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A first generation simulator of Thailand transportation system

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A FIRST GENERATION SIMULATOR OF THE THAILAND TRANSPORTATION SYSTEM

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A FIRST GENERATION SIMULATOR OF THE

THAILAND TRANSPORTATION SYSTEM

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ABSTRACT

This paper describes a first effort to simulate the transportation system of Thailand. Although not programmed for computer use, the simulator is documented in flow diagram form so that it might be easily programmed. Movement of six basic commodities by highway, rail, and inland waterway is considered between major centers in the country. Input data is furnished, and a sample simulation is documented. Possible areas for future work are also discussed.

ERRATA SHEET

1. Page 2, lines 2 and 3: hyphenate "pro-grammed" vice "program-med".
2. Page 5, stem VIII: close parenthesis after "served".
3. Page 5, stem IX: "Cassava" vice "Cassasa".
4. Page 26, line 2: "each" vice "eack".
5. Page 32, third line from bottom: (5, 6, 2) vice (5, 6, 3).
6. Page 35, Figure 5: Add flow line from block 4 to block 5.
7. Page 43, line 1: change semi-colon to a comma.
8. Page 44, paragraph 2, line 2: "Malaysia" vice "Malaysis".
9. Page 44, paragraph 2, lines 3 and 4: "as-sumed" vice "assum-ed".
10. Page 48, seventh line from bottom: insert "and" between "kenaf" and "maize".
11. Page 48, bottom line: insert "and" between "Kerosene" and "diesel oil".
12. Page 51, lines 16 and 17: hyphenate "capa-bility" vice "cap-ability".
13. Page 53, lines 1 and 2: "capa-bilities" vice "cap-abilities".
14. Page 55, Table XIV, note "a": "400" vice "40".
15. Page 59, paragraph 2, line 4: change comma after "preferred cost" to semi-colon.
16. Page 67, line 2: insert "23" in the blank space following "page".
17. Page 81, stem 13, lines 2 and 3: hyphenate "pro-grammed" vice "program-med".

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CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM

The country of Thailand -- due to its strategic location in Southeast Asia, its friendly government, and its economic importance in Southeast Asian affairs -- is increasingly becoming a point of interest to the United States. The United States Department of Defense is currently expending a great deal of time and effort examining Thailand's military capability. In particular, DOD is closely scrutinizing the ability of the Thai government to fight a counterinsurgency action. The effectiveness of a counterinsurgency action depends to a large extent on how well the counterinsurgency forces can be supported logistically. Thus, the adequacy of the transportation system of Thailand is of critical importance.

The problem considered in this paper is that of designing a model, adaptable to computerization, which will simulate the transportation system of Thailand. The effort is to simulate the system as it is at the present time so that it might be adjusted later to simulate phenomena of interest, and is not an effort to find an "optimum" system: nor will evaluations be made as to how "efficient" the present system is.

PURPOSE

The basic purpose of the Thailand transportation simulator is to allow a researcher to simulate various aspects of the transportation of goods within Thailand by suitable manipulation of input parameters. For example, one might modify the parameters to simulate a system in which the major emphasis is on movement of goods by rail, and compare the results with those obtained by placing major emphasis on transportation by inland waterway.[1]

By modeling the system as it is now, one need only change the value of the parameter representing the capacity of a rail line to determine the effect of damage to or loss of that section of railroad, whether from an act of sabotage or natural disaster. To determine the effect of a military build-up in a particular area on the transportation system as a whole, one would need only to make a small number of changes to the input parameters, such as increasing the quantity of supplies required in the area and changing the primary supply point for that area. By changing other combinations of parameters, effects of other phenomena may be estimated. For example, the effect of installing a more efficient rail system might be simulated by increasing the value of the parameter representing the tonnage of goods which may be shipped over each rail link in each time period.

METHOD OF ATTACK

The transportation system of Thailand is envisioned as a network of nodes representing supply and distribution points which are connected by arcs, each arc representing

[1] Research Analysis Corporation, Computer Simulation Of A Theater Transportation System: A Feasibility Study, Research Analysis Corporation, TP-146 (McLean, Virginia: Research Analysis Corporation, 1965), p. 4.

one of the various modes of transportation between two nodes. For example, two nodes may be connected by one arc representing a highway, a second arc representing a rail-road line, and a third representing an inland waterway connection. By specifying arc capacities (the tonnage per unit time which can be transported over the transportation link represented by the arc), and other parameters, one can essentially represent the salient aspects of the transportation system.

The completed simulator attempts to duplicate the procedures which are normally involved in the operation of a transportation system. This includes determining the availability of commodities at designated supply points, and through pre-set decision rules, determining the proper mode of transport and route to be followed in the re-supply action.

SCOPE OF THE SIMULATION

Due to time limitations and the limited storage space in most of today's computers, all possible combinations of types of goods, routes and modes of transportation, supply and distribution points, and possible scenarios cannot be included. Thus, the scope of the problem has been limited here in four significant ways.

In this paper, only three modes of transportation will be considered. These are highway, rail, and inland waterway. It is felt that the exclusion of air from consideration is done with little loss of accuracy since at the present time the amount of freight transported within Thailand by air is very small.[2] It is recognized that military air facilities within Thailand are being used to transport military goods, but this type of transport activity will not be considered here. However, the simulator could be easily modified to handle transport by air if, for example, one wished to study the effect of improved air transport facilities on the transportation system.

A second assumption inherent in the model is that there is no full-scale war within Thailand. It is to be suspected that at the outbreak of hostilities, the transportation network would be changed to a considerable degree, due to the destruction of existing facilities, the construction of new facilities, and an increasing use of air transport. This problem will not be considered here. However, a simulation of the current transportation system should be a reasonable framework within which to examine transportation problems in a counterinsurgency situation.

The simulator will include the transport of only principal commodities. Included here will be petroleum products, rice products, rubber, tin, lumber products, and one class including cassava, kenaf, and maize. These particular commodities were chosen because they constitute a significant percentage (approximately 60%) of the tonnage

[2] Robert L. Pendleton, Thailand (New York: Duell, Sloan and Pearce, 1962), p. 283.

transported within Thailand.[3] It is recognized that if the present counterinsurgency effort were expanded into a full-scale war, the relative importance of these and other commodities would be changed drastically.

The final limitation of the scope is built into the network itself. Although Thailand is divided politically into subdivisions called Changwads (analogous to small states), the simulator considers only major geographical and economic subdivisions. This is thought to be a relatively minor limitation, since expanding the system to include more nodes would involve only a regrouping of the data and a change to the network.

The intent of this paper is to provide a basic structure for the transportation simulator. It is envisioned that as a follow-up to this effort, the limitations can be reduced one by one. As more detail is added, the results obtained and the conclusions reached by use of this model should become more and more realistic.

[3] Robert J. Muscat, Development Strategy in Thailand: A Study of Economic Growth (New York: Frederick A. Praeger, 1966), pp. 82, 221; Pendleton, op. cit., pp. 306-311; State Railway of Thailand, RSR Information Booklet (Bangkok, Thailand: Nai Utai Sanguanvai, 1966), p. 27; and United States Department of Agriculture, Economic Research Service, Regional Analysis Division, Foreign Agricultural Economic Report No. 8: Agricultural Diversification and Economic Development in Thailand (Washington: Government Printing Office, 1961), pp. 4, 13.

CHAPTER II

THE NETWORK

NETWORK ASSOCIATED ASSUMPTIONS

1. There is sufficient storage capacity within each geographical area of Thailand to accommodate the supplies transported into that area.

2. All subdivisions within each geographical area can be supplied by a central supply point in the area.

RATIONALE

The transportation system of Thailand is envisioned as a network of nodes joined by arcs. A node on the network is a representation of a supply or distribution point for commodities considered in the simulator. The nodes are joined by arcs which represent the modes of transportation being considered between the nodes.

The existence of arcs on the network does not necessarily imply the actual existence of that mode of transportation on the ground. Those arcs which are not physically present in Thailand will be represented in the simulator as having zero capacity. (That is, the maximum tonnage which can be transported along these arcs is zero.) This is to enable the user of the simulator to expand the network, either because of actual expansion on the ground or as part of an experiment, with a minimum of effort. For example, if a new highway is constructed, the user has only to change the arc capacity of one arc rather than to rewrite the simulator. If a researcher wished to know what effect on the transportation system a proposed rail link might have, he again would need only to change one number.

The problem to be considered utilizing this network is that of the transportation of major commodities within Thailand. This includes imports, which will be traced from their points of entry into Thailand to their final destination; and exports, which will move along the network from their points of origin to the node from which they depart the country.

The problem of distributing the supplies to the subdivisions within the geographical/economic area represented by a particular node is not considered within the scope of this problem. For example, supplies shipped to the southern Central Plain will be traced in the network to the supply point for the southern Central Plain (Bangkok), but will not be traced from the supply point to the Changwads within that area.

GEOGRAPHICAL DIVISION OF THAILAND

The present transportation system of Thailand, even with the advent of modern techniques, reflects the physical environment -- topography, climate, vegetation -- and man's use of the land in the different sections of the country. On the basis of the differences of these characteristics, Thailand may be divided into four regions: (1) Northeast Thailand (the Khorat); (2) the Central Plain; (3) Northern Thailand; and (4) Peninsular Thailand.

(1) Northeast Thailand (the Khorat). The erratic rainfall and the quick drying soils inhibit the production

of the region's most important commodity, rice. These same soils, however, make relatively good roads. Almost the entire Khorat is suited to ox-cart traffic and is crisscrossed by a network of rough tracks which carry considerable traffic during the dry season. Since the Mun-Chi River system is usable only during the flood period of September-October, and since rice is shipped during the winter dry season, land transport becomes all-important. It is by ox-cart that the outlying areas of the Khorat have been linked with the supply point for the area and the rail line.[4]

As the road system is modernized and more mechanized means of transport such as trucks are introduced, the transportation system of the region will become more efficient.[5]

(2) Central Plain. The rainfall in this region supplemented by irrigation water from the rivers flowing from North Thailand to the Bangkok delta plain and the dark heavy clay soil combine to make this region the rice basket of Thailand. Although the Central Plain has only 24% of

[4]Pendleton, op. cit., pp. 285-286

[5]John Hugh Jones, Economic Benefits From Development Roads in Thailand, Seato Graduate School of Engineering, Technical Note No. 15 (Thailand: Seato Graduate School of Engineering, 1964), p. 11.

Thailand's land and 35% of its people, rice production in this region is in excess of 50% of the country's annual crop.[6]

The waterways, river, and navigable canals which make the region a rich rice-growing area also make all-weather motor roads relatively rare.[7] In the Central Valley these waterways form the main highways throughout the entire year. Generally, the few usable roads, as well as the railway system, are only supplementary to the waterways. The inland waterways are the transportation system of the Central Plain.

(3) North Thailand. Although this mountainous region is about the same size as, and receives about as much rain as the Central Plain, its major commodity is teak instead of rice. The rice production is limited by the small amount of level land found on the valley floors. Most of the region is still covered with mixed deciduous forest which is the source of most of the teak harvest. This region also provides irrigation water for the Central Plain.[8]

[6] Harold D. Smith, Agricultural Production and Consumption Patterns: Market Potential in Thailand, Department of Agricultural Economics, University of Maryland (Maryland: University of Maryland, 1963), p. 8.

[7] Angelo C. Giarranta, The Highway System of Thailand, Research Analysis Corporation Field Office-Thailand, FP-2, (Thailand: Research Analysis Corporation, 1964), pp. 13, 14.

[8] "Thailand", Encyclopaedia Britannica, XXI (New York: The Encyclopaedia Britannica, Inc., 1967), p. 926.

In the narrow valley plains and in the foothills, the major form of transportation is ox-cart. In the mountains, carriers and pack trains form the transportation system beyond and around the rail terminus at Chiangmai. This system is seasonal, as only during the dry winters are the mountain trails passable; and it is in this season that farmers have no field work and can act as carriers, form pack trains, and drive carts.

Here, as in Northeast Thailand, as the road and rail systems are expanded and modernized, the transportation system will become more efficient.

(4) Peninsular Thailand. This area is the rubber and mining region of Thailand. Its physical location, shape and output have required the development of a high payload transportation system. Thus it is that the greatest progress in road construction has been made in the Peninsula.[9] For many of the same reasons, the railroad system has been undergoing almost constant improvement and extension in the Peninsula since World War II.

SELECTION OF NODES

Although all modern means of transportation have proved invaluable in strengthening economic, administrative, and cultural ties between Bangkok and the rest of Thailand, it has been the railway system that has been primarily responsible for drawing the nation together.[10] It was not until the early 1950's -- concurrent with the awakening of

[9]Pendleton, op. cit., p. 296.

[10]Pendleton, op. cit., p. 293.

world interest in Thailand -- that highways in Thailand were considered to be of value as a system of transport rather than merely feeder lines to the railroad system. Since they are established commerce centers and distribution points, most of the primary nodes in the network are rail centers.

The network representing the transportation system of Thailand has been constructed with nodes representing the following areas:

(1) External to Thailand. Any point external to the boundaries of Thailand is considered to be within this one node. Thus, any imports or exports will involve transport through this node. This eliminates the problem of considering separately all countries having economic transactions with Thailand.

(2) The Port of Bangkok. In this network, the node representing the Port of Bangkok will be considered separately from the city of Bangkok and the Central Plains area. The capacity of the arc between the Port of Bangkok and Bangkok itself is the loading/unloading capacity of the port. That is, the arrival of a supply ship at the Port of Bangkok does not constitute the supply of the Central Plain. This area is considered supplied only when the cargo -- or any part of it -- has cleared the Port of Bangkok. The separation of Bangkok and Port of Bangkok and the defining of the arc as loading/unloading capacity

was done because the clearing of the port was thought to be a possible major bottleneck[11] in the over-all transportation system.

(3) Central Plain. Within the Central Plain, three nodes will be considered. The South and Southwestern portions of this region are supported from the node at Bangkok, the Northern part of the region from the node at Nakhonsawan, and the Southeastern part from the node at Chantaburi. A separate node was included for the Southeastern portion of this area so that the simulator might be more easily modified to include the new port facilities at Sattahip if desired.

(4) North Thailand. Chiangmai, the northern terminus of the Thai railroad, has been chosen as the supply distribution point for this area. Chiangmai has for centuries been the market place of North Thailand. Before the advent of the railroad and highway, the trade routes to the North passed through Chiangmai. Thus it is the natural choice as the node on the network representing this area.

(5) South (Peninsular) Thailand. This finger-like appendage of Thailand, with the railroad as its major means of transport, uses local internal highway systems as feeder lines to coastal shipping ports and to the railroad. The Northern part of this area is supplied in the simulator from Prachuapkhirikhan, and the Southern part from Songkhla.

[11]James Bercos, Thailand Ports Cargo Handling Capabilities, Research Analysis Corporation Field Office-Thailand, FP-14 (Thailand: Research Analysis Corporation, 1966), p. 19.

(6) Northeast Thailand. The Northeastern section of the country will be supported from three nodes of the network -- the Northern part of the area from Nong Khai-Udonthani, the Southwestern portion from Nakhon Ratchasima (Korat), and the Southeastern part from Ubon.

a. Nakhon Ratchasima (Korat) is the most important center of the region. It is the railway junction of the lines to the Nong Khai-Udonthani terminus and the Ubon terminus as well as the last center in the Northeast on the route south to Bangkok.

b. Nong Khai-Udonthani is the northeastern rail terminus on the Laos-Thailand border as well as Thailand's port in Laos. It is adjacent to Vientiane, Laos, with which a great deal of legal and illegal trade is conducted.[12]

c. Ubon is a rail terminus and the terminal point of the Mun River which is used for transport primarily during the flood season of September-October.

THE NETWORK

The division of Thailand into geographical areas and sub-areas is depicted on the map in Figure 1. The major components of the transportation network of the country, before being abridged to fit the purposes of this simulator, looks basically as in Figure 2. When broken into the nodes mentioned above, it is as in Figure 3. Thus the network considered in the simulator consists of eleven nodes and twenty-two arcs. This is the framework within which the simulator will operate.

[12]Opinion expressed by Cdr. Joseph Metcalf, III, personal interview.

FIGURE 1

THE GEOGRAPHIC DIVISION OF THAILAND BY NODE

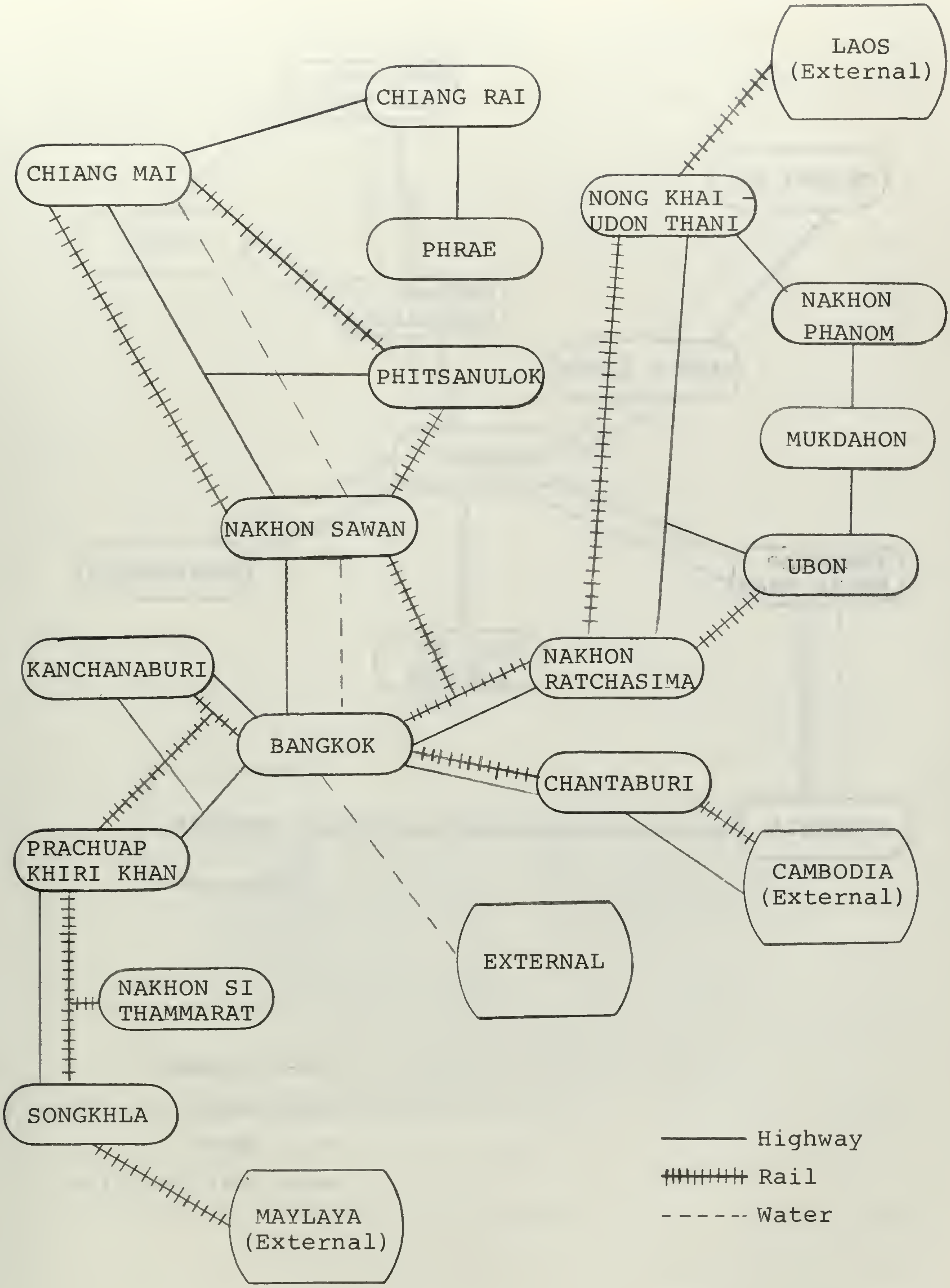

FIGURE 2

TRANSPORTATION NETWORK OF THAILAND

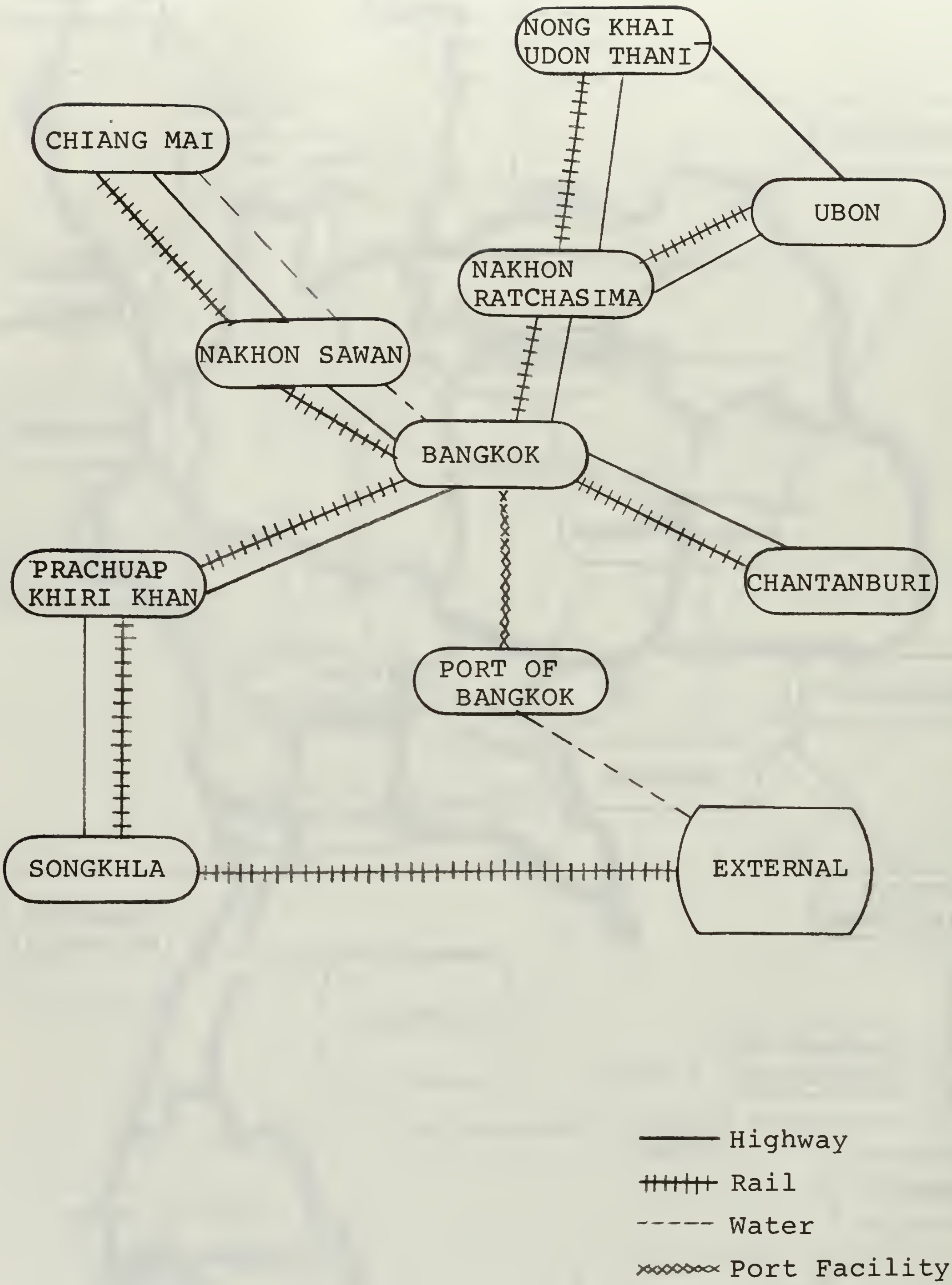

FIGURE 3

SIMULATED TRANSPORTATION NETWORK OF THAILAND

[illegible]

b. The simulator progresses through a fixed sequence of steps for eack week, and appropriate records are kept for output purposes.

c. Policies for the assignment of modes of transportation and transportation routes are governed by the ordering of certain criteria and the ranking of alternatives within each criterion. These criteria and the decision rules which have been developed will be discussed later.

d. As in any computer simulation, events are sequential. That is, requirements of nodes are not examined collectively before supply action is initiated. Supply action starts as soon as the first node is examined.

e. Node requirements and arc capacities are data which must be furnished as input and are not generated within the simulator.

f. In the first approximation to the problem, seasonal effects can be simulated by changing the availability data and arc capacities. As a suggested extension, subroutines may be added later to simulate seasonal effects.

CRITERIA AND DECISION RULES

There are five factors which are important in determining the actions taken by the simulator. They are:

a. Destination. This is the node to which commodities must be transported in fulfilling a supply requirement.

b. Commodity. These are the goods which must be transported over the network.

c. Mode of transportation. The simulator must determine which of the three modes of transportation should be used in fulfilling a supply action.

d. Source of supply. The order in which possible supply points for the commodities considered are examined must be determined by the model.

e. Route of transport. An order of priority which is given various routes from a selected supply point to a selected destination must be determined.

The simulator must examine for each week every destination-commodity combination for which a supply requirement exists. However, it need only examine enough combinations of the other three factors to find a solution to the requirement. For each of the factors -- mode of transportation, source of supply, and route of transportation -- an ordering of priorities has to be included. Also, the order in which these three factors are considered must be decided upon.

The order in which the commodities will be considered will be on a priority basis. The order of priority selected for purposes of simulation are as follows: (1) petroleum products, (2) rice products, (3) cassava, kenaf, and maize, (4) rubber, (5) tin, and (6) lumber products. Petroleum was selected as the most important because it is a factor in moving all of the other commodities. Rice was considered ahead of the other four commodities because, in addition to being a money commodity like all the others, it is <u>the</u> important food crop. The order of the other four goods is based on their export value.

The determination of the order in which the nodes will be examined will be random for each commodity and each time period. That is, for the commodity with the highest priority, the order of supply will be determined by a random procedure. Then for the next commodity, another random selection of order of supply will be made, and so on through the other four commodities. For the next time period, this process will be repeated, and so on until the end of the simulation. This randomization is done because there is no priority system for users of highways, inland waterways, and railroads other than first come, first served. It is felt that this process is essentially random in nature.

The order in which modes of transportation will be considered is determined by cost. For each commodity-source-destination combination, there is an ordering by cost of the three modes of transportation considered (see Table VIII, page 46). If highly perishable material were being transported or if the scenario were changed to full scale war, timeliness might be a more important criterion than cost. However, within the scope of this simulator, the least-cost method of selection is considered to be reasonable.

Determination of primary and secondary sources of supply is an input to the simulator, and the data which is developed in Chapter IV is considered to be as realistic as possible.

Selection of routes from one node to another once the mode of transport is decided upon is based on the distance involved. Admittedly, this is based on the assumption that, given a mode of transport and a source and destination, it is more "convenient" to go by the shortest route. At first glance, this may seen to be a strong assumption, but within the network, parallel paths of the same mode of transport were consolidated into one arc. Thus alternate routes on the same mode of transportation are usually widely separated in distance. As an example, consider highway transportation from Nong Khai to Nakhon Ratchasima. As can be seen in the network in Figure 3, page 24, the obvious route (and the first one which the simulator would select) is the one which runs directly between the two points. An alternate route in this case would be the one which goes by way of Ubon.

Now that decision rules for each of the five factors have been developed, only one further important question remains to be answered. To illustrate, let us consider the following example.

Suppose that Nakhon Ratchasima is the primary supply point for supplying Nong Khai with a certain commodity and that highway is the preferred mode of transport. If for some reason, the highway between Nakhon Ratchasima and Nong Khai cannot be used, the question arises. Should the highway mode of transport still be used even though the alternate route through Ubon would have to be taken or should the direct railroad route be taken? In another case, the simulator may have to choose between taking an alternate mode of transportation or selecting an alternate supply point.

To resolve this dilemma, the various factors which we have considered -- mode of transport, source of supply, and route priority -- must be ordered in importance among themselves. Only the last three of the five factors are mentioned here because the first two -- destination and commodity -- determine the requirement that is being examined. The other three are used to fill this requirement.

In ordering mode, source, and route, one must take into account the following facts. Sources of supply are determined by the availability of commodities. For most commodities, there is really no convenient choice as to the source of supply for a given node. That is, if supplies are not obtained from the designated source, a shortage would ensue, and supplies to remedy this shortage would again have to come through the same node. Secondly, alternate routes, due to the manner in which the network has been formulated, are usually very much longer than the primary routes.

Thus, in line with these restrictions, the source of supply is considered to be the last thing one would try to change, and the route is next most important. Then in the above example, when the primary highway route between Nong Khai and Nakhon Ratchasima cannot be used, the simulator would check the direct rail link between the two nodes. Only if this arc could not be used would the alternate highway route be examined.

DESCRIPTION OF RECORDS

The simulator uses two types of records to describe actions which it takes. Link records show which commodities and how much of each was shipped over each arc in the network during each time period. A sample link record is shown in Table I.

TABLE I

Sample Weekly Link Data Record

Link Number	Capacity per Week	Tons Transported in Week 1	Commodities
(1,6,1)			
(1,6,3)			
(2,3,1)			
(2,3,2)			
(2,4,1)			
(2,4,2)			
.			
.			
.			

The first column of the record identifies which arc is being dealt with; the second column, its weekly capacity (in tons); and the third and fourth columns contain a breakdown of the tonnage of each commodity which is transported over that arc during the week for which that record is kept.

The other type of record which is necessary is the commodity record, one of which is kept for each node. A sample commodity record is shown below.

TABLE II

Sample Commodity Record

Node 5 (BANGKOK)							
Commodity	Weekly Requirement	Delivered in Time Period 1	2	3	4	5	6
Petroleum							
Rice							
Cassava, kenaf, maize							
Rubber							
Tin							
Lumber							

OPERATION OF THE SIMULATOR

For purposes of computerization, the network in Figure 2, page 23, is displayed in Figure 4 on the following page with its nodes and arcs numbered. The arcs are numbered according to the following scheme. Each arc will be identified by a triplet (i,j,k) where i and j identify the nodes which the arc connects, but do not connote any direction of traffic flow. The possible values of k and the meaning of each is listed below:

1. Highway link.
2. Rail link
3. Waterway
4. Port handling capability.

Thus the rail link from Bangkok to Nakhon Sawan would be denoted by (5,6,3) and the water link from Nakhon Sawan to Chiang Mai would be (1,6,3). Although arcs such as (3,4,2) and (8,11,1) do not appear on the network and have not at

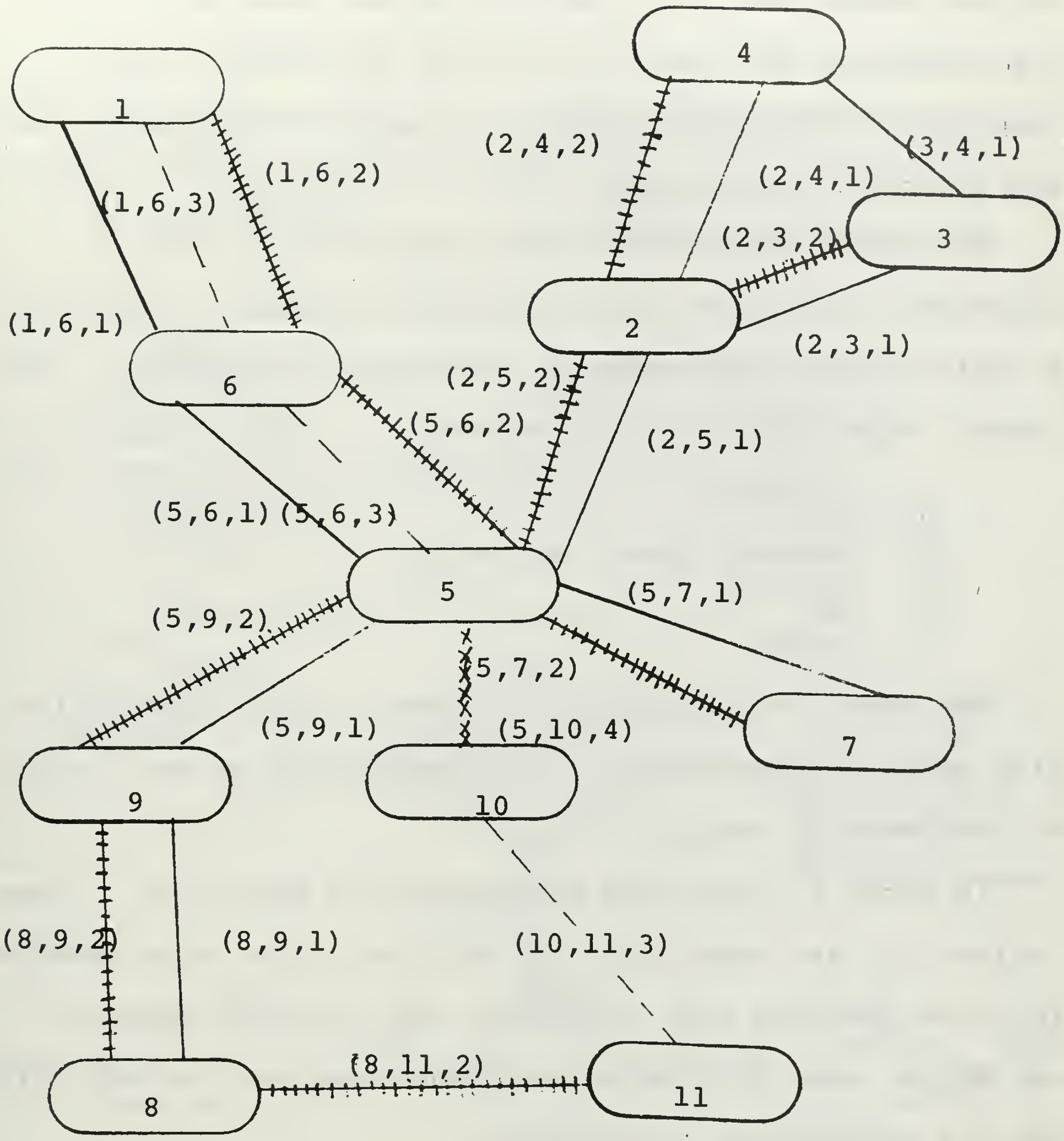

FIGURE 4

NETWORK SIMULATOR

the present time even been constructed, it is felt that they and several other feasible links which might be built in the future should be included in the computerization of the simulator with their capacities set equal to zero. Then only the capacities need be changed when these links are actually constructed.

The actual operation of the simulator can best be described through the use of the flow diagram in Figure 5. In this figure, the symbol C_i represents commodity i. The index i runs from 1 to 6 to denote:

1. Petroleum.
2. Rice.
3. Cassava, kenaf, and maize.
4. Rubber.
5. Tin.
6. Lumber.

The symbol t designates the number of the time period with which we are dealing. The number of time periods to be simulated is denoted by t_o.

In block 1, the input parameters are specified. These include t_o, arc capacities for each arc, node requirements for each node and each commodity, and relative costs of the three types of transportation between each supply point and the nodes which it supplies.

In block 2, the time indicator, t, and the index for commodities, i, are initialized.

Block 3 indicates that for commodity i, an order of supply should be determined. This will be done by use of a random number table or other random device when the

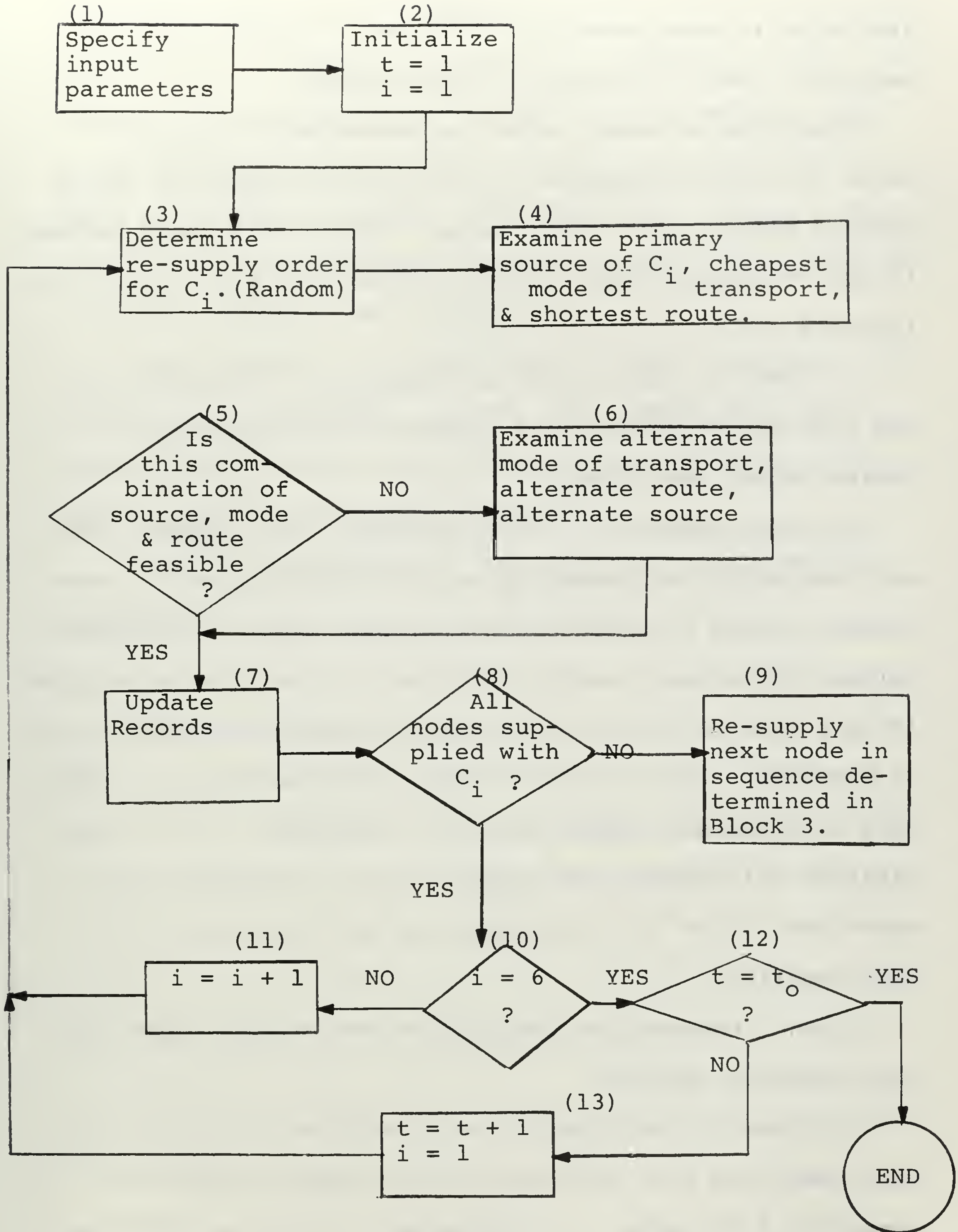

FIGURE 5

SIMULATOR FLOW DIAGRAM

simulator is done manually, or by use of a random number generator when the process is computerized.

After the re-supply order is determined, the node which is to be re-supplied first is interrogated as to its primary supply point, the cheapest mode of transport between it and its supply point and the primary route. This is done in block 4.

In block 5, the records are examined to determine if the node can be re-supplied using this combination of source, mode, and route.

If this combination is not feasible (for example, the arc over which the commodity is to be transported is overloaded), block 6 examines the alternate means of transport between the primary supply point and the node to be supplied. If this mode will not handle the re-supply, the routes will be examined. Only if none of these combinations will work, will an alternate supply point be considered. If no combination will handle the supply action, the records are noted that there is a stock-out for that commodity in that location.

Block 7 handles the updating of the records, both link and commodity records.

In block 8, the question as to whether or not all of the nodes have been considered in re-supply actions of commodity i is asked. If not, block 9 indicates that the next node in the re-supply sequence determined in block 3 should be put at the top of the list, and the simulator returns to block 4.

If the answer to the question in block 8 is yes, block 10 asks if all commodities have been examined in this time period. If not, block 11 increments the commodity index, i, and the simulator returns to block 3 to determine an order of re-supply for the next commodity. If so, block 12 asks if the simulator has examined as many time periods as the user indicated was necessary.

If the answer to the question in block 12 is yes, the simulation is finished. If not, the commodity index is initialized once more, the time counter is incremented, and the simulator returns to block 3.

A sample run-through of the simulator is documented in Chapter V.

CHAPTER IV

DEVELOPMENT OF DATA INPUTS

INTRODUCTION

Due to the nature of the simulator, certain inputs are required for its operation. Among the input parameters which must be specified are arc capacities (the tonnage per unit time which can be transported over the transportation link represented by the arc,) node requirements (the tonnage of each commodity which is required at the supply or distribution point represented by the node,) and relative costs of the various modes of transportation (highway, rail, and water) which are considered in this model.

Specifically, the data requirements can be reduced to the following:

(1) Arc capacities for each arc of the network;

(2) Node requirements for each node and each commodity considered;

(3) Primary source of supply for each node and each commodity (For example, Songkhla gets its supply of rice from Bangkok. Thus Bangkok is the primary supply point for rice for the node represented by Songkhla;)

(4) Relative costs of the three modes of transportation for each combination of supply point, node supplied, and commodity.

To obtain numerical values for many of these required input parameters, relative populations of areas specified by the various nodes were used. Table III shows the population of the areas specified. It is of note that no population

TABLE III

The Estimated Population[a] of the Area, the Changwads,[13] Served by the Node Indicated

Node Number[b]	Geographical Region	Node Name	Estimated Population of the Area Served
1	North	Chiang Mai	3,481,000
2	Northeast	Nakhon Ratchasima	3,619,000
3	Northeast	Ubon	3,080,000
4	Northeast	Nongkhai-Udon Thani	2,581,000
5	Central Plain	Bangkok	6,116,000
6	Central Plain	Nakhon Sawan	3,185,000
7	Central Plain	Chanthan Buri	1,468,000
8	Peninsula	Songkhla	3,165,000
9	Peninsula	Prachuap Khiri Khan	378,000
10	Not Applicable	Port of Bangkok	Not Applicable
11	World	External	Not Applicable

[a]Based on the 1960 census and 3% growth rate.[14]

[b]In the remainder of this section, nodes will be referred to by the node numbers here designated, and will be taken as representative of the areas they serve.

[13]National Statistical Office, Thailand, Changwat-Amphoe Statistical Directory (Thailand: Department of Local Administration, 1965), pp. 1-71.

[14]Department of the Army, The Army Area Handbook For Thailand (Washington: Government Printing Office, 1963), p. 33.

is given for the node Port of Bangkok or for the external node. As explained previously, these nodes are merely for convenience of the simulation, and population data is not applicable for them.

The six commodities considered in the simulation will be considered individually in determining the parameter values.

RICE

To estimate the annual average rice consumption for the areas considered in the simulator, the relationship of 190 kilograms per person per year[15] was used. This data is shown in Table IV.

In estimating rice production by area it was assumed that there is equal productivity of acreage within an area. That is, within the area of Bangkok node, each acre produces an equal amount of rice. Within the area of the Chiang Mai node, each acre also produces an equal amount of rice, but not necessarily the same as the figure for Bangkok. In all cases, U.S. Department of Agriculture figures were used as a data base.

The division of production on a weekly basis as in Table V is an artificial division made for the purposes of comparison. It implies that rice production is uniform throughout the year which is not the case. However, it will be considered in this manner for purposes of the current simulation.

[15]Smith, op. cit., p. 63.

TABLE IV

The Estimated Annual Consumption and Production of Rice In Thousands of Metric Tons By Node (Per Area Served)

Node Number	Rice Consumption	Rice Production[16]
1	662	720
2	688	1100
3	586	896
4	490	629
5	1170	1613
6	600	1600
7	269	712
8	597	573
9	71	65

It is of note that a comparison of the rice surplus of Thailand as depicted in Table V exceeds the often quoted[17] figures of 1.5 to 1.9 million metric tons annually exported, by .8 to 1.3 million metric tons. This is partially because Thailand's surplus rice often finds it way illegally across the Laotian border. This smuggling amounts to about 10% of

[16]Division of Agricultural Economics, Ministry of Agriculture, Thailand, Agricultural Statistics of Thailand, 1963 (Bangkok, Thailand: 1964), p. 41; and United States Department of Agriculture, Economic Research Service, Regional Analysis Division, Foreign Agricultural Economic Report No. 8: Agricultural Diversification and Economic Development In Thailand (Washington: Government Printing Office, 1963) p. 4.

[17]Muscat, *op. cit.*, p. 82; Pendleton, *op. cit.*, p. 308; Smith, *op. cit.*, p. 9.

the annual crop -- .8 to .9 million metric tons. The remaining discrepancy unaccounted for is the result of the sources and estimations made.

TABLE V

The Estimated Annual and Weekly Rice Surplus In Thousands Of Metric Tons By Node (Per Area Served)

Node Number	Annual Rice Surplus	Weekly Rice Surplus
1	58	1.15
2	412	7.94
3	310	5.96
4	139	2.68
5	443	8.50
6	1000	19.20
7	443	8.50
8	-24	-.46
9	-6	-.12
11	2705	58.35

The absence of sign in Table V indicates that that amount is shipped from the node indicated; whereas a negative sign indicates that that amount is to be shipped to that node.

The shortages indicated in Table III for the areas served by nodes eight and nine, the Peninsula, are supplied by node five, Bangkok. The primary reason for this method of supply is that the transportation system of Thailand resembles a wheel with the hub centered on Bangkok -- all roads lead to and through Bangkok.

The positive surplus indicated in nodes 1 through 7 is considered to be exportable and is taken to be the demand of the external node.

RUBBER

Rubber is an important commercial crop; and, after rice, the largest Thai foreign exchange earner. There are about one million acres in southern Thailand planted in rubber on small estates under Thai, Malay and Chinese control. Production cannot expand to any great extent without a substantial replanting program; but government encouragement of such a program -- the Rubber Replanting Act of 1960 -- is hampered by competition from synthetic rubber production.

Southern Thailand is the prime producer of rubber. It is considered that for the purposes of the paper, the yield of the small acreage found in Chanthaburi changwad on the southeast coast of the mainland is negligible. Therefore, the primary source of supply for rubber is Songkhla. The internal transport of rubber other than for purposes of export is considered to be negligible. The rubber is shipped to Malaysia for processing and for export.

TABLE VI

The Estimated Average Annual and Weekly Production of Rubber[18] In Thousands of Metric Tons By Node (Per Area Served)

Node Number	Annual Production	Weekly Production
8	190.0	3.66
11	-190.0	-3.66

[18]Muscat, op. cit., p. 82.

TIN

Tin mining which was originated in South Thailand by the Chinese continues to be the only product of major importance in the Thai mining industry, and ranks third with maize in order of export value -- after the two leading exports, rice and rubber. Tin mining, however, like most of Thailand's developing industries must contend with the problems of underdeveloped transport facilities in the mineral regions and with the scarcity of experienced mining personnel and skilled labor.

As adequate smelter facilities are not available within Thailand, the tin is sent to Malaysia for processing. The amounts of tin concentrates given in Table VII will be assumed to be those available for transport from the indicated nodes to Malaysia[19] for export.

TABLE VII

The Estimated Annual and Weekly Production of Tin[20] in Thousands of Metric Tons By Node (Per Area Served)

Node Number	Annual Production	Weekly Production
8	15.24	0.29
9	2.76	0.05
11	-18.00	-0.34

[19]Dorothy C. Clark and Angelo C. Giarrantana, Transportation Systems Of Thailand, Research Analysis Corporation Field Office-Thailand, TP-180 (Thailand: Research Analysis Corporation, 1966), p. 44.

[20]Agricultural Statistics of Thailand, 1957-1958 (Bangkok, Thailand: Board of Investment, 1959), p. 28; and Muscat, op. cit., p. 82.

LUMBER PRODUCTS

Forests of one type or another occupy at least 70 to 80 per cent of Thailand, about 125,000 square miles. Of the products from these forests, only teak constitutes an appreciable percentage of total export value -- 2.5%. However, although comparable market value is less than that of teak, the amount of yang timber cut makes it the number two forest product. Annual production of 200,000 cubic meters rivals that of teak. This production may be indicative of future trends in the Thai forestry industry. With the decline of teak due to overcutting in past years, the - at present unknown - marketing and consumption statistics of yang could be or could become significant in this part of the data.

Teak, in the past, has been produced in such a manner that it could be rafted down to the mills (Bangkok) during the wet season, June - October. The trip length for some unusually large logs has taken as long as twelve years, but the average length from forest cutting to Bangkok milling has been estimated at five years. This type of movement is not to be considered here. However, with the increasing utilization of portable sawmills and modern logging applications, some milled timber -- lumber -- is available for shipping.[21] This is the transportation of lumber products considered in this simulation.

[21] Pendleton, op. cit., pp. 216-231.

TABLE VIII

The Estimated Annual and Weekly Production of Teak[22] In Thousands of Cubic Meters and Metric Tons By Node (Per Area Served)

Node Number	Annual Teak Prod.		Weekly Teak Prod.	
	Cubic M.	Metric T.	Cubic M.	Metric T.
1	136.0	109.0	2.62	2.10
7	45.0	36.0	0.87	0.69
5	-116.0	- 93.0	-2.24	-1.79
11	- 65.0	- 52.0	-1.25	-1.00

CASSAVA, KENAF, MAIZE

One of the results of the Thai government's efforts to encourage crop diversification -- as well as a favorable world market at the time -- has been the marked increase in the production of cassava, kenaf, and maize.[23] It is this increase in production that has made the three crops of sufficient importance to be considered in this simulator.

Node 8, Songkhla, which is the only node in which production does not exceed intake is supplied from node 7, Chanthan Buri and node 9, Prachuapkhirikhan.

[22] Division of Agricultural Economics, Ministry of Agriculture, Thailand, Agricultural Statistics of Thailand, 1963, (Bangkok, Thailand: 1964), pp. 106, 128; Muscat, loc. cit., p. 82; and Agricultural Statistics of Thailand, 1957-1958, op. cit., p. 29

[23] Muscat, op. cit., pp. 83-86.

TABLE IX

The Estimated Annual Cassava, Kenaf, Maize[24] Surplus In Thousands of Metric Tons By Node (Per Area Served)

Node Number	Cassava	Annual Surplus Kenaf	Maize
1	--	--	14
2	--	113	146
3	--	--	--
4	--	34	- 5
5	--	--	133
6	19	--	241
7	1373	--	9
8	- 965	--	- 6
9	16	--	34
11	- 443	-143	-566

-- Less than 500 metric tons or nil.

[24] United States Department of Agriculture, Economic Research Service, Regional Analysis Division, Foreign Agricultural Economic Report No. 8: Agricultural Diversification and Economic Development In Thailand (Washington: Government Printing Office, 1963), pp. 4,9,13,22; Smith, op. cit., pp. 10, 11, 64; Agricultural Statistics of Thailand 1957-1958, op. cit., pp. 5, 10, 17; Muscat, op.cit., pp. 82-86; and Pendleton, op. cit., pp. 178-182.

TABLE X

The Estimated Weekly Cumulative (By Tonnage) Cassava, Kenaf, Maize Surplus in Thousands of Metric Tons By Node (Per Area Served)

Node Number	Weekly Surplus
1	.27
2	4.98
3	----
4	.59
5	2.56
6	5.00
7	26.70
8	-18.70
9	.96
11	-22.20

--- Less than 500 metric tons or nil.

The relatively high money value as compared to any other crops raised, of cassava, kenaf, maize constitutes the reasons for their rapid as possible transport to the markets of Bangkok.

PETROLEUM PRODUCTS

Civilian use of petroleum products constitutes consumption of approximately 70 per cent[25] of petroleum imports. The 70 per cent includes MOGAS, Kerosene, diesel oil.

[25]Royal Thai Government Department of Customs, Monthly Reports Of The Imports And Exports of Thailand: December 1960, 1961, 1962 (Thailand: 1961, 1962, 1963).

Within Thailand, there are three possible natural sources of oil. Two of the sources are of the oil shale type: Krabi and Tak changwads contain these. The Krabi deposits are relatively unknown because of little exposure. The Tak deposits are estimated to be in excess of 2,000,000 tons of oil shale.[26] Exploitation of the Tak deposits has been inhibited by the difficulty of access. The third source is in Chiangmai changwad near the Thai-Burmese border. The quality and quantity to date are such that the output is not of significant commercially competitive value; the operation is more or less still in the developmental stage.

[26]Pendleton, op. cit., p. 261.

TABLE XI

The Estimated Annual and Weekly Petroleum Products[27]

Surplus In Thousands of Units By Node (Per Area Served)

Node Number	Annual Barrels	Annual Metric Tons	Weekly Metric Tons
1	- 854	- 123	- 2.36
2	- 891	- 127	- 2.44
3	- 755	- 108	- 2.08
4	- 634	- 91	- 1.75
5	-1489	- 213	- 4.09
6	- 779	- 111	- 2.14
7	- 368	- 53	- 1.02
8	- 779	- 111	- 2.14
9	- 97	- 14	- 0.27
11	+6646	+ 951	+18.29

(7 barrels equal 1 metric ton)

PORT CAPACITY[28]

The following discussion of the capacity of the Port of Bangkok has been studied extensively in Thailand Ports Cargo Handling Capabilities by James Bercos, Research Analysis Corporation Field Office, Bangkok, Thailand.

[27] Royal Thai Government Department of Customs, Monthly Reports of the Imports and Exports of Thailand: December 1960, 1961, 1962, *loc. cit.*

[28] Bercos, *op. cit.*, pp. 9-19.

Following Bercos' approach, the following definitions are necessary for the discussion:

(1) reception capability is the number and types of ships that can be moved into and held at the harbor or sheltered coastal areas of the terminal -- here given in terms of tons of cargo;

(2) discharge capability is the number of ships per day that can be discharged -- here given in terms of tons of cargo -- in the terminal;

(3) clearance capability is the amount of cargo per day that can be moved through and out of the terminal as determined by the total clearance capabilities of the railway, roads, and inland waterways;

(4) terminal throughput capacity is determined by the least of the following three major factors: reception capability, discharge capability, and clearance capability.

The discussion will include the two cases; one in which inland waterways are not used to directly channel lighters and barges away from Bangkok and the other in which inland waterways are used. Consideration of the two cases is necessary because in the former case, only seventy-five percent of the available dry cargo berths and anchorages can be used for dry cargo discharge: whereas in the latter case, use of one hundred percent to achieve maximum discharge assumes necessary mobilization of the required barges and personnel. This latter case also does not consider the problem of clearance -- the availability of barge and lighter off-load equipment at barge-to-truck or -rail transfer points. In reality, the actual operation is neither just one case or the other, but rather a combination of the two.

TABLE XII

The Port of Bangkok
Reception, Discharge, Clearance Capabilities

Capabilities	Waterways Not Used	Waterways Used
Reception:		
Dry Cargo	145,000 L/T	145,000 L/T
Bulk POL	36,000 L/T	36,000 L/T
Discharge:		
Dry Cargo	5,500 L/T/day	29,000 L/T/day
Bulk POL	18,000 L/T/day	18,000 L/T/day
Clearance:		
* 1) DRY CARGO:		
Truck	3,600 L/T/day	3,600 L/T/day
BULK POL:		
Barge	1,070 L/T/day	1,070 L/T/day
**2) DRY CARGO:		
Truck	1,610 L/T/day	1,610 L/T/day
Rail	800 L/T/day	800 L/T/day
Waterway	- -	24,300 L/T/day
BULK POL:		
Truck	2,950 L/T/day	2,950 L/T/day
Rail	2,000 L/T/day	2,000 L/T/day

* 1) refers to the case of movement in the local Bangkok area;

**2) refers to the case of movement upcountry from Bangkok.

Since throughput capacity is the least of the capabilities given in Table XII from Table XIII below -- the bulk POL throughput capacity from the Bangkok port is the clearance capability. The dry cargo throughput capacity from the Bangkok Port is the discharge capability both when inland waterways are not used and when inland waterways are used.

TABLE XIII

BANGKOK PORT THROUGHPUT CAPACITY (L/T)

Total port capability	Waterways Not Used	(Dry Cargo) Used	Waterways Not Used	(Bulk POL) Used
Reception	145,000	145,000	36,000	36,000
Discharge	5,500	29,000	18,000	18,000
Clearance	6,010	30,310	6,020	6,020

RAILWAY CAPACITY

In determining rail capacity, a capacity of ten units is assigned to a four wheel car and twenty units to an eight wheeler to reflect the twofold difference in carrying capacity. (A unit is defined as one four hundredth of the capacity of the average Thai train.) Most of the track that was originally built to accommodate coal and wood-burning locomotives is still in service. Although the percentage of diesel locomotives was increased from from seventeen to thirty-six per cent in 1964[29], this

[29]State Railway of Thailand, RSR Information Booklet (Bangkok, Thailand: Nai Utai Sanguanvai, 1966), p. 14.

will not materially increase the capacity of the railway system. The maximum siding capacity is 400 units regardless of the type of engine employed: diesel capacity is rated at 560[30] units whereas non-diesel capacity is 400 units.

Because of the capacities of the sidings and the engines, the capacity of a train is assigned as 400 units.[31] For a 400 unit train, the carrying capacity is about 455 metric tons. Table XIV depicts the schedules of the nine daily scheduled trains. The total capacity of the nine trains is 4095 metric tons.

[30] Dorothy K. Clark and Agenlo C. Giarranta, The Railway System of Thailand, Research Analysis Corporation Field Office-Thailand, FP-3 (Thailand: Research Analysis Corporation, 1966), pp. 3-6, 11.

[31] Ibid., p. 11.

TABLE XIV

The Estimated Freight Traffic[32] on State Railway of Thailand

Lines By Node (Per Area Served)

Node From	Node To	Trains[a] Per Day	Turn around, days Fastest,	Turn around, days Usual, oil-tank	Seasonal Cargo Peaks From Bangkok	Seasonal Cargo Peaks Toward Bangkok
Bangkok	Chiang-Mai via Nakhon-sawan	3	5-6	8-9	Apr-May	Feb-Mar
Bangkok	Korat[b]	4	4-5	8-9	Apr-May	Feb-Apr
Korat	Nong-khai	2	4-5	7-8	Apr-May	Feb-Apr
Korat	Ubon	2	4-5	7-8	Apr-May	Feb-Apr
Bangkok	Chanthan Buri c	1	nd[d]	nd[d]	Apr-May	Feb-Mar
Bangkok	Song-khla	2	7	10-13	June	- - - -

[a]The capacity of each train is 40 units; the carrying capacity of each train is 455 metric tons.

[b]Nakhonratchasima

[c]Aranyaprather train

[d]No data

[32]Dorothy K. Clark and Angelo C. Giarrantana, Transportation Systems of Thailand, op. cit., p. 43.

HIGHWAY CAPACITY

The capacity of the highways depicted in the network in Figure 3 was determined by averaging the average daily truck and bus traffic on the highways in question and by assigning to each the respresentative load of ten metric tons;[33] buses as well as trucks are used to carry loads upcountry.

The term capacity is here used to indicate the amount of tonnage that is carried on the highways in question by the traffic that usually uses the highways. Capacity as used here is not intended to indicate present maximum or future expected potential tonnage.

[33]Bercos, *op. cit.*, p. 14; Giarratana, *op. cit.*, pp. 6, 25; and Pendleton, *op. cit.*, p. 296.

TABLE XV

The Estimated Capacity of The Highway System[34] By Node

(Per Area Served)

In Thousands of Metric Tons Per Week

Node From	To	Weekly Capacity (1000s of metric tons)
Chiangmai	Nakhonsawan	39.6
Nakhonsa-wan	Bangkok	269.0
Bangkok	Chanthan Buri	58.5
- - - -	Prachuap Khiri Khan	168.2
Prachuap Khiri Khan	Songkhla	42.6
Nongkhai	NakhonRatchasima	150.7
- - - -	Ubon	36.4
Ubon	NakhonRatchasima	129.7
Nakhon-Ratchasima	Bangkok	430.9

INLAND WATERWAYS CAPACITY

To attempt to estimate the inland water capacity of Thailand, constrictions such as the locks and dams (Yanhee and Chainat dams; the Rama VI Barrage locks; the Supan River, the Noi river locks) have been assumed to have a bottleneck effect at the northern most node of the arcs on which they appear.

[34]Giarratana, *op. cit.*, pp. 18-25.

Thus the locks maximum capability on the Bangkok to Nakhonsawan waterways is the maximum capacity of that arc. There are on the Nakhonsawan-Bangkok arc two parallel sets of locks which determine the capacity of the arc. On either, the smallest, and thereby the limiting, locks can be operated ten times per day and can pass eight barges per operation. With five of the daily lock operations made to pass northbound barges, at an average cargo load of thirty metric tons, 1220 metric tons per set of locks or approximately 2440 metric tons may be transported to Nakhonsawan.[35] However, an unlimited number of barges may operate in the waterway south of Nakhonsawan.

Assuming half the 2440 metric tons as the full capacity of the Chiangmai-Nakhonsawan arc subject to no further reductions does not seem overly artificial when the relatively new Yanhee dam and its yet to be determined effects on waterway traffic on the arc are considered.

TABLE XVI

The Capacity of The Inland Waterways In Metric Tons Per Week By Node (Per Area Served)

Node		Weekly Capacity
From	To	
Bangkok	Nakhonsawan	15,680
Nakhonsawan	Chiangmai	7,340

[35]Bercos, op. cit., pp. 15-16.

It is worthy of note that the very nature of the inland waterway traffic makes it difficult to estimate; the barges can and do make stops wherever they can find the necessary loading/unloading facilities for their current cargo.

RELATIVE COSTS OF MODES OF TRANSPORTATION

The cost relationship among the three modes of transportation is presented in Table XVII for all commodities. It is of note that in this table, rail is usually indicated as representing the lowest, the preferred cost, this situation is a result of the growth of the transportation system of Thailand. It is somewhat surprising that the inland waterway system is not considered to be the least expensive. One must remember, however, that the arcs of the simulator represent fairly long-distance transportation. If shorter distances were being represented, the waterway system would have a higher preferability.

This table states the relative costs of transport of specific commodities by the designated arcs. It is of note that there is no specific reference for the table. That is intentional. The data from which the table was compiled is found in a number of references such as Transportation Systems of Thailand by Dorothy K. Clark and Angelo C. Giarratana (Research Analysis Corporation), Thailand by Robert L. Pendleton; Economic Benefits From Development Roads in Thailand by John Hugh Jones (Seato Graduate School of Engineering, Thailand); and Thailand Ports Handling Capabilities by James Bercos (Research Analysis Corporation, Thailand).

From these and other similar references (see bibliography), a composite picture of the arcs was developed with respect to: the transport facilities available by mode; the condition of the facilities; the commodities shipped; the peak times of shipping; the commodity marketing statistics; and transport costs.

On the basis of the composite picture, a cost ranking by commodity of the modes of transport was made and is shown in Table XVII. The ranking consists of a three letter group. The letters -- R,H,W -- stand respectively for rail, highway, waterways. The order in which they appear from left to right is least expensive to most expensive. If a letter is omitted, the mode is either unused or impracticable.

The ranking represents not just the financial cost, but reflects other considerations such as convenience, timeliness, and the other factors that went into developing the composite picture. For example, failure of the SRT to provide adequate freight cars to ship rice at times caused Thai in Chiangmai to resort to the more dependable, but more venturesome mode of highway transport to ship their rice. Usually, the freight cars are available. Rail is therefore used. In the same area, seasonal variations in the inland waterways as well as dam and lock construction has made highway transport preferable to water transport. However, the poor condition of the highway system makes rail preferable to highway.

Thus, in Table XVII for the arc Chiangmai to Nakhonsawan, the ranking for rice is RHW. But along the same arc -- because of the relatively high value and small unit volume involved -- the ranking for cassava, kenaf, maize is HRW.

TABLE XVII

THE RELATIVE COSTS OF TRANSPORT OF COMMODITIES SPECIFIED

Nodes From	Nodes To	Rice	Rubber	Tin	Teak	Cassava etc.	Petroleum
Nongkhai	Bangkok	RH	--	--	--	HR	R
Ubon	Korat[a]	RH	--	--	--	RH	R
Korat	Bangkok	RH	--	--	--	HR	RH
Chiang mai	Nakhon sawan	RHW	--	--	WRH	HRW	RWH
Chiang mai	Bangkok	RH[b]	--	--	WRH	HRW	WRH
Nakhon sawan	Bangkok	HRW	--	--	HRW	HWR	WHR
Chanthan buri	Bangkok	H	--	--	--	H	H
Bangkok	Pra chuap	RH	RH	RH	--	HR	HR
Prachuap	Songkhla	RH	RH	RH	--	RH	R

[a]Nakhonratchasima

[b]As a result of Yanhee Dam, water shipment direct from Chiangmai to Bangkok is no longer possible; transshipment is assumed to occur at the dam on the trip from Chiangmai to Nakhonsawan.

CHAPTER V

SAMPLE SIMULATION

In order to determine if the simulator would give reasonable results for sample inputs, a manually executed sample run consisting of one time period was made. The input was taken from Tables III to XVII discussed in an earlier chapter with one modification. Since the commodities considered in the simulation comprised approximately sixty per cent of the tonnage moved by the Thai transportation system, a factor of 0.6 was applied to each of the arc capacities. For example, the capacity of the highway from Bangkok to Nakhonsawan is shown in Table XV to be 269,000 metric tons per week. Sixty per cent of this capacity is 161,400 metric tons and this was used as the value of the arc capacity in the sample simulation.

It appears that the results of the trial simulation are reasonable and resemble operational conditions.

Tables XVIII and XIX display the results of the sample simulation in the Link Weekly Data Record Form and the Commodity Record Form. It should be remembered that there is two way transportation on all arcs of the network and that the first two numbers of the triplet identifying the link merely indicate the terminals of the link and not the direction of the flow.

Recalling that the purpose of this trial with the simulator was to determine if the simulator would yield reasonable results for sample inputs, one should not attempt further interpretations in a real world context.

TABLE XVIII

LINK DATA RECORD

Link Number	Capacity Per Week	Tons Transported In Week 1	Commodities
(1,6,2)	5,865	1,150	Rice
		270	C,K,M[a]
		2,100	Lumber
(1,6,3)	4,700	2,360	POL[b]
(2,3,1)	78,400	4,130	Rice
(2,3,2)	3,910	2,080	POL
		1,830	Rice
(2,4,1)	90,400	1,750	Rice
		590	C,K,M
(2,4,2)	3,910	1,750	POL
		2,160	Rice
(2,5,1)	258,000	20,170	Rice
		5,570	C,K,M
(2,5,2)	7,820	6,270	POL
		1,550	Rice
(5,6,1)	161,400	19,200	Rice
		5,000	C,K,M
(5,6,2)	5,865	1,150	Rice
		270	C,K,M
		2,100	Lumber
(5,6,3)	9,400	4,500	POL
(5,7,1)	35,000	26,700	C,K,M
		7,565	Rice
		690	Lumber
(5,7,2)	1,955	1,020	POL
		935	Rice
(5,9,1)	101,000	16,820	C,K,M

TABLE XVIII (Con'd)

LINK DATA RECORD

Link Number	Capacity Per Week	Tons Transported In Week 1	Commodities
(5,9,2)	3,910	2,410	POL
		580	Rice
		920	C,K,M
(5,10,4)	127,300	18,290	POL
		53,350	Rice
		22,200	C,K,M
		1,000	Lumber
(8,9,1)	25,500	17,390	C,K,M
		50	Tin
(8,9,2)	3,910	2,140	POL
		460	Rice
		1,310	C,K,M
(8,11,2)	4,000	3,660	Rubber
		340	Tin

[a]Cassava, Kenaf, Maize

[b]Petroleum products

TABLE XIX

COMMODITY RECORD

Node Number	Commodity	Weekly Requirement	Delivered In Time Period 1
1	POL	2,360	2,360
2	POL	2,440	2,440
3	POL	2,080	2,080
4	POL	1,750	1,750
5	POL	4,090	4,090
	Lumber	1,790	1,790
6	POL	2,140	2,140
7	POL	1,020	1,020
8	POL	2,140	2,140
	Rice	460	460
	C,K,M	18,700	18,700
9	POL	270	270
	Rice	120	120
11	Rice	53,350	53,350
	C,K,M	22,200	22,200
	Rubber	3,660	3,660
	Tin	340	340
	Lumber	1,000	1,000

CHAPTER VI

RECOMMENDED EXTENSIONS

Because the work discussed on previous pages is an initial effort to simulate the Thai transportation system, several limiting assumptions and simplifications were made. Consequently, there are several areas in which additional work would be fruitful. Some of these possible areas of extension have been mentioned throughout the body of this paper. These and others will be discussed here.

First, an assumption which severely limits the application of this simulator is that of a constant demand over time. In the constant demand case, one has perfect foresight as to what the transportation requirements will be. To extend the realism of the simulation, one might develop a probability distribution of demand and apply this distribution to the simulation (perhaps through Monte Carlo methods). Or one, for instance, might use historical data from 1963 to simulate the transportation system of 1963.

Another limitation of the scope of the problem was the use of the limited number of nodes in the network. This, in effect, precluded the simulation of short distance transportation, as only the movement between the rather widely separated nodes was considered. As one increases the number of nodes in the network, the network resembles more closely the actual configuration of the system, which in turn makes the simulation more accurate by including more of the short distance transport. As a start in this direction, one might use the network diagram in Figure 2 on page as a guide.

One might also be interested in additional simulation of the area around Bangkok and its extensive inland waterways system. This network would require a large number of arcs and nodes.

The number of commodities considered for the simulation was limited to the six used, because at the present time these six constitute approximately sixty per cent (by weight) of the inland freight within Thailand. This was felt to be sufficient for a first approximation to the simulator. However, considering other commodities, such as military goods, textiles, industrial machinery, medicines, paper products, chemicals, tires, etc., would again add to the accuracy of the simulation. This requires little or no addition to the simulation, but would require a great deal of data gathering. The inclusion of military goods would seem to be a necessary addition, in order for full value to be obtained from the model.

One might also expand the applicability of the simulation by including the use of air transport. While this mode is not important in transporting the six commodities considered in the basic model, it does become important when military goods are added. Also, if the model is to be used to simulate a wartime situation, the inclusion of the air mode of transport would seem to be mandatory.

Perhaps the most necessary extension of all is that of programming the model for a computer. Even in its present form, the simulator is very difficult to manage manually. If output for several time periods is desired, then computerization is almost mandatory.

After the model is computerized, one might then want to add subroutines which would simulate effects of weather, seasons, and/or interdiction.[36] This would of course cause an addition to the input requirements, such as a degradation factor for each arc due to weather, and a factor for each arc measuring the susceptibility to interdiction.

The basic model did not use a parameter representing total vehicles required or available. The parameter representing arc capacity was measured in tonnage per week, and volume (cubic measure) was not considered at all in the development of the simulator. With additional input information, such as dimensions of transportable units of each of the commodities, one might examine requirements on a volume rather than a tonnage basis or volume and tonnage simultaneously.

The data which was developed in Chapter IV is the result of an extended publications search and was undertaken at a distance of several thousand miles from Thailand. It represents in most cases a best estimation culled from many different sources. Thus, an extension in the accuracy of the simulation might well be accomplished by refining the data.

[36] Research Analysis Corporation, op. cit., p. 15.

As the simulator stands at the present time, it represents a framework within which much useful information may be obtained. As this framework is built upon, the model will become capable of simulating with increasing accuracy more contingency situations pertaining to the Thailand transportation system.

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APPENDIX

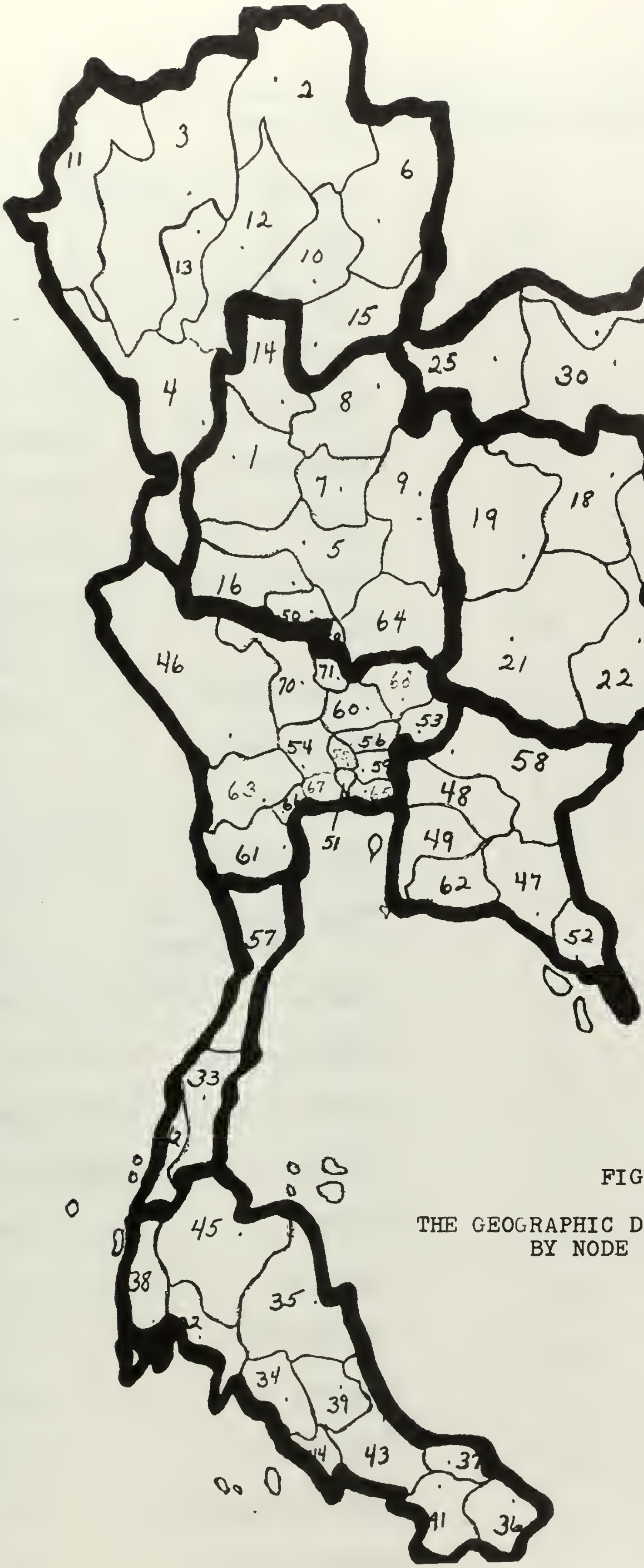

FIGURE 6

THE GEOGRAPHIC DIVISION OF THAILAND
BY NODE BY CHANGWAD

THE CHANGWADS OF THAILAND

Angthong	71
Buri Ram	22
Chachoengsao	48
Chai Nat	50
Chaiyaphum	19
Chanthaburi	47
Chiang Mai	3
Chiang Rai	2
Chon Buri	49
Chumphon	33
Kalasin	17
Kamphaeng Phet	1
Kanchanaburi	46
Khon Kaen	18
Krabi	32
Lampang	12
Lamphun	13
Loei	25
Lop Buri	64
Mae Hong Son	11
Maha Sarakham	23
Nakhon Nayok	53
Nakhon Panom	20
Nakhon Pathom	54
Nakhon Ratchasima	21
Nakhon Sawan	5
Nakhon Si Thammarat	35
Nan	6
Narathiwat	36
Nong Khai	29
Nontha-Buri	55
Phang-Nga	38
Pathum Thani	56
Phatthalung	39
Pattani	37
Phetchaburi	61
Phetchabun	9
Phichit	7
Phra Nakhon	59
Phra Nakhon Si Ayutthaya	60
Phuket	40
Phitsanulok	8
Prachin Buri	58
Prachuap Khiri Khan	57
Phrae	10
Ranong	42
Ratchaburi	63
Rayong	62
Roi-Et	24
Sakhon Nakhon	27
Samut Prakan	65

THE CHANGWADS OF THAILAND (Cont'd)

Samut Sakhon	67
Samut Songkhram	66
Saraburi	68
Satul	44
Sing Buri	69
Songkhla	43
Si Sa Ket	26
Sukhothai	14
Suphan Buri	70
Surat Thani	45
Surin	28
Tak	4
Thon Buri	51
Trang	34
Trat	52
Ubon Ratchathani	31
Udon Thani	30
Uthai Thani	16
Uttaradit	15
Yala	41

TABLE XX

THE DIVISION OF THE CHANGWADS OF THAILAND BY NODE

North Thailand	
Node: Chiang Mai	
Chiang Mai	3
Chiang Rai	2
Lampang	12
Mae Hong Son	11
Nan	6
Phrae	10
Tak	4
Uttaradit	15
Northeast	
Node: Nakhon Ratchasima	
Buri Ram	22
Chaiyaphum	19
Khon Kaen	18
Maha Sarakham	23
Nakhon Ratchasima	21
Node: Ubon	
Roi-Et	24
Si Sa Ket	26
Surin	28
Ubon Ratchathani	31
Node: Nong Khai-Udon Thani	
Kalasin	17
Loei	25
Nakhon Panom	20
Nong Khai	29
Sakon Nakhon	27
Udon Thani	30
Central Plain	
Node: Bangkok	
Angthong	71
Kanchanaburi	46
Nakhon Nayok	53
Nakhon Pathom	54
Nontha-Buri	55
Pathum Thani	56
Phetchaburi	61
Phra Nakhon	59
Phra Nakhon Si Ayutthaya	60
Ratchaburi	63
Samut Prakan	65
Samut Sakhon	67
Samut Songkhram	66
Saraburi	68
Suphan Buri	70
Thon Buri	51
Node: Nakhon Sawan	
Chai Nat	50

Kamphaeng Phet	1
Lop Buri	64
Nakhon Sawan	5
Phetchabun	9
Phichit	7
Phitsanulok	8
Sing Buri	69
Sukhothai	14
Uthai Thani	16

Node: Chanthan Buri

Chachoengsao	48
Chantanburi	47
Chon Buri	49
Prachin Buri	58
Rayong	62
Trat	52

Peninsula Thailand

Node: Songkhla

Krabi	32
Nakhon Si Thammarat	35
Narathiwat	36
Phang-Nga	38
Phatthalung	39
Pattani	37
Phuket	40
Satul	44
Songkhla	43
Surat Thani	45
Trang	34
Yala	41

Node: Prachuap Khiri Khan

Chumpon	33
Prachuap Khiri Khan	57
Ranong	42

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13. ABSTRACT

This paper describes a first effort to simulate the transportation system of Thailand. Although not programmed for computer use, the simulator is documented in flow diagram form so that it might be easily programmed. Movement of six basic commodities by highway, rail, and inland waterway is considered between major centers in the country. Input data is furnished, and a sample simulation is documented. Possible areas for future work are also discussed.

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