J) < 501 THEN FAC = 50;
  IF UNITSD (I,J) > 500 THEN FAC = 40;
/*TENDER*/
  COSTFTC1 = (MATLFTC (I,J) + LABFTC (I,J)) * (FAC / 100);
```

```
  COSTFTC2 = (MATLFTC (I,J) + LABFTC (I,J)) * (FAC / 100);
  COSTFTC3 = 1.2 * (MATLFTC (I,J) + LABFTC (I,J)) * (FAC / 100);
  MATLFTC (I,J+1) = MATLFTC (I,J) * MATINC (I,J) / 100;
  LABFTC (I,J+1) = LABFTC (I,J) * LABINC (I,J) / 100;
  COSTUNITC1 = UNAREAD1 * COSTFTC1;
  COSTUNITC2 = UNAREAD2 * COSTFTC2;
  COSTUNITC3 = UNAREAD3 * COSTFTC3;
  TENDER(I,J) = ((PROFIT(I,J) + 100)/100) * ((COSTUNITC1 * UNITSD1) +
  (COSTUNITC2 * UNITSD2) + (COSTUNITC3 * UNITSD3));
/*QUOTE*/
  COSTFTB1 =(MANHOURSFT (I,J) * HRRT (I,J) + MATLFTB (I,J)) *
  (FAC / 100);
  COSTFTB2 =(MANHOURSFT (I,J) * HRRT (I,J) + MATLFTB (I,J)) *
  (FAC / 100);
  COSTFTB3 =(MANHOURSFT (I,J) * HRRT (I,J) + MATLFTB (I,J)) *
  (FAC / 100) * 1.2;
  HRRT (I,J+1) = HRRT (I,J) * HRINC (I,J) / 100;
  MATLFTB (I,J+1) = MATLFTB (I,J) * MATINC (I,J) / 100;
  COSTUNITB1 = UNAREAD1 * COSTFTB1;
  COSTUNITB2 = UNAREAD2 * COSTFTB2;
  COSTUNITB3 = UNAREAD3 * COSTFTB3;
  QUOTE (I,J) = (COSTUNITB1 * UNITSD1) + (COSTUNITB2 * UNITSD2) +
  (COSTUNITB3 * UNITSD3);
/*CONSTRUCTION CHOICE - POLICY FAVORS CONTRACTOR*/
  IF TENDER (I,J) <= BUDGET (I,J) THEN DO;
/*CONTRACT    COST = TENDER*/
  PROFIT (I,J+1) = 10.0;
  UNITST (I,J) = UNITSD1 + UNITSD2 + UNITSD3;
  UNITSQ (I,J) = 0;

/*HOUSING SITUATION    CONTRACT*/
  TOTUNITS (I,J+1) = TOTUNITS (I,J) + UNITST (I,J);
  POPHOU (I,J) = (UNITSD1 * FAMILY1 (I,J) + UNITSD2 *
  FAMILY2 (I,J) + UNITSD3 * FAMILY3 (I,J));
  TOTPOPHOU (I,J) = (TOTUNITS (I,J) * POPROP1 (I,J) *
  FAMILY1 (I,J)) + (TOTUNITS (I,J) * POPROP2 (I,J) * FAMILY2 (I,J)) +
  (TOTUNITS (I,J) * POPROP3 (I,J) * FAMILY3 (I,J));
  POPUNHOU (I,J) = TOTPOP (I,J) - TOTPOPHOU (I,J);
 *COST INFORMATION FEEDBACK TO PROGRAMMING*/
  COSTFTP1 (I,J+1) = COSTFTC1;
  COSTFTP2 (I,J+1) = COSTFTC2;
  COSTFTP3 (I,J+1) = COSTFTC3;
 *FEEDBACK TO DESIGN*/
  COSTFTD1 (I,J+1) = (COSTFTC1 + COSTFTB1) / 2;
  COSTFTD2 (I,J+1) = (COSTFTC2 + COSTFTB2) / 2;
  COSTFTD3 (I,J+1) = (COSTFTC3 + COSTFTB3) / 2;
  END;
```

```
    ELSE DO;
  /*DIRECT LABOUR    COST = QUOTE*/
  /*IF COSTS TOO HIGH   PROGRAM CUT*/
    UNITS1 = BUDGET (I,J) * POPROP1 (I,J) / COSTUNITB1;
    UNITS2 = BUDGET (I,J) * POPROP2 (I,J) / COSTUNITB2;
    UNITS3 = BUDGET (I,J) * POPROP3 (I,J) / COSTUNITB3;
    PROFIT (I,J+1) = 9.0;
    UNITSQ (I,J) = UNITS1 +UNITS2 +UNITS3;
    UNITST (I,J) = 0;

  /*HOUSING SITUATION    QUOTE OR DIRECT LABOR*/
    TOTUNITS (I,J+1) = TOTUNITS (I,J) + UNITSQ (I,J);
    POPHOU (I,J) = (UNITSD1 * FAMILY1 (I,J) + UNITSD2 *
    FAMILY2 (I,J) + UNITSD3 * FAMILY3 (I,J));
    TOTPOPHOU (I,J) = (TOTUNITS (I,J) * POPROP1 (I,J) *
    FAMILY1 (I,J)) + (TOTUNITS (I,J) * POPROP2 (I,J) * FAMILY2 (I,J)) +
    (TOTUNITS (I,J) * POPROP3 (I,J) * FAMILY3 (I,J));
    POPUNHOU (I,J) = TOTPOP (I,J) - TOTPOPHOU (I,J);
  /*COST INFORMATION FEEDBACK TO PROGRAMMING*/
    COSTFTP1 (I,J+1) = COSTFTC1;
    COSTFTP2 (I,J+1) = COSTFTC2;
    COSTFTP3 (I,J+1) = COSTFTC3;
  /*FEEDBACK TO DESIGN*/
    COSTFTD1 (I,J+1) = (COSTFTC1 + COSTFTB1) / 2;
    COSTFTD2 (I,J+1) = (COSTFTC2 + COSTFTB2) / 2;
    COSTFTD3 (I,J+1) = (COSTFTC3 + COSTFTB3) / 2;
    END;
    UNITS (I,J) = UNITSQ (I,J) + UNITST (I,J);
  /*POPULATION INCREASE - NATURAL AND IMMIGRATION*/
    DENS (I,J) = TOTPOP (I,J) / TOTUNITS (I,J);
    TOTPOP (I,J+1) = TOTPOP (I,J) *
    ((100 + NATINC (I,J) + IMMIG (I,J)) / 100);
    POPINC (I,J) = TOTPOP (I,J+1) - TOTPOP (I,J);
  /*DESIGN COST*/
    IF UNITS (I,J) >    0 & UNITS (I,J) <   21 THEN TEAMNO = 1;
    IF UNITS (I,J) >   20 & UNITS (I,J) <   51 THEN TEAMNO = 2;
    IF UNITS (I,J) >   50 & UNITS (I,J) <   76 THEN TEAMNO = 3;
    IF UNITS (I,J) >   75 & UNITS (I,J) <  101 THEN TEAMNO = 4;
    IF UNITS (I,J) >  100 & UNITS (I,J) <  201 THEN TEAMNO = 5;
    IF UNITS (I,J) >  200 & UNITS (I,J) <  501 THEN TEAMNO = 6;
    IF UNITS (I,J) >  500 & UNITS (I,J) <1001 THEN TEAMNO = 7;
    IF UNITS (I,J) > 1000 THEN TEAMNO = 8;
    DESCOST (I,J) = TEAMNO * 10000;
    AREA (I,J) = (UNITSD1 * UNAREAD1) + (UNITSD2 * UNAREAD2) +
    (UNITSD3 * UNAREAD3);
    END;
    SUNITSP (J) = SUM (UNITSP (*,J));
```

: PROC OPTIONS (MAIN);


```
SAREAP (J) = SUM (AREAP (*,J));
STOTCOSTP (J) = SUM (TOTCOSTP (*,J));
SEXPEND (J) = SUM (EXPEND (*,J));
SBUDGET (J) = SUM (BUDGET (*,J));
SUNITSD (J) = SUM (UNITSD (*,J));
SAREAD (J) = SUM (AREAD (*,J));
STOTCOSTD (J) = SUM (TOTCOSTD (*,J));
STENDER (J) = SUM (TENDER (*,J));
SQUOTE (J) = SUM (QUOTE (*,J));
SPOPINC (J) = SUM (POPINC (*,J));
STOTPOP (J) = SUM (TOTPOP (*,J));
SPOPHOU (J) = SUM (POPHOU (*,J));
STOTPOPHOU (J) = SUM (TOTPOPHOU (*,J));
SPOPUNHOU (J) = SUM (POPUNHOU (*,J));
SUNITST (J)= SUM (UNITST (*,J));
SUNITSQ (J)= SUM (UNITSQ (*,J));
SUNITS (J) = SUM (UNITS (*,J));
STOTUNITS (J) = SUM (TOTUNITS (*,J));
SDESCOST (J) = SUM (DESCOST (*,J));
SHOUSIT (J) = SUM (HOUSIT (*,J));
SDENS (J) = SUM (DENS (*,J));
SAREA (J) = SUM (AREA (*,J));
END;
PUT PAGE;
X(1,*,*) = UNITSP     (*,*);
X(2,*,*) = AREAP      (*,*);
X(3,*,*) = TOTCOSTP   (*,*);
X(4,*,*) = EXPEND     (*,*);
X(5,*,*) = BUDGET     (*,*);
X(6,*,*) = UNITSD     (*,*);
X(7,*,*) = AREAD      (*,*);
X(8,*,*) = TOTCOSTD   (*,*);
X(9,*,*) = TENDER     (*,*);
X(10,*,*) = QUOTE      (*,*);
X(11,*,*) = POPINC     (*,*);
X(12,*,*) = TOTPOP     (*,*);
X(13,*,*) = POPHOU     (*,*);
X(14,*,*) = TOTPOPHOU  (*,*);
X(15,*,*) = POPUNHOU   (*,*);
X(16,*,*) = UNITST     (*,*);
X(17,*,*) = UNITSQ     (*,*);
X(18,*,*) = UNITS      (*,*);
X(19,*,*) = TOTUNITS   (*,*);
X(20,*,*) = DESCOST    (*,*);
X(21,*,*) = HOUSIT     (*,*);
X(22,*,*) = DENS       (*,*);
X(23,*,*) = AREA       (*,*);
```

```
: PROC OPTIONS (MAIN);

  GET LIST (NAME);
  DO J = 1970 TO 1990;
  PUT SKIP (3);
  PUT EDIT ('AMSM        BSIP        COOK        FIJI        GEIC        FRPY        NO
     NHEB        TPNG        TONG        TTMR        WESM') (COLUMN (15),A(120));
  PUT SKIP (2);
  DO K = 1 TO 23;
  PUT LIST (NAME (K));
  PUT EDIT (X(K,1,J)) (COLUMN (10),F(10,1));
  DO I = 2 TO 12;
  PUT EDIT (X(K,I,J)) (F(10,1));
  END;
  PUT SKIP;
  END;
  PUT SKIP (3);
  PUT LIST (J);
  PUT PAGE;
  END;
  PUT PAGE;
  Y (1,*) = SUNITSP (*);
  Y (2,*) = SAREAP (*);
  Y (3,*) = STOTCOSTP (*);
  Y (4,*) = SEXPEND (*);
  Y (5,*) = SBUDGET (*);
  Y (6,*) =SUNITSD (*);
  Y (7,*) = SAREAD (*);
  Y (8,*) = STOTCOSTD (*);
  Y (9,*) = STENDER (*);
  Y (10,*) = SQUOTE (*);
  Y (11,*) = SPOPINC (*);
  Y (12,*) = STOTPOP (*);
  Y (13,*) = SPOPHOU (*);
  Y (14,*) = STOTPOPHOU (*);
  Y (15,*) = SPOPUNHOU (*);
  Y (16,*) =SUNITST (*);
  Y (17,*) =SUNITSQ (*);
  Y (18,*) =SUNITS (*);
  Y (19,*) = STOTUNITS (*);
  Y (20,*) = SDESCOST (*);
  Y (21,*) = SHOUSIT (*);
  Y (22,*) = SDENS (*);
  Y (23,*) = SAREA (*);
  GET LIST (SNAME);
  PUT EDIT ('1970              1975              1980              1985              1
  ) ( COLUMN (19),A(120));
  PUT SKIP (2);
  DO K = 1 TO 23;
```

```
)G: PROC OPTIONS (MAIN);
```



```
PUT LIST (SNAME (K));
PUT EDIT (Y(K,1970))(COLUMN (10),F(15,1));
DO J = 1975 TO 1990 BY 5;
PUT EDIT (Y(K,J)) (F(15,1));
END;
PUT SKIP;
END;
PUT PAGE;
GET LIST (TITLE);
DO I = 1 TO 12;
DO K = 0 TO 100 BY 10;
PUT EDIT (K) (COLUMN (K+10),F(3));
END;
PUT SKIP;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP;
DO J = 1970 TO 1990;
PUT LIST (J);
PUT EDIT ('P') (COLUMN ((TOTPOPHOU (I,J) / 1000)+12),P'X');
PUT EDIT ('T')        (COLUMN ((TOTPOP(I,J) / 1000)+12),P'X');
PUT SKIP (2);
END;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP (3);
PUT LIST ('KEY');
PUT SKIP (2);
PUT LIST
('P = POPULATION HOUSED * 1000, T = TOTAL POPULATION * 1000');
PUT SKIP (3);
PUT LIST (TITLE (I));
PUT PAGE;
DO K = 0 TO 100 BY 10;
PUT EDIT (K) (COLUMN (K+10),F(3));
END;
PUT SKIP;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP;
DO J = 1970 TO 1990;
PUT LIST (J);
IF (EXPEND (I,J) / 10000) < 112 THEN DO;
PUT EDIT ( 'B' )       (COLUMN ((BUDGET(I,J) / 10000)+12),P'X');
```

```
PUT EDIT ( 'E' )        (COLUMN ((EXPEND(I,J) / 10000)+12),P'X');
END;
ELSE DO;
PUT EDIT ( 'B' )        (COLUMN ((BUDGET(I,J) / 10000)+12),P'X');
PUT EDIT (EXPEND (I,J) / 10000) (COLUMN (112),F(10,1));
END;
PUT SKIP (2);
END;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP (3);
PUT LIST ('KEY');
PUT SKIP (2);
PUT LIST ('E = EXPENDITURE * 10000, B = HOUSING BUDGET *10000');
PUT SKIP (3);
PUT LIST (TITLE (I));
PUT PAGE;
DO K = 0 TO 100 BY 10;
PUT EDIT (K) (COLUMN (K+10),F(3));
END;
PUT SKIP;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP;
DO J = 1970 TO 1990;
PUT LIST (J);
PUT EDIT ('S')        (COLUMN ((UNITS(I,J) / 100)+12),P'X');
PUT EDIT ('U')        (COLUMN ((TOTUNITS (I,J) / 100)+12),P'X');
PUT SKIP (2);
END;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP (3);
PUT LIST ('KEY');
PUT SKIP (2);
PUT LIST ('S = ANNUAL HOUSING UNIT PRODUCTION *100');
PUT LIST ('U = TOTAL NUMBER OF HOUSING UNITS *100');
PUT SKIP (3);
PUT LIST (TITLE (I));
PUT PAGE;
DO K = 0 TO 100 BY 10;
PUT EDIT (K) (COLUMN (K+10),F(3));
END;
PUT SKIP;
```

```
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP;
DO J = 1970 TO 1990;
PUT LIST (J);
PUT EDIT ('D') (COLUMN ((DENS(I,J)) +12),P'X');
PUT SKIP (2);
END;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP (3);
PUT LIST ('KEY');
PUT SKIP (2);
PUT LIST ('D = DENSITY (PEOPLE PER HOUSE)');
PUT SKIP (3);
PUT LIST (TITLE (I));
PUT PAGE;
DO K = 0 TO 100 BY 10;
PUT EDIT (K) (COLUMN (K+10),F(3));
END;
PUT SKIP (2);
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP;
DO J = 1970 TO 1990;
PUT LIST (J);
PUT EDIT ('A') (COLUMN ((AREA(I,J) /10000) +12),P'X');
PUT SKIP (2);
END;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP (3);
PUT LIST ('KEY');
PUT SKIP (2);
PUT LIST ('A = AREA OF HOUSING BUILT * 10000');
PUT SKIP (3);
PUT LIST (TITLE (I));
PUT PAGE;
END;
END CONPROG;
```

```
JG: PROC OPTIONS (MAIN);
```



```
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP;
DO J = 1970 TO 1990;
PUT LIST (J);
PUT EDIT ('D')        (COLUMN ((DESCOST(I,J) /1000)+12),P'X');
PUT SKIP (2);
END;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP (3);
PUT LIST ('KEY');
PUT SKIP (2);
PUT LIST ('D = ANNUAL DESIGN COST *1000');
PUT SKIP (3);
PUT LIST (TITLE (I));
PUT PAGE;
DO K = 0 TO 100 BY 10;
PUT EDIT (K) (COLUMN (K+10),F(3));
END;
PUT SKIP;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP;
DO J = 1970 TO 1990;
PUT LIST (J);
PUT EDIT ('H'        ) (COLUMN ((HOUSIT(I,J) )+12),P'X');
PUT SKIP (2);
END;
DO K = 0 TO 100 BY 10;
PUT EDIT ('|') (COLUMN (K+12),P'X');
END;
PUT SKIP (3);
PUT LIST ('KEY');
PUT SKIP (2);
PUT LIST ('H = PERCENTAGE OF POPULATION HOUSED');
PUT SKIP (3);
PUT LIST (TITLE (I));
PUT PAGE;
DO K = 0 TO 100 BY 10;
PUT EDIT (K) (COLUMN (K+10),F(3));
END;
PUT SKIP;
DO K = 0 TO 100 BY 10;
```

Identifiers and their meaning

Unless otherwise stated identifiers relate to one territory and one time period or year.

AREA	:	Total housing area constructed.
AREAD	:	Housing area designed.
AREAP	:	Housing area programmed.
AREAP1	:	Type 1 housing area programmed.
AREAP2	:	Type 2 housing area programmed.
AREAP3	:	Type 3 housing area programmed.
BUDGET	:	Proportion of expenditure allocated to housing construction.
CORE1	:	Services area for type 1 house.
CORE2	:	Services area for type 2 house.
CORE3	:	Services area for type 3 house.
COSTFTB1	:	Square foot cost rate for direct labor construction of type 1 house.
COSTFTB2	:	Square foot cost rate for direct labor construction of type 2 house.
COSTFTB3	:	Square foot cost rate for direct labor construction of type 3 house.
COSTFTC1	:	Square foot cost rate for contract construction of type 1 house.
COSTFTC2	:	Square foot cost rate for contract construction of type 2 house.
COSTFTC3	:	Square foot cost rate for contract construction of type 3 house.
COSTFTD1	:	Estimate of square foot cost rate for house type 1 at design stage.
COSTFTD2	:	Estimate of square foot cost rate for house type 2 at design stage.

COSTFTD3	:	Estimate of square foot cost rate for house type 3 at design stage.
COSTFTP1	:	Estimate of square foot cost rate for house type 1 at program stage.
COSTFTP2	:	Estimate of square foot cost rate for house type 2 at program stage.
COSTFTP3	:	Estimate of square foot cost rate for house type 3 at program stage.
COSTP	:	Total cost of all house types at program stage.
COSTP1	:	Sum cost of house type 1 at program stage.
COSTP2	:	Sum cost of house type 2 at program stage.
COSTP3	:	Sum cost of house type 3 at program stage.
COSTUNITB1	:	Direct labor construction cost of house type 1.
COSTUNITB2	:	Direct labor construction cost of house type 2.
COSTUNITB3	:	Direct labor construction cost of house type 3.
COSTUNITC1	:	Contract construction cost of house type 1.
COSTUNITC2	:	Contract construction cost of house type 2.
COSTUNITC3	:	Contract construction cost of house type 3.
COSTUNITD1	:	Estimated cost of house type 1 at design stage.
COSTUNITD2	:	Estimated cost of house type 2 at design stage.
COSTUNITD3	:	Estimated cost of house type 3 at design stage.
DENS	:	Average number of people per available house.
DESCOST	:	Cost of design of houses.
EXPEND	:	Total expenditure.
EXPINC	:	Percentage annual increase in expenditure.
FAC	:	Factor derived from the scale effect of quantity.
FAMILY1	:	Number of members in family type 1.
FAMILY2	:	Number of members in family type 2.
FAMILY3	:	Number of members in family type 3.
HOUFAC	:	Factor determined by the housing situation which determines housing budget.

HOUSIT	:	Percentage of people satisfactorily housed as determined by present standards.
HRINC	:	Percentage annual increase in hourly work rates.
HRRT	:	Hourly rates of pay determined from skilled and unskilled figures.
I	:	Identifier representing the number of territories.
IMMIG	:	Percentage of population immigrating to the urban area.
J	:	Identifier representing the total time span.
K	:	General purpose Identifier.
LABFTC	:	Labor rate per foot for contract house construction.
LABINC	:	Percentage increase in labor rates.
MANHOURSFT	:	Number of manhours per square foot of building.
MATINC	:	Percentage annual increase in material costs.
MATLFTB	:	Cost of materials per square foot of housing constructed by contract.
NAME	:	Data list of the names of territories.
NATINC	:	Percentage of natural population increase.
PERAREA1	:	Standard area rate per person housed in house type 1.
PERAREA2	:	Standard area rate per person housed in house type 2.
PERAREA3	:	Standard area rate per person housed in house type 3.
POPHOU	:	Number of people housed satisfactorily per time cycle.
POPINC	:	Total population increase per time cycle.
POPROP1	:	Proportion of population of family size 1.
POPROP2	:	Proportion of population of family size 2.
POPROP3	:	Proportion of population of family size 3.
POPUNHOU	:	Number of people not satisfactorily housed.
PROFIT	:	Profit rate required by contractors.
QUOTE	:	Estimate for direct labor construction work.
SAREA	:	
SAREAD	:	
SAREAP	:	

SBUDGET	:	
SDENS	:	
SDESCOST	:	
SEXPEND	:	
SHOUSIT	:	
SLAREA	:	
SNAME	:	
SPOPHOU	:	
SPOPINC	:	
SQUOTE	:	Identifiers SAREA to SUNITST represent the sum
STENDER	:	of the identifier, minus the initial "S" for all
STOTCOSTD	:	territories.
STOTCOSTP	:	
STOTPOP	:	
STOTPOPHOU	:	
STOTUNITS	:	
SUNITS	:	
SUNITSD	:	
SUNITSP	:	
SUNITSQ	:	
SUNITST	:	
TEAMNO	:	Number of design teams required to cope with construction program.
TENDER	:	Bid by contractor for housing construction.
TITLE	:	Data list of the graph titles.
TOTCOSTD	:	Total cost of complete project at design stage.
TOTCOSTP	:	Total cost of complete project at programming stage.
TOTPOP	:	Total population.
TOTPOPHOU	:	Population satisfactorily housed.
TOTUNITS	:	Total inventory of housing units.
UNAREAD1	:	Floor area of housing unit type 1 at design stage.

UNAREAD2	:	Floor area of housing unit type 2 at design stage.
UNAREAD3	:	Floor area of housing unit type 3 at design stage.
UNAREAP1	:	Floor area of housing unit type 1 at programming stage.
UNAREAP2	:	Floor area of housing unit type 2 at programming stage.
UNAREAP3	:	Floor area of housing unit type 3 at programming stage.
UNITS	:	Actual housing units constructed.
UNITS1	:	Actual house type 1 units constructed.
UNITS2	:	Actual house type 2 units constructed.
UNITS3	:	Actual house type 3 units constructed.
UNITSD	:	Number of housing units designed.
UNITSD1	:	Number of housing units type 1 designed.
UNITSD2	:	Number of housing units type 2 designed.
UNITSD3	:	Number of housing units type 3 designed.
UNITSP	:	Number of housing units programmed.
UNITSP1	:	Number of housing units type 1 programmed.
UNITSP2	:	Number of housing units type 2 programmed.
UNITSP3	:	Number of housing units type 3 programmed.
UNITSQ	:	Number of housing units constructed by direct labor.
UNITST	:	Number of housing units constructed by contract.
X	:	Data array.
Y	:	Data array.

Appendix 3.

Sample Output

In all cases the printer has been used as the output device but this has been used to produce output data in two forms.

1. Tables of the key variables for each territory. One table has been produced for each year in time. Appropriate notation identifies each table. Another table shows the total of all key variables from all areas, these are set out in five year intervals which relate to the charts produced in the results.

2. Graphical output has been used to present the change of the variables over the total time spectrum. Each variable with its related variables is graphed on the same chart to facilitate comparisons. For instance total population is graphed with the total population housed. This chart implicitly also shows the population that is not housed (the difference between the population housed and the total population) and the number of people housed in each year (the increment in the population housed). The other charts have similar implications.

Figure 21

	1970	1975	1980	1985	1990
SUNITS	18061.0	21184.2	27191.1	35973.6	48111.4
SAREAP	12741211.0	14897536.0	19146352.0	25373616.0	34201568.0
STOTCOSTP	26339488.0	31545376.0	40391552.0	51040192.0	69254928.0
SEXPEND	199439760.0	238797888.0	286289664.0	343675392.0	413110528.0
SBUDGET	1224790.0	1335919.0	1537206.0	2294961.0	2435698.0
SUNITSD	1404.3	1375.6	1545.2	2712.1	2376.0
SAREAD	814458.1	804391.6	902062.8	1490268.0	1416631.0
STOTCOSTD	1224789.0	1335918.0	1537205.0	2294960.0	2435697.0
STENDER	1641960.0	1666152.0	1912812.0	2648793.0	2900474.0
SQUOTE	1047077.7	1101950.0	1330015.0	1972539.0	2207654.0
SPOPINC	12223.4	15974.8	21044.6	28002.0	37724.0
STOTPOP	238140.3	306319.2	395708.9	513944.6	672063.0
SPOPHOU	8378.2	8252.4	9178.2	15527.0	14382.9
STOTPOPHOU	128003.6	178252.4	231467.3	296277.3	379005.8
SPOPUNHOU	110136.6	128066.6	164241.3	217667.1	293057.0
SUNITST	0.0	0.0	0.0	1176.8	144.7
SUNITSQ	1648.7	1664.4	1790.2	1789.4	2485.1
SUNITS	1648.7	1664.4	1790.2	2966.1	2629.8
STOTUNITS	20830.3	28850.1	37433.0	47882.3	61234.2
SDESCOST	450000.0	490000.0	510000.0	550000.0	580000.0
SHOUSIT	675.6	705.0	695.9	680.5	664.3
SDENS	154.9	146.0	149.5	156.2	165.1
SAREA	814458.1	804391.6	902062.8	1490268.0	1416631.0

Figure 22

	AMSM	BSIP	COOK	FIJI	GEIC	FRPY	NCAL	NHEB	TPNG	TONG	TTMR	WESM
UNITSP	965.5	754.0	1155.5	4219.6	1217.4	1555.1	5238.0	318.8	1877.8	4986.3	1055.2	3847.9
AREAP	895583.0	397338.1	778038.7	3038093.0	819747.7	1031019.0	3634220.0	214645.6	1021829.6	3153056.0	761222.1	3401564.0
TOTCOSTP	2319903.0	486542.3	952711.9	4741436.0	1756622.0	2145428.0	10146248.0	306640.4	1042696.2	6756631.0	1242826.0	8493908.0
EXPEND	16631260.0	7195784.0	5257323.0	33134800.0	2489149.0	71264960.0	32809840.0	6020960.0	98978704.0	1714012.0	1864872.0	8928648.0
BUDGET	166312.6	50370.5	52573.2	231943.6	32358.9	285059.6	426527.5	24083.8	98978.6	34280.2	18648.7	116072.3
UNITSD	89.4	91.1	78.6	279.4	29.4	287.4	277.4	30.5	227.8	40.2	16.4	97.7
AREAD	73920.4	45453.7	47441.4	179041.1	17742.1	154499.6	170607.7	18415.4	99832.7	21117.4	10538.0	63453.7
TOTCOSTD	166312.3	50370.5	52573.2	231943.3	32358.9	285059.4	426527.1	24083.8	98978.5	34280.2	18648.7	116072.3
TENDER	206374.2	60403.0	63044.5	302244.4	41260.5	347749.9	513457.8	28550.7	110555.1	49110.6	18671.6	171392.4
QUOTE	144254.9	45677.1	47674.6	188477.4	27006.4	252906.6	385839.6	22062.9	96987.9	23589.5	20283.4	75258.7
POPINC	2094.3	659.7	923.6	3327.4	754.0	1875.5	3199.2	377.0	2638.9	2047.5	791.7	2356.1
TOTPOP	17452.9	13197.5	18476.5	83230.5	15082.9	37518.7	53321.6	7541.4	52790.2	34125.8	15837.0	47134.1
POPHOU	728.7	483.7	526.8	1971.1	197.0	1440.3	1506.9	204.5	1131.2	213.3	118.5	656.3
TOTPOPHOU	9624.4	9263.5	10773.2	53445.3	6966.6	29743.3	24750.6	5416.2	43592.8	8110.5	8300.2	21481.2
POPUNHOU	7828.5	3934.0	7703.4	29785.3	8116.3	7775.4	28570.9	2125.2	9197.4	26015.3	7536.9	25652.8
UNITST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNITSQ	103.1	100.4	86.7	344.0	35.2	324.0	306.8	33.3	232.5	58.4	15.1	150.7
UNITS	103.1	100.4	86.7	344.0	35.2	324.0	306.8	33.3	232.5	58.4	15.1	150.7
TOTUNITS	1145.8	1597.2	1584.3	7423.0	1024.5	5719.9	4419.8	796.5	8072.7	1398.4	1092.1	3159.0
DESCOST	50000.0	50000.0	40000.0	60000.0	20000.0	60000.0	60000.0	20000.0	60000.0	30000.0	10000.0	50000.0
HOUSIT	55.1	70.2	58.3	64.2	46.2	79.3	46.4	71.8	82.6	23.8	52.4	45.6
DENS	15.2	8.3	11.7	11.2	14.7	6.6	12.1	9.5	6.5	24.4	14.5	14.9
AREA	73920.4	45453.7	47441.4	179041.1	17742.1	154499.6	170607.7	18415.4	99832.7	21117.4	10538.0	63453.7

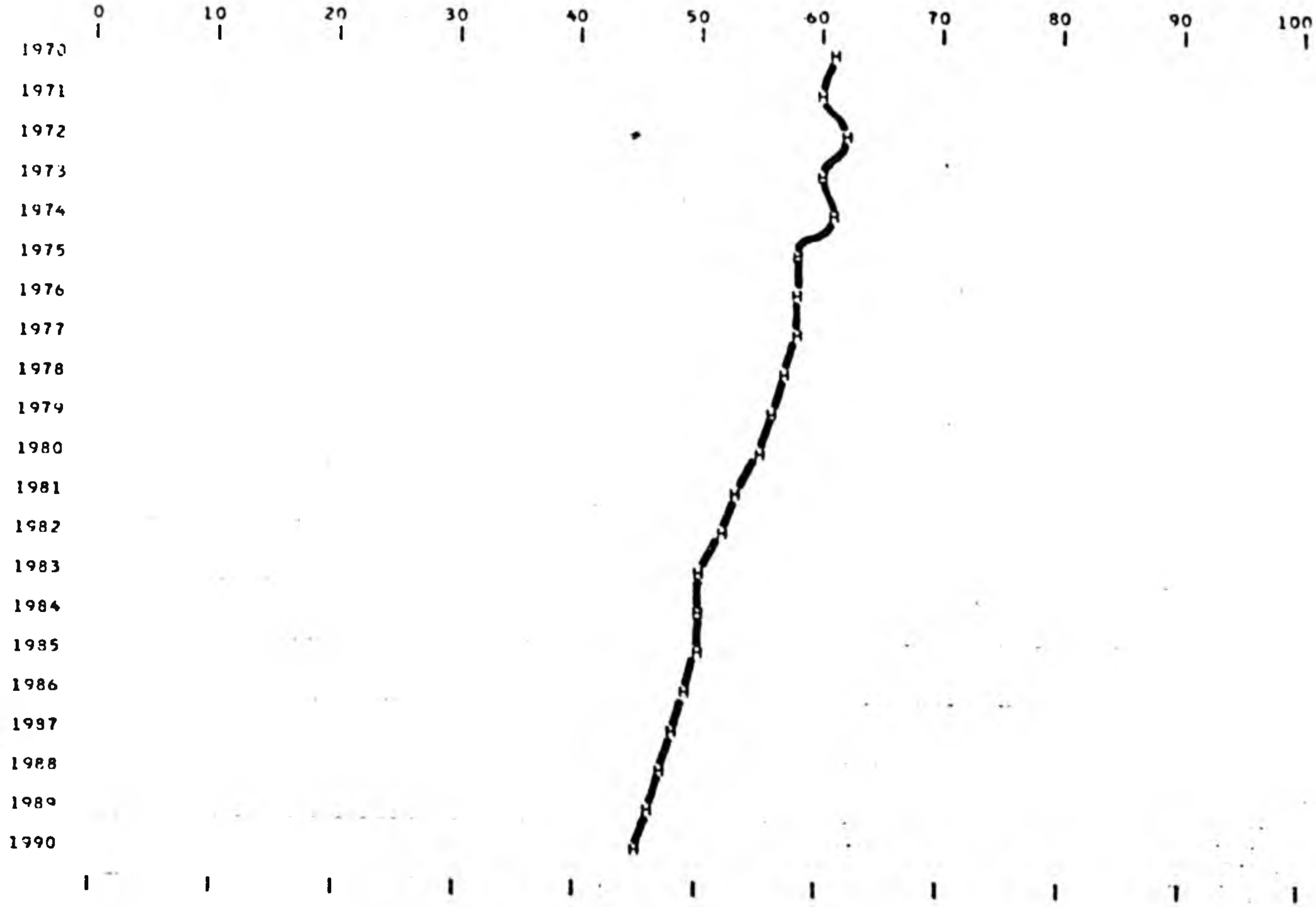
1980

Figure 23

	AMSM	USIP	COOK	FIJI	GEIC	FRPY	NCAL	NHEB	TPNG	TONG	TTMR	WESM
UNITSP	3660.4	1235.3	1922.1	5870.2	2217.9	2371.7	9201.7	542.3	3215.2	9459.5	2158.5	6256.2
AREAP	3395649.0	650965.3	1294214.0	4226538.0	1493378.0	1572433.0	6384291.0	365172.3	1749592.0	5981710.0	1557207.0	5530473.0
TOTCOSIP	7330031.0	664258.5	1584771.0	6596199.0	3200135.0	3272049.0	17824064.0	447155.1	1785320.0	12818105.0	2224609.0	11509264.0
EXPEND	27090256.0	9670501.0	7065379.0	49047472.0	3345193.0	05489440.0	53443312.0	8091641.0	33018640.0	2089355.0	2760458.0	11999320.0
BUDGET	352173.0	67693.5	70653.8	343332.3	53523.1	421957.4	694762.4	56641.5	133018.6	41797.1	44167.3	155991.[illegible]
UNITSD	220.1	141.5	101.8	396.0	47.5	411.0	430.6	82.1	298.9	48.4	42.9	155.1
AREAD	182056.1	70603.6	61409.3	253768.0	28686.2	220955.4	264824.1	49574.3	130998.3	25413.4	27625.3	100719.9
TOTCOSTD	352172.8	67693.4	70653.7	343332.0	53523.0	421957.1	694762.1	56641.4	133018.4	41787.1	44167.3	155990.9
TENDER	423557.6	78904.3	68005.1	428390.0	66711.8	497326.9	797000.6	66483.1	145067.8	59101.2	43221.7	226708.4
QUOTE	318173.4	64210.8	55849.0	296892.7	46096.8	390831.9	665610.8	53069.6	133610.4	29465.4	49335.8	104511.1
POPINC	6504.2	1074.5	1504.3	4924.3	1228.0	3054.6	5729.1	614.0	4297.9	3666.6	1289.4	3337.4
TOTPOP	54203.8	21494.8	30092.8	123175.1	24565.5	61106.9	95488.4	12282.7	85979.3	61112.7	25793.8	76767.3
POPHOU	1794.7	751.3	681.9	2793.8	318.5	2059.8	2339.1	550.5	1484.4	256.7	310.5	1041.7
TOTPOPHOU	24521.5	15049.6	17278.8	81738.3	9779.6	49248.4	45297.4	8667.1	70231.4	11758.6	10375.9	35059.4
POPUNHOU	29682.3	6445.2	12814.0	41436.8	14785.9	11858.5	50191.1	3615.6	15747.9	49354.1	15417.9	41708.0
UNITST	0.0	0.0	101.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.9	0.0
UNITSQ	243.7	149.1	0.0	458.1	55.2	443.8	449.7	87.7	297.6	68.6	0.0	231.5
UNITS	243.7	149.1	101.8	458.1	55.2	443.8	449.7	87.7	297.6	68.6	42.9	231.5
TOTUNITS	2919.2	2594.8	2541.0	11352.6	1438.2	9470.9	8088.8	1274.6	13005.8	2027.3	1365.3	5155.8
DESCOST	60000.0	50000.0	50000.0	60000.0	30000.0	60000.0	60000.0	40000.0	60000.0	30000.0	20000.0	60000.0
HOUSIT	45.2	70.0	57.4	66.4	39.8	80.6	47.4	70.6	81.7	19.2	40.2	45.7
DENS	18.6	8.3	11.8	10.8	17.1	6.5	11.8	9.6	6.6	30.1	18.9	14.9
AREA	182056.1	70603.6	61409.3	253768.0	28686.2	220955.4	264824.1	49574.3	130998.3	25413.4	27625.3	100719.9

1990

Figure 24

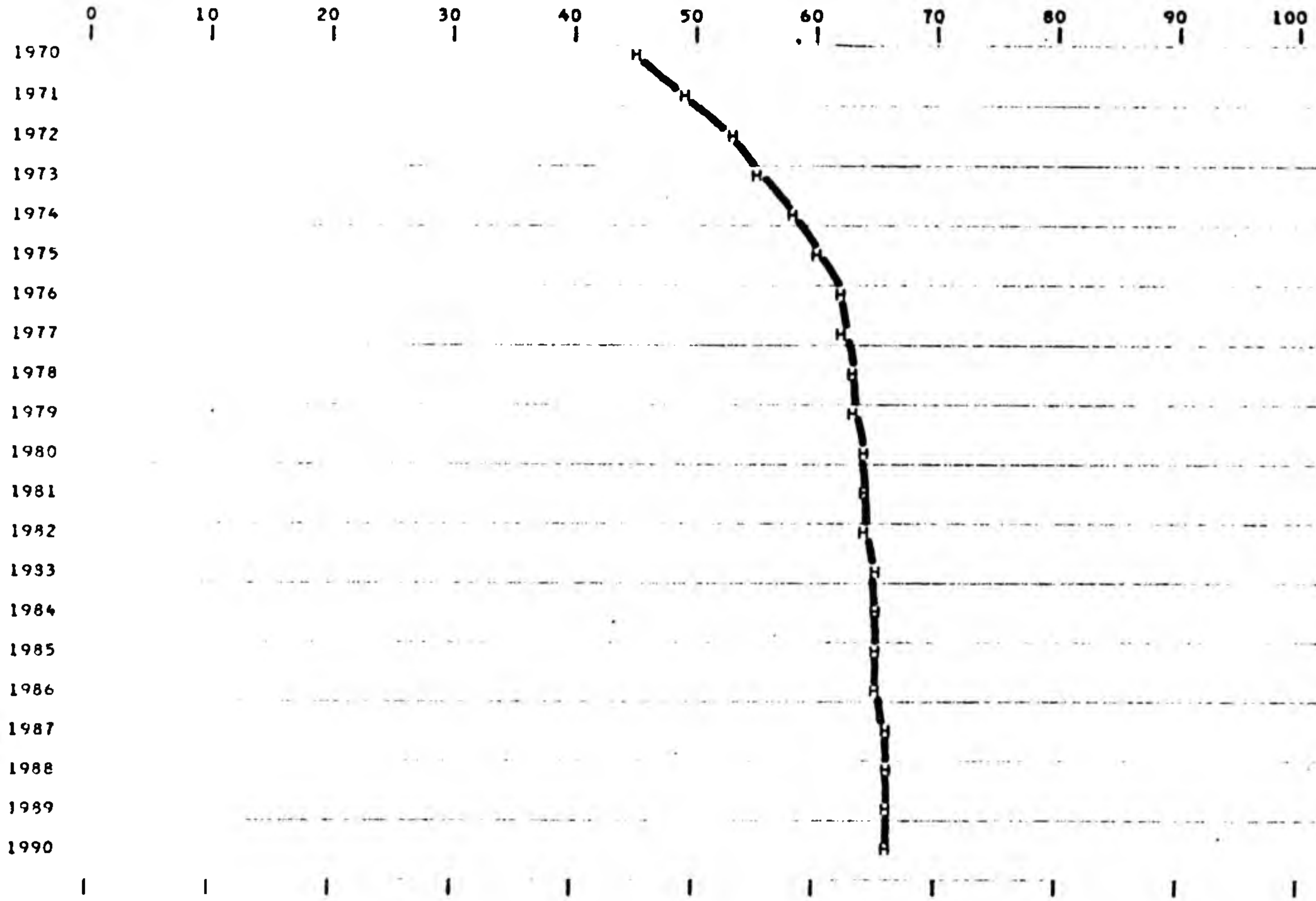


KEY

H = PERCENTAGE OF POPULATION HOUSED

AMERICAN SAMOA

Figure 25

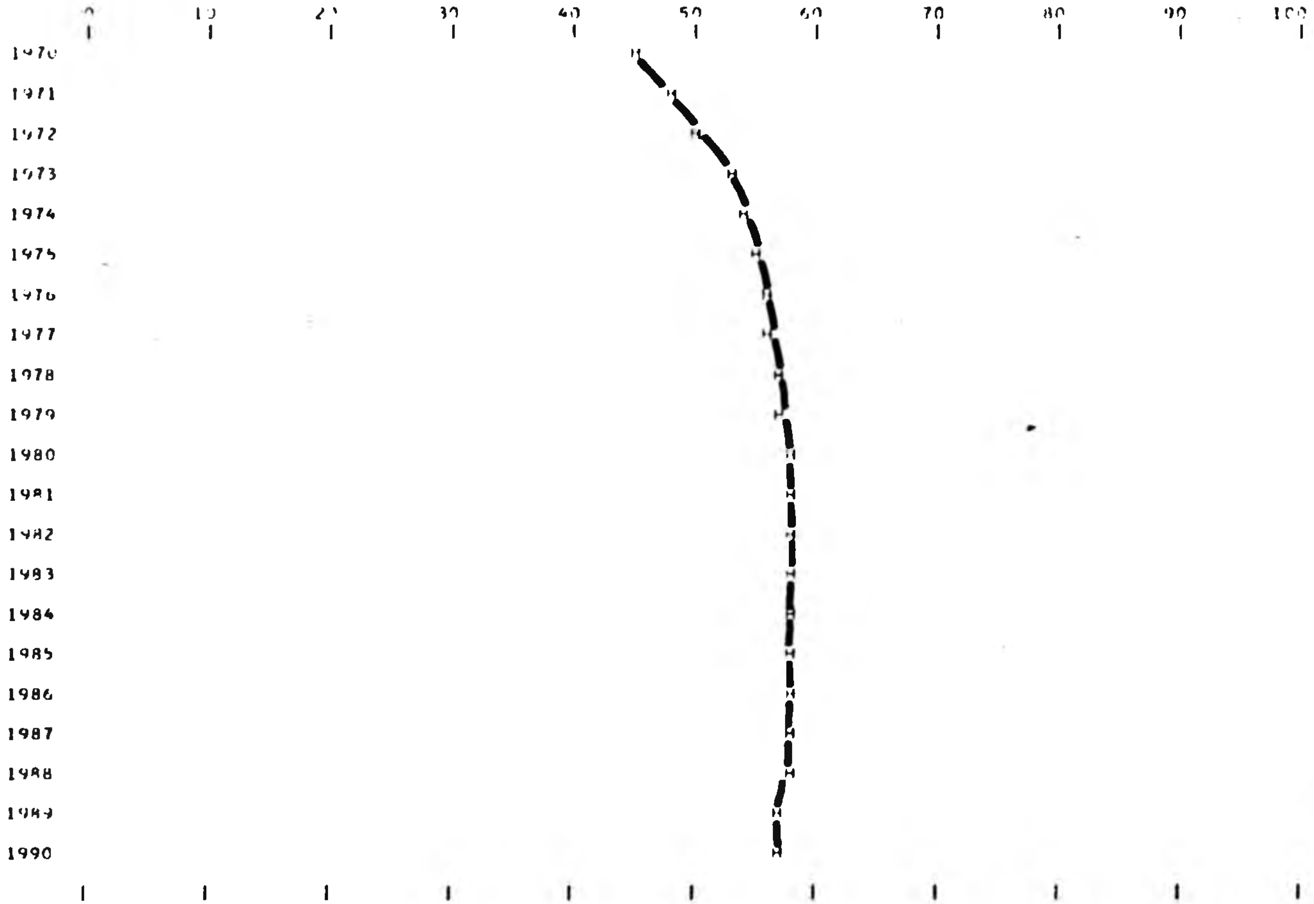


KEY

H = PERCENTAGE OF POPULATION HOUSED

FIJI ISLANDS

Figure 26

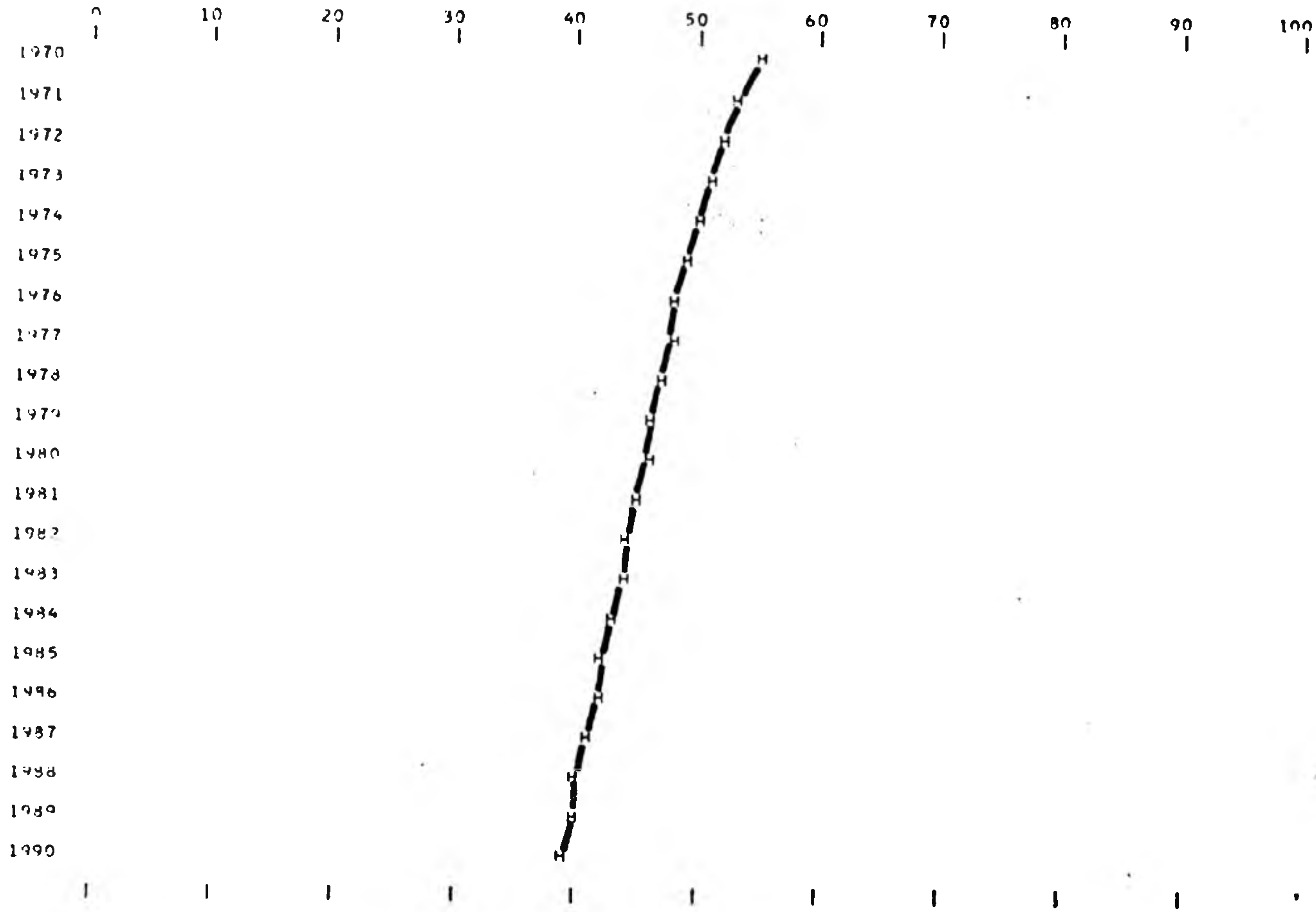


KEY

H = PERCENTAGE OF POPULATION HOUSED

COOK ISLANDS

Figure 27

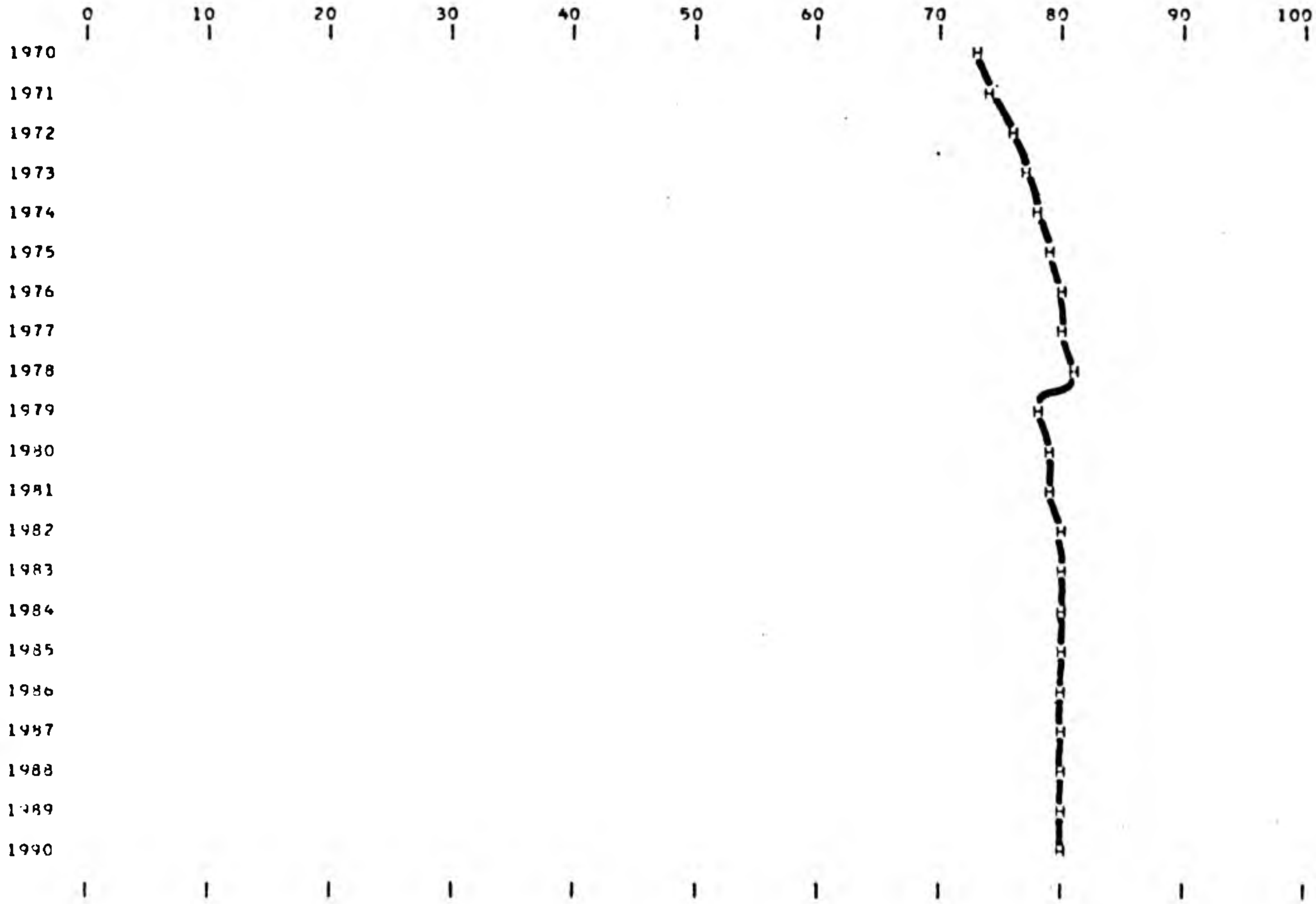


KEY

H = PERCENTAGE OF POPULATION HOUSED

FRENCH POLYNESIA

Figure 28

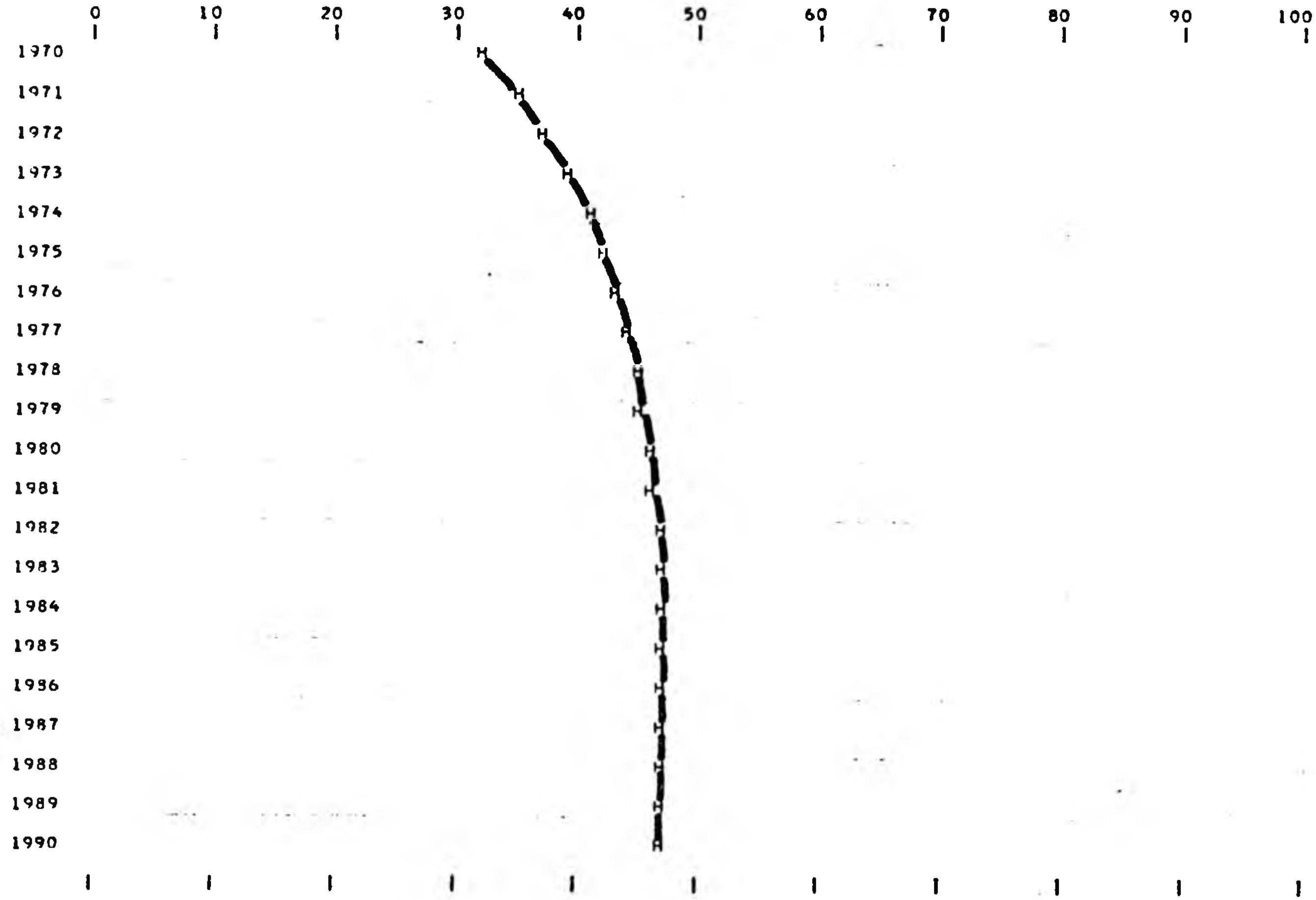


KEY

H = PERCENTAGE OF POPULATION HOUSED

GILBERT AND ELLICE ISLANDS

Figure 29

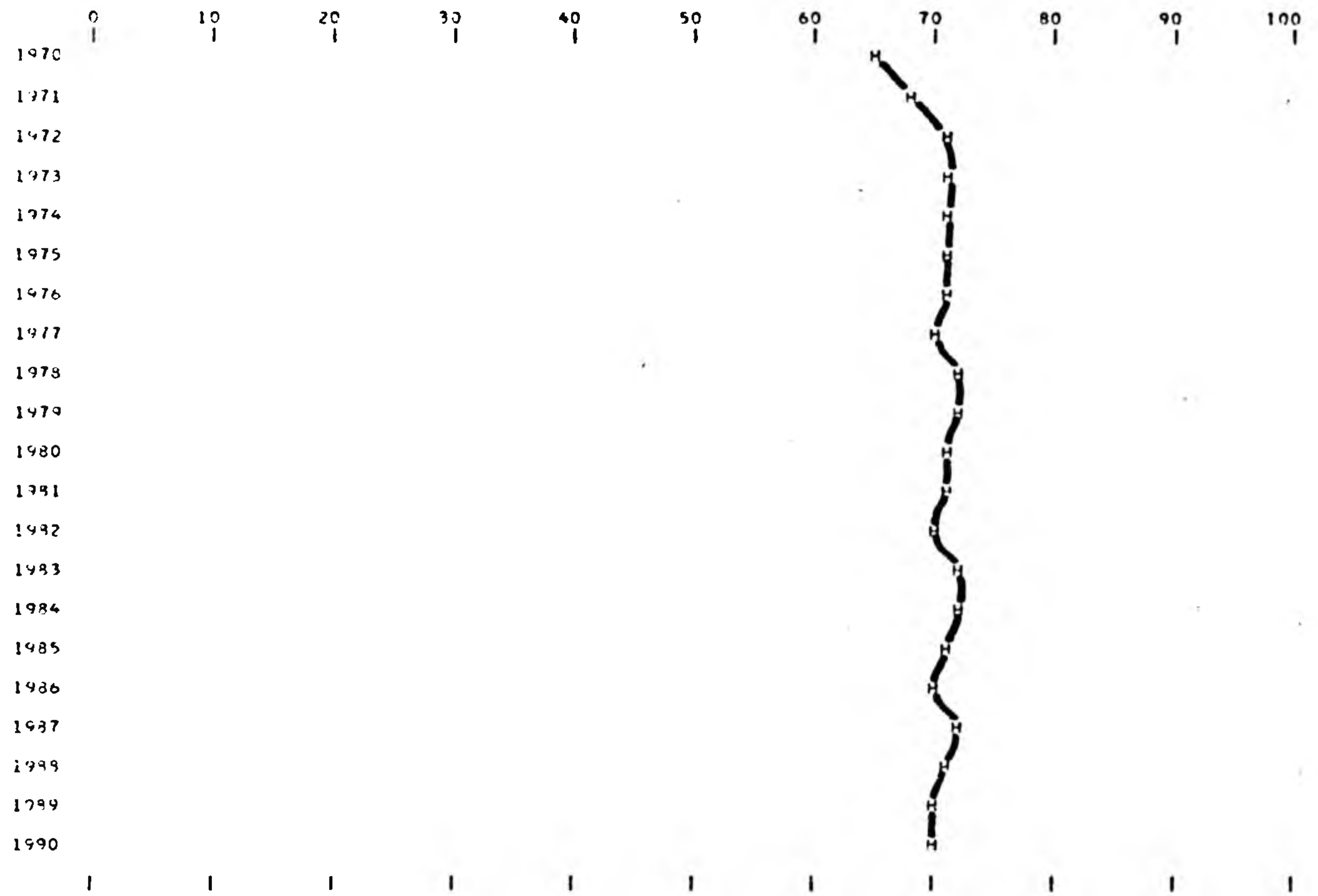


KEY

H = PERCENTAGE OF POPULATION HOUSED

NEW CALEDONIA

Figure 30

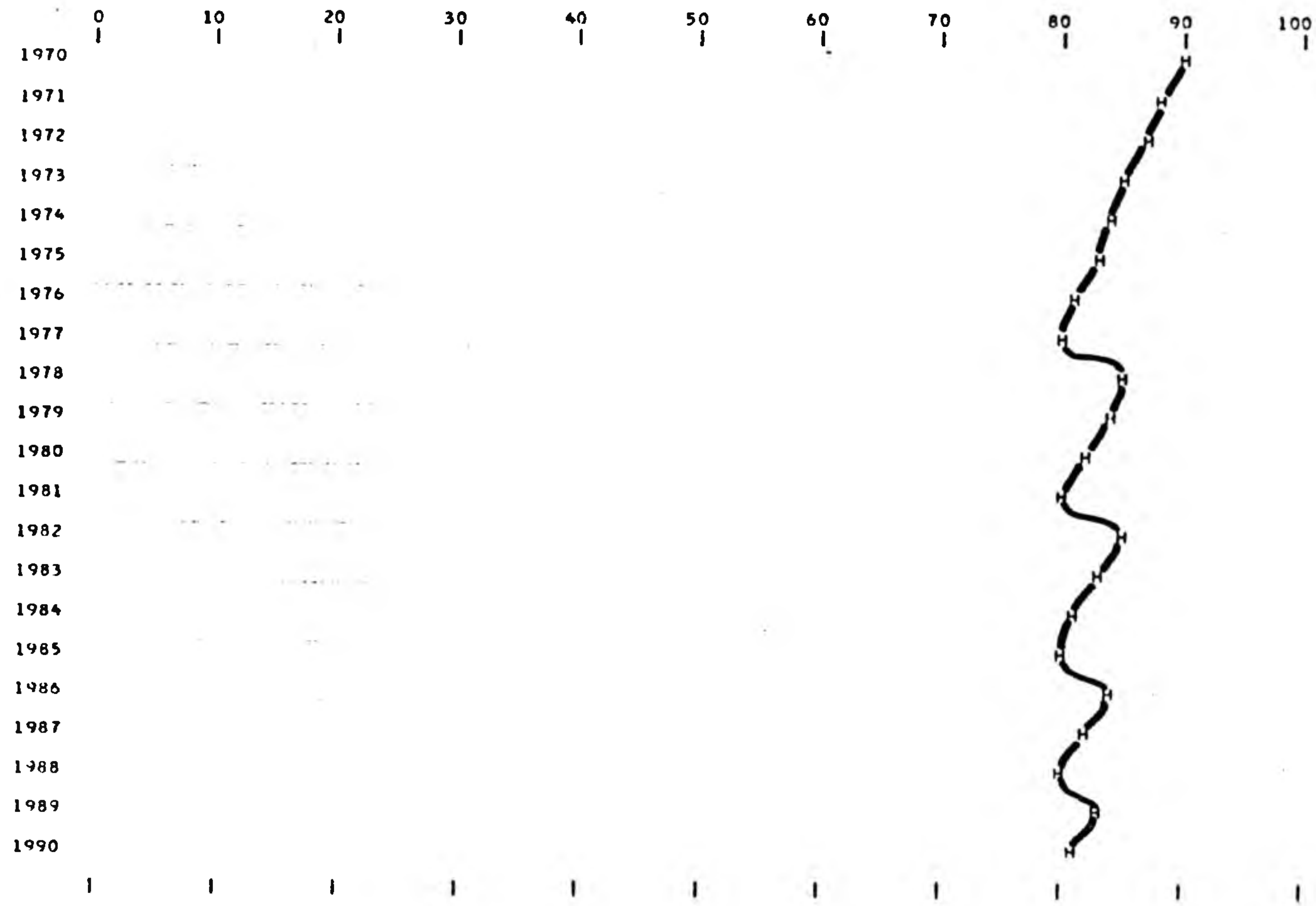


KEY

H = PERCENTAGE OF POPULATION HOUSED

NEW HEBRIDES

Figure 31

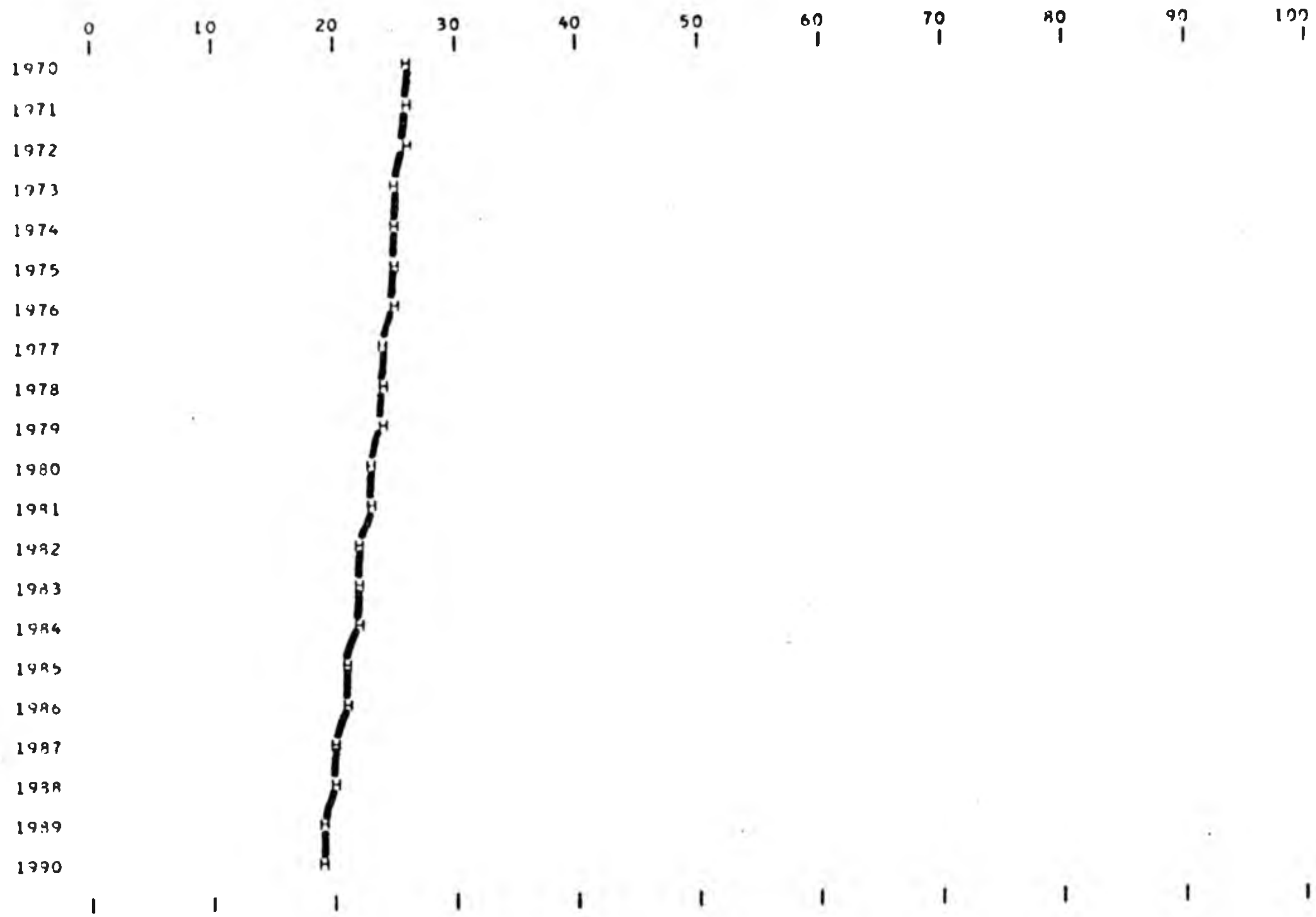


KEY

H = PERCENTAGE OF POPULATION HOUSED

TERRITORY OF PAPUA NEW GUINEA

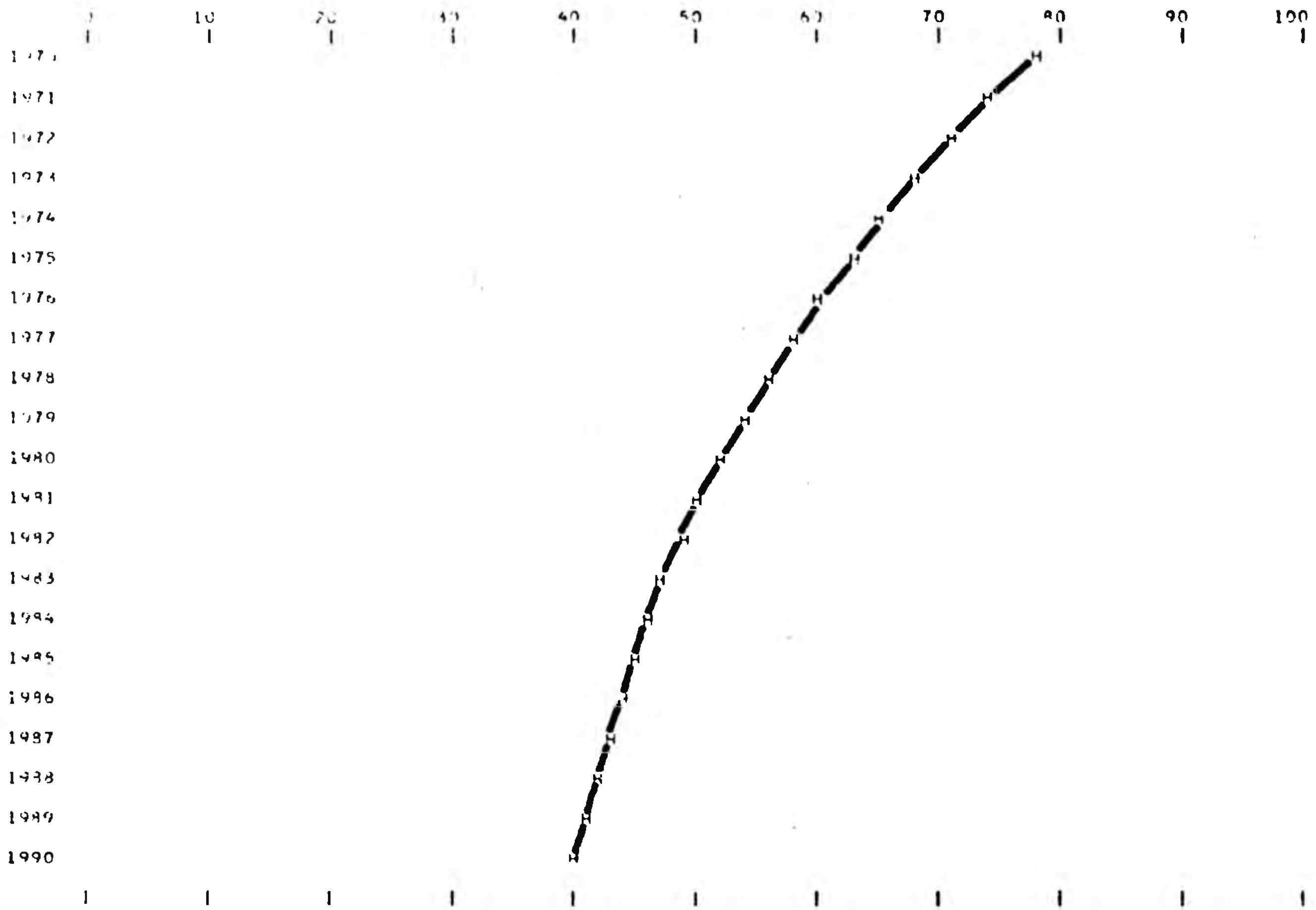
Figure 32



KEY

H = PERCENTAGE OF POPULATION HOUSED

TONGA



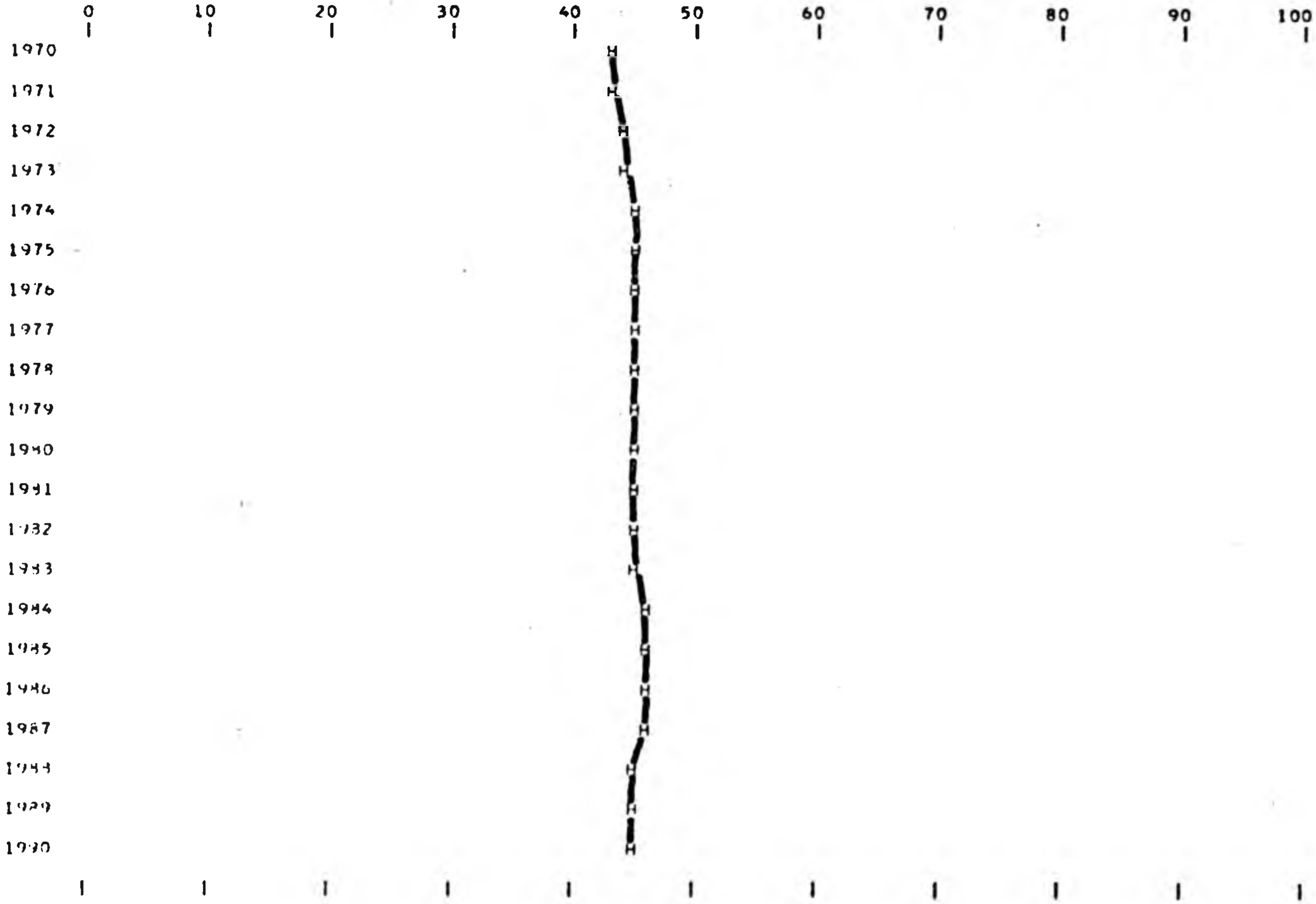
KEY

H = PERCENTAGE OF POPULATION HOUSED

TRUST TERRITORY OF MICRONESIA

Figure 33

Figure 34



KEY

H = PERCENTAGE OF POPULATION HOUSED

WESTERN SAMOA

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