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A GPSS II MODEL OF A

LOGISTIC TRANSPORTATION PROBLEM

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CHAPTER I

INTRODUCTION

Nature of the Problem

"Battles, campaigns, and even wars have been won or lost primarily because of logistics."
--General Dwight D. Eisenhower (6)

Military logistics is the transportation, supply, and maintenance of men and material for the Armed Forces. In fulfillment of the foregoing, both the logistician and the tactician invest a tremendous amount of time and effort in planning the structure of support forces. Current planning guides for the logistician are available in military field manuals, directives, and other publications.

In this investigation of the field of logistics, the research effort has been limited to the area of Army truck transportation. Once the tactical forces are determined for employment, transportation resources must be allocated by the logistician to provide the continuous resupply that the combat force requires. If transport means are available, the supplies are moved to the supported forces; if not, a delay in movement is encountered until such time as the means are available. This delay, as General Eisenhower's statement states, may be extremely costly and disastrous.

A simplified block diagram depicting the resupply system is shown in Figure 1. In layman's terms, the combat or supported forces submit supply requirements to a support command headquarters, that is the controlling agency of support resources. Assuming the commodities are available, the transportation facility is levied with the movement requirement to the forward forces.

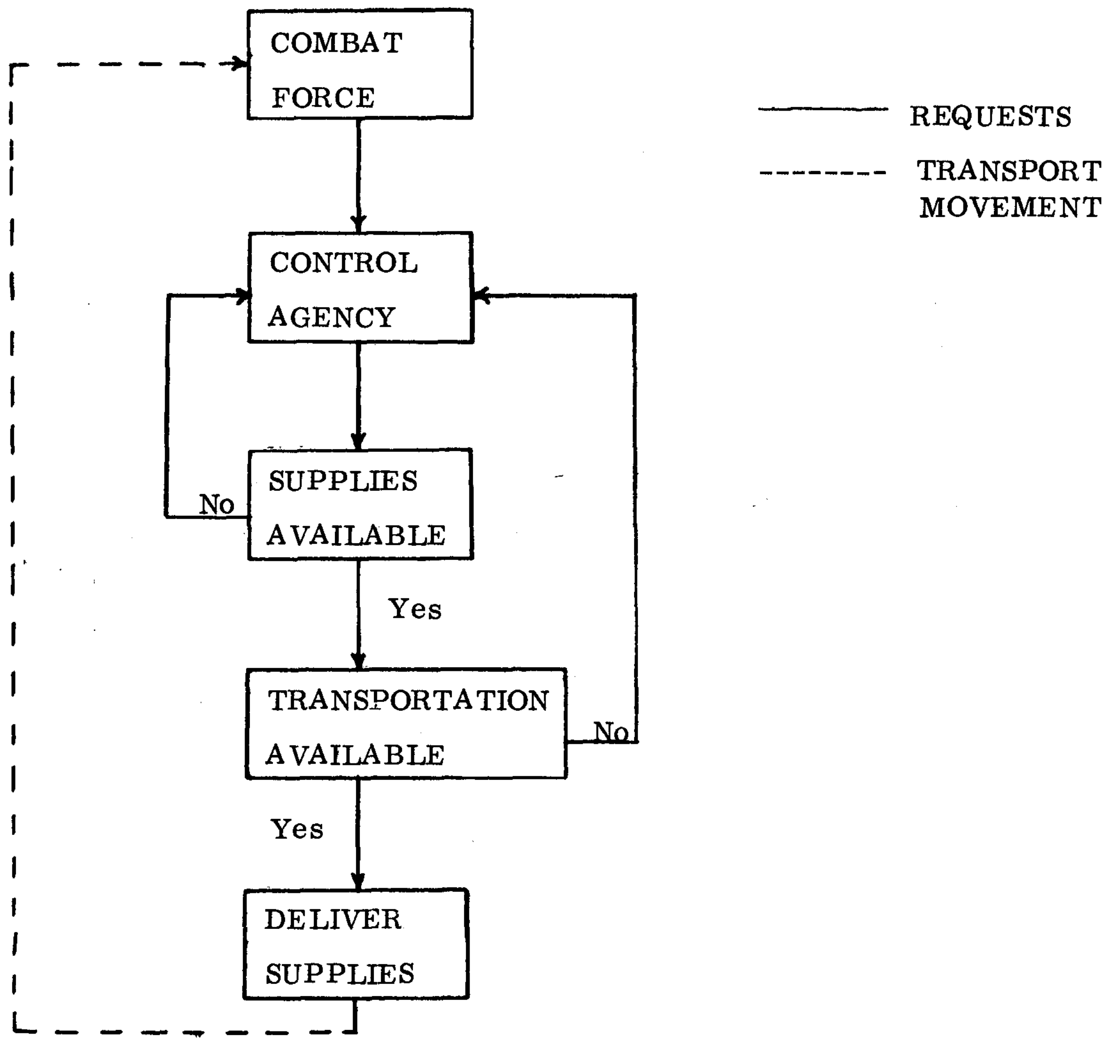


Figure 1. Resupply System.

Statement of Objectives

The purpose of a logistics system is to provide the combat forces with the required materials and supplies in sufficient quantities at the proper time. Concurrently, commodities and transportation media necessary to fulfill this mission must be available to the logistician.

The purpose of this research is to provide the logistician with an alternative tool in developing line haul transport requirements to support forward combat forces. The system is shown in Figure 2. Supplies are carried to the port or airfield by appropriate means and then are locally delivered to existing depots. The line-haul system can be initiated once the supplies are at the depot.

The specific objective of the research is two-fold:

(1) To develop a computer simulation assignment model of the line haul transportation system, and

(2) to conduct experiments designed to establish truck transport requirements to support combat forces.

In constructing the model, the simulation language known as GPSS II (General Purpose Systems Simulator II) will be used. Since the model will be utilized for explanatory or positive analysis, it will be subjected to direct empirical observation for either verification or refutation. Naylor states that the verification of models remains today as the most elusive of all unresolved problems associated with computer simulation techniques (22). However, according to Koopmans (20) the direct treatment of the simulation results is a widely used practice for this type of model. Furthermore, Chapanis notes that models are judged by the

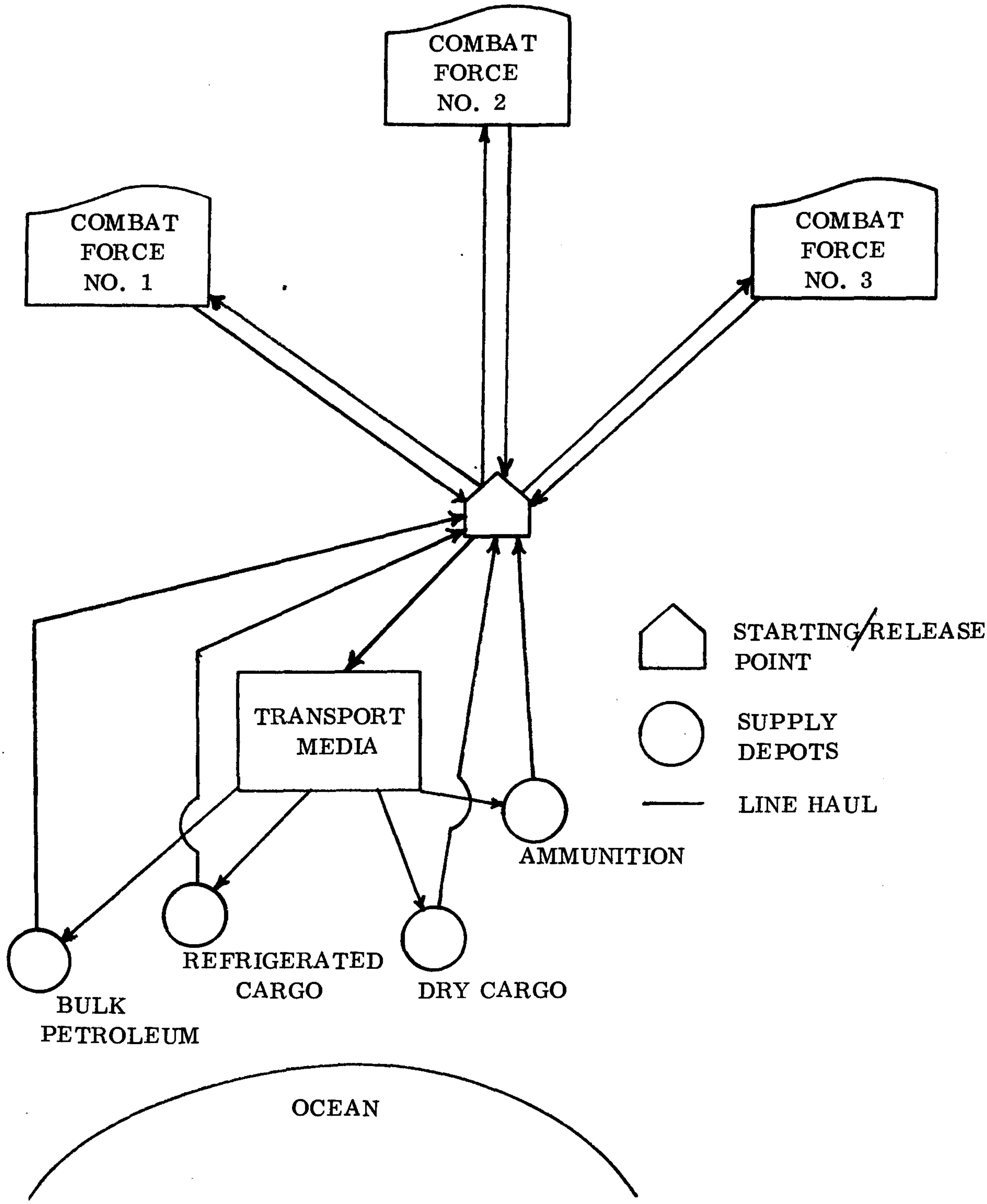


Figure 2. Line Haul System.

criterion of usefulness, whereas theories are judged by the criterion of truth (3).

Experiments will be run depending on a specific scenario situation. The latter is primarily affected by different requirements in supply tonnages as a result of combat posture (attack, defense, pursuit, or inactive).

The following assumptions are made in order to reach the stated objectives and to make the model as realistic as possible:

1) There are no restrictions in the use of transport equipment and personnel.
2) Supply levels at the depots are inexhaustible.
3) An adequate roadnet exists in the theater of operations.
4) A hostile environment exists in the theater of operations.

Scope and Limitations

The scope of this research should be applicable to any transportation system in any theater of operations. The effort may be utilized in planning for the transport requirements regardless of the size of the unit, e.g. a field army or a battalion.

This research does not consider the transport capability of any mode except the truck medium. This restriction was made primarily due to the time element. It is noteworthy that Research Analysis Corporation required two years to accomplish a feasibility study of the entire transportation system for the U. S. Army (17).

Another limitation of the model is that the volume occupied by the tonnage is not considered. However, it is felt that this factor will not significantly affect results since only approximately five per cent of transported cargo "cubes out" prior to overloading by weight. Also, the model considers three locations of supported forces from which requirements are originated. Multiple program runs can accommodate any number of nodes by varying functional inputs.

Transportation Doctrine

The capabilities of lines of communications are quantitative statements of the ability of the lines to transport cargo. Transportation capabilities are primarily dependent on turnaround time, (i.e., time required for one vehicle to complete one cycle) which encompasses the following parameters (8):

(1) Number, lift capacities, and speed potential of available transportation media.

(2) Environmental factors (terrain, climate, road conditions, etc.) influencing the operating characteristics of the vehicle, particularly in regard to speed limitations.

(3) Distances between origins and destinations.

(4) Loading and unloading capabilities.

(5) Maintenance capabilities.

(6) Enemy action.

(7) Indigenous traffic.

The Table of Organization (TOE) for each type transportation unit (pertinent to this investigation) is listed in Table 1 with its capability and/or mission. Also included is the assignment of each type unit (9, 10).

In the resupply of the combat forces air and motor transport are the primary modes of transport employed. Rail transport is used if available, but the length of

Table 1. Transportation Units, Their Missions and Assignments

Unit	TOE	Mission and/or capability	Assignment
Headquarters and headquarters company, transportation motor transport command.	55-11	To command, plan, supervise coordinate, and control the activities of transportation highway transport groups and other assigned or attached units required in the movement of cargo or personnel by highway transport, particularly in a continuous intersectional or other linehaul operation.	To an army or to a theater army logistical command.
Headquarters and headquarters detachment, transportation truck group.	55-12	To command, plan, and control operations of transportation truck, amphibious truck, or tracked vehicle battalions.	To an army, COMMZ, or logistical command. May be attached to a highway transport command headquarters, but may operate separately under appropriate staff transportation officer.
Headquarters and headquarters detachment, transportation truck battalion.	55-16	To command and supervise units engaged in all types of motor transport, such as direct support of tactical units, port or beach clearance, depot and terminal operations, and linehauls.	To a field army or COMMZ. May be attached to a transportation truck group headquarters or a highway transport command headquarters, but may operate separately under appropriate transportation staff officer.
Transportation light truck company.	55-17	To provide truck transportation for movement of personnel and general cargo, using either 2-1/2-ton or 5-ton cargo trucks. Normally, 60 task vehicles are assigned per company	To logictical command or field army. Normally attached to a transportation truck battalion, but may operate separately under appropriate staff transportation officer.

Table 1. (Continued)

Unit	TOE	Mission and/or capability	Assignment
Transportation medium truck company.	55-18	To transport, by semitrailer of type required, general cargo, bulk petroleum products, refrigerated cargo, and missiles. Normally, 60 task vehicles are assigned per company.	To a logistical command or field army. Normally attached to a transportation truck battalion, but may operate separately under appropriate staff transportation officer.

time and the construction effort required to repair the damage to the rail line by combat operations usually preclude reliance on rail operations in the environment (11). Unless the required commodities are in emergency demand, the supplies are transported by means of motor transport rather than air, due to the economics involved.

Tactical line-haul movements are those which exploit the mobility of motor transport for timely delivery of supplies from distances of 25 to 100 miles (9).

Detailed motor transport units and operations are defined in Department of Army FM 55-35.

CHAPTER II

LITERATURE SEARCH

Digital Simulation

The development of digital computers has given considerable impetus to military research through digital simulation. Military problems which involve many interrelated activities can be formulated as a computer simulation. Simultaneously, the parameters of the model can be varied affording sensitivity analysis of their effects on model behavior. Inherently, there are some disadvantages in digital simulation. Even a small simulation requires an immense computer capacity and the building and programming of the model of human decision processes into computer language is difficult. In addition, simulation can be extremely expensive and time consuming. For example, the Signal Corps Ground Combat Simulator required five years to program and debug into an operating simulation (2). At the present time considerable misunderstanding exists among the military about computer simulations (23, 31). Some express a complete lack of confidence in the machine simulation, while others accept simulation results as an entirely valid prediction of how the problem will be ultimately solved. The problem in this regard is to realize that simulation techniques are intimately tied to model building, and that it is the model and its author which must be judged rather than the computer. The model of any simulation must include all pertinent factors of the activity being studied and accurately reflect the real world relationships between them (3).

Simulation Languages

Generally, computer languages are divided into two distinct categoried: general-purpose and special purpose languages. Simulation projects can be written in either of the two categories. However, there are pronounced disadvantages in utilizing a general-purpose language which can be summarized as follows:

> If one attempts to write a simulation program using only a general-purpose language, one rapidly becomes enmeshed in the complexities of this sequencing control, which is not of great interest but nevertheless affords surprisingly fertile ground for minor errors. Moreover, mistakes here are liable to produce obscure effects, and are correspondingly difficult to eradicate (32).

On the other hand, special-purpose languages allow the simulation model to be described in "real world language" by shifting a great deal of the translation task to the computer. The degree to which this translation shift takes place does, of course, vary with each special purpose program. The result is more powerful languages which require less complicated flow diagrams, fewer instructions to the computer, much less programming skill by the programmer, and a considerable increase in computer running time for comparative models (19).

The special-purpose simulation languages can be classified into two major types: continuous-change and discrete-change. Some problems are clearly best described by one type or the other; for other problems either type may be used (26).

Continuous-change languages are appropriate when the analyst considers the system under study, as consisting of a continuous flow of information or material counted in aggregate rather than as individual items. The resulting models are usually represented mathematically by differential or difference equations that describe rates of change of the variables over time. This type of model has wide application in economics, social sciences and dynamic military models (21, 26, 28).

In discrete-change languages, the changes in the state of the system are conceptualized as discrete rather than continuous. Systems are idealized as network flow systems and are characterized by components, transaction flows, and finite capacities. The analytical techniques which may be used to solve such problems are queueing theory and stochastic processes. Examples of problems which have been formulated and studied as discrete-change models are job shops, communication networks, traffic systems and logistical systems (26). IBM's General Purpose Systems Simulator II (GPSS II) is one language that falls into the discrete category (18). GPSS II can be applied generally to a broad class of systems while maintaining a relatively fixed set of procedures for carrying out the simulation automatically (1). This language is best suited to certain types of scheduling and waiting line problems (22).

GPSS II is often called a block diagram language due to the fact that the structure of the system being simulated is described in a form of a block diagram drawn with a fixed set of predefined block types. Each block type represents a specific action that is characteristic of some basic operation that can occur in a system. Connections between the blocks of the diagram indicate the sequence of actions that occur in the system. Where there is a choice of actions, more than one connection is made from a block to indicate the choice (18, 27). Once the programmer masters the functions of the block types, their respective attributes, the rules for combining them, and constructs the flow diagram of the model, the program is easily written (15, 18, 27).

Military Applications of Digital Simulation

A search of the literature revealed that the majority of the known simulation projects has been developed by the RAND Corporation, Research Analysis Corporation (RAC), and other civilian firms under contract with the Department of Defense. It is estimated that approximately 300 major simulation projects have been completed during the past three years (5). The majority of the projects for the Army have been programmed in either FORTRAN or SIMSCRIPT. The primary reason for using these languages is that the hardware in the Army inventory has been furnished by IBM and both languages are compatible with IBM hardware. The majority of the models developed involve some aspect of a tactical problem. However, some of the projects encompass the logistical phase.

In the remainder of this chapter, a number of computer simulations with logistical orientation will be examined. Before proceeding, it should be worthwhile to reflect upon an admonition by Rand's E. S. Quade given in 1959 to a group of military and civilian decisionmakers associated with the Department of Defense (23).

> The high-speed digital computer is sometimes equated with modern decision-making. There exists a belief that all that is needed to solve the most difficult problems is a bigger computing machine which is sure to come along. On the contrary, today a computer alone does not solve the problems of interest to military decision makers; all that it does is execute that series of instructions, laid out by some mathematician, that may lead to a solution. It is just a tool; it cannot do anything with problems it is not told to do. Solutions by computers are only as good and as sensible as the people who define the problem, state the objective, and choose the criterion can make them.

Planned Logistics Analysis and Evaluation Technique

Planned Logistics Analysis and Evaluation Technique (PLANET) is a series of four computer simulation models designed to examine the hardware configuration/

operations/logistics support interactions of a variety of weapon systems in a single or multibase environment (29, 30). Its purpose is to help the manager gain an understanding of the operation of his system and find a rationale for allocating resources effectively and efficiently. PLANET is programmed in SIMSCRIPT.

The PLANET package includes five computer programs:

1. The availability and base cadre simulator, which furnishes the framework for the logistics resources assigned to a support base or bases,

2. The Bench Repair Simulator, which processes the reparables through the base repair shops or diverts them to a depot, thus converting the reparables to serviceables;

3. The Depot Transportation Simulator, which processes the movement of reparables from the base(s) to the depot(s) or factory and return;

4. The Depot Repair and Overhaul Simulator, which simulates the functions in a repair or overhaul facility;

5. The Reports and Analysis Library, consisting of twelve different output programs.

The simulator can be used separately to examine specific areas of the logistics system, or conjointly to simulate the complete weapon-system operation from the site or point of demand through to the depot.

The Depot Transportation Simulator, described here, simulates the movement of logistics resources (people, parts, and/or equipment) from base to base and from base to depot or factory and return. The transportation network may consist of as many different load and offload points (bases) as desired. The simulator takes as inputs the various operating characteristics of the transportation system, the expected cargo to be moved through time, and a planned set of transport vehicles. The vehicles can be any combination of trucks, airplanes, ships, etc.

It then simulates the operation of the system through time, records the data from which reports can be printed that reflect the performance of the transportation system under the conditions specified by the inputs. Performance is measured in terms of the amount of different types of cargo moved during the simulation.

The outputs from the simulation can be used as an aid in determining the quantity of resources that can be moved over time and the costs associated with the operation of the system.

The Bench Repair Simulator can be added to the Depot Transportation Simulator; this makes it possible to examine problems encompassing the generation of reparables on base(s) and the impact that these reparables may have on some existing transportation system.

The Depot Repair and Overhaul Simulator can also be added to the Depot Transportation Simulator; doing so permits the examination of the depot repair processes in conjunction with the flow of reparables from the transportation system and the flow of serviceables into the transportation system back to the base(s).

The Army Deployment Simulator

This simulation describes a computer program designed to simulate the deployment of Army units via transport aircraft from peacetime locations into an area of actual or potential combat (24). The program is written in FORTRAN IV and requires the following inputs to perform its simulation:

a. Location and capabilities of onload, enroute and offload bases.

b. Location and composition of army units to be deployed.

c. Location and composition of required prepositioned equipment.

d. Location, characteristics, capabilities and number of available transport aircraft.

e. Statement of deployment priorities.

From this input data, the program:

a. Selects maximum flow routes by aircraft type to and from each onload base.

b. Allocates aircraft to onload bases.

c. Performs a detailed loading of each aircraft.

d. Prepares a plot of the cumulative deliveries of personnel and cargo at the offload area during deployment.

There are two phases to the program. The network phase accomplishes route selection. Thereafter, the loading phase allocates aircraft to bases and priority groups, loads the aircraft and completes the deployment. The program will be briefly described in terms of these phases.

The program accomplishes route selection through a network analysis of the system of onload, enroute and offload bases. The deployment bases constitute the nodes and the non-stop distances between every pair of bases constitute the branches of the network. As an entity the network is generally complex. A brief discussion of the data inputs required for the network phase best explains this complexity. Ferry ranges vary according to payload and individual type aircraft which in turn determine a number of branch denials. Base characteristics such as runway length and maintenance capabilities will constitute base denials to some type of aircraft. The base components of ground time, which are considered as part of appropriate branch lengths, will generally vary from base to base. Political considerations such as forbidden overflight will alter some branch lengths. With these inputs the computer routine executes a searching procedure to select feasible routes and from among these orders them from maximum to minimum flow. In the final step a payload-time out table for each combination of aircraft type and onload base is prepared specifying its maximum-flow route(s).

The loading phase accomplishes aircraft allocation, loading and deployment through an algorithm based on inputs that spell out requirements by priority, locations of troops and vehicles, and the quantity and capabilities of available transport aircraft. The routine is quite straight-forward for the initial sorties, being easily determined by priorities and capabilities. Completion of the deployment is thereafter achieved by the application of several rules which in turn consider priorities for remaining requirements, aircraft type, eligible stock lists, branch flow capabilities and passed-over aircraft through a series of logic statements in the algorithm.

The program outputs include vehicle data, a distance table, a priority group composition listing, a priority group graph, an offload base activity listing and a listing of aircraft release times. The computer running time is relatively small. Deployments of a reinforced division from several locations over multiple routes have been simulated in less than ten minutes.

Interdiction Model of Highway Transportation

This computer program evaluates the capability of transportation networks to deliver supplies, as road segments or arcs of the network are successively destroyed and repaired. The program, written in FORTRAN IV, can be adapted for any of several large-scale computers (13). Required inputs are a description of the considered transportation road system and the cargo-carrying vehicles utilizing the network.

Given the input data, the program furnishes a profile of maximum cargo flow as a function of the number of vehicles made available to the system, and then selects and destroys that vulnerable link in the network which reduces the cargo flow rate most severely. The program repeats these steps until flow on the network is totally stopped or the predesignated number of links have been destroyed. The program then steps to the next "day" or "period," restores to service all previously destroyed links that have been repaired by this date, and repeats the process of profile generation and link removal.

The program presently will accept a network of up to 1000 links, but this number may be modified to suit the capacity of a particular computer system. By properly describing the network, some combinations of rail, road, and water transportation can be analyzed. The program should be a useful tool in targeting, in logistics system analysis, in allocating funds for expansion of transportation systems, and allocating road-repair efforts.

Underway Replenishment Ship Operations

This program describes resupply at sea of naval operations and is written in FORTRAN IV (25). Each simulation run accommodates as many as 32 cases wherein the activities of up to 20 carrier task groups (CTGs) are examined for 90 days. The CTGs are resupplied with oil or ammunition by underway replenishment (unrep) ships cycling between base and up to eight unrep locations. The task groups operate according to an input schedule that is always met, and the program determines the number of logistics ships needed to meet requirements. Daily printouts record the location, activity, receipts or issues, and inventory of each task group and each unrep ship and at the end of the 90-day simulation runs a final summary printout is made. Unlike most computer simulations, this model has no built-in stochastic features; input data decks can be randomized, if desired. The main routine and nine subroutines have extensive internal documentation and commentary.

SIGMALOG Theater Maintenance Model

This model is one of the logistics models of the SIGMALOG system developed for the Deputy Chief of Staff for Logistics (DCSLOG) of the U. S. Army (12). The program is written in FORTRAN IV. This system is a set of computerized models for determining various logistic implications of a given theater force structure. The SIGMALOG maintenance model is concerned with calculating for various maintenance categories. A measure of required maintenance for the equipment associated with U. S. Army units of a given troop list. In studies to date, the measure of required maintenance has been equipment equivalents for ordnance and signal items, and the number of aircraft of flying hours for fixed-wing airplanes and helicopters. In terms of these measures, the model calculates the required maintenance in each region during each time period to support (1) all U. S. Army units of a given troop list and (2) all U. S. Army units excluding divisions and separate brigades. The maintenance player may then use the former to determine the required general-support maintenance units, and the latter to determine the required direct-support maintenance units.

Port Facility Simulation

Davis and Faulkender completed a port simulation at Georgia Institute of Technology in June, 1967 (7). The project was written in GPSS III and later translated into GPSS II by Steine. This simulation encompasses the ship's arrival at the port, offloading of the ship and delivery of the cargo to nearby depots for storage. The objective of their effort was two-fold:

(1) To determine the quantity of transportation and terminal service units required for satisfactory port operation within the bounds of the established problem.

(2) To investigate the suitability and worth of GPSS III in the solution of logistical problems of this nature.

Davis and Faulkender conclude that GPSS III, although with some limitations, provides a ready means to approach the study of complex logistics systems.

The Nature of Military Simulations

Digital simulation programs for military logistics are numerous and offer a wide variety, both in scope and approach. Some are built from general-purpose languages, while others are true computer languages with their own specially oriented compilers. Many other useful and valid logistical military simulations exist in addition to those dealt with in this chapter; however, those discussed were selected as a representative cross-section of what is available.

Simulation truly does provide a new dimension in military problem solving, though E. S. Quade's admonition of ten years ago must not be forgotten, "....it cannot do anything with problems it is not told to do...." (23).

CHAPTER III

MODEL DEVELOPMENT

General

In order to realize the stated objectives of developing and validating a transportation simulation model, the plan of attack is to develop the computer program in terms of a specific military situation. With a situation defined, the problem is readily formulated with regard to its boundaries and scope. The computer simulation program provides an insight into the real-world logic, the flow diagram, and the validation of the model.

Problem Formulation

The problem is formulated in a generalized military environment; one that could occur anywhere in the world, is of conventional nature and have mid-intensity operations. In the theater of operations, four types of divisions are conducting operations; namely, the airborne, infantry, mechanized and airmobile divisions. The manpower strengths of the divisions are as follows:

Airborne	-	12,972
Infantry	-	15,637
Mechanized	-	16,013
Airmobile	-	15,847

These divisions operate in four different postures defined as follows:

ATTACK - Deliberate engagement or contact against an enemy in a static position.

DEFENSE - Prevention, repulsion or defeat of an enemy attack.

PURSUIT - An offensive action against a retreating enemy force.

INACTIVE - Facing or confronting the enemy; a virtual stalemate.

Considering a year as the span of operation, the divisions will be predominately in the following postures (expressed in per cent of time):

Infantry, Airmobile, Mechanized		Airborne	
Attack	65%	Attack	20%
Defense	15%	Defense	10%
Pursuit	10%	Pursuit	0%
Inactive	10%	Inactive	70%

The reason for stating the above percentages is that the input functions are constructed with these considerations. Division daily tonnage utilization factors in the stated postures were obtained from Combat Developments Command at Fort Eustis, Virginia (4). The numerous tonnage factors were combined into categories of bulk petroleum, refrigerated cargo, dry cargo and ammunition. This combination was accomplished for analytical simplicity and because they correspond to the characteristics of the selected transport types. For example, bulk petroleum products will be transported in 5,000 gallon semi-trailers, refrigerated cargo in 7-1/2 ton vans, and dry cargo and ammunition on 10-ton stake and platform trailers, 5-ton cargo trucks or 2-1/2 ton cargo trucks. Each type of vehicle will transport its above stated nominal capability.

Logic Model

Requirements of the supported force(s) are originated daily. The tonnage per day of each category of supply is determined from four classes of demand in a serviced destination. At present the model is capable of supplying three destinations or nodes by priority. The input functions are constructed on the basis of unit posture and tonnage required per posture. Requirements per day are then originated by a random number generator built into the simulation language. Running the program over the span of a year should minimize any chance variation. Knowing requested tonnages by type, requirements are matched against capabilities of the transport media. For bulk petroleum and refrigerated cargo the operation is simple; that is, if the appropriate type of trailer is available with tractor power the cargo moves, and if not available, it does not move. However, for dry cargo and ammunition tonnages, three different modes are available: (a) stake and platform (S & P) trailers, (b) 5-ton cargo trucks, and (c) 2-1/2 ton cargo trucks. For both requested tonnages, the cargo will first attempt to move via S & P trailer, then 5-ton truck and finally 2-1/2 ton truck. The above priority of loading is not always standard operation procedure, but will be used for this model. Since nominal carrying capacities are being utilized, the model is constructed (to eliminate non-integers) in terms of capacities multiplied by ten; that is, an S & P trailer can transport 100 tons; a 5-ton cargo truck, 50 tons; and the 2-1/2 ton cargo truck, 25 tons. It should be noted that the input tonnages are inflated likewise.

Computer Flow Diagram

A detailed explanation of the characteristics of each GPSS II block type used in the flow diagram is not attempted because it may be obtained by referring to the Univac or IBM reference manuals (18, 27). However, a brief description of the blocks utilized in the model developed in this study is explained. The model is depicted in Figure 3 and each block is numbered at the top.

ORIGINATE blocks 1, 2, and 3 create transactions or requirements from nodes 1, 2, and 3. The requirements are originated on the third hour of a twenty-four hour day.

ASSIGN blocks 4, 5, and 6 place numerical values 1, 11, and 21 respectively in parameter field 1 of the respective transaction. A parameter is a positive integer which is unique to any transaction.

ASSIGN blocks 7, 8, and 9 establish a priority on each transaction from different nodes. That is, parameter 6 contains the respective priority for each node.

SPLIT block 10 creates a duplicate of each transaction that enters the block. Since the duplicate transaction may be synchronized with the original, this block is useful in representing simultaneous events in the system.

SPLIT blocks 11 and 50 serve the same function as SPLIT block 10. With the three SPLIT blocks three transactions flow in four different routes of the system. The four paths depict the fuel, refrigerated, dry cargo, and ammunition requisitions from each node.

ASSIGN blocks 12, 51 and 52 add constants 1, 2 and 3 to parameters one of the transactions in their path. For example, in path one the three transactions contain the values of 1, 11 and 21. However, in path two, since the value of one has been added to the value of parameter one in this path, the three transactions contain the values of 2, 12, and 22. The same argument is applicable to paths

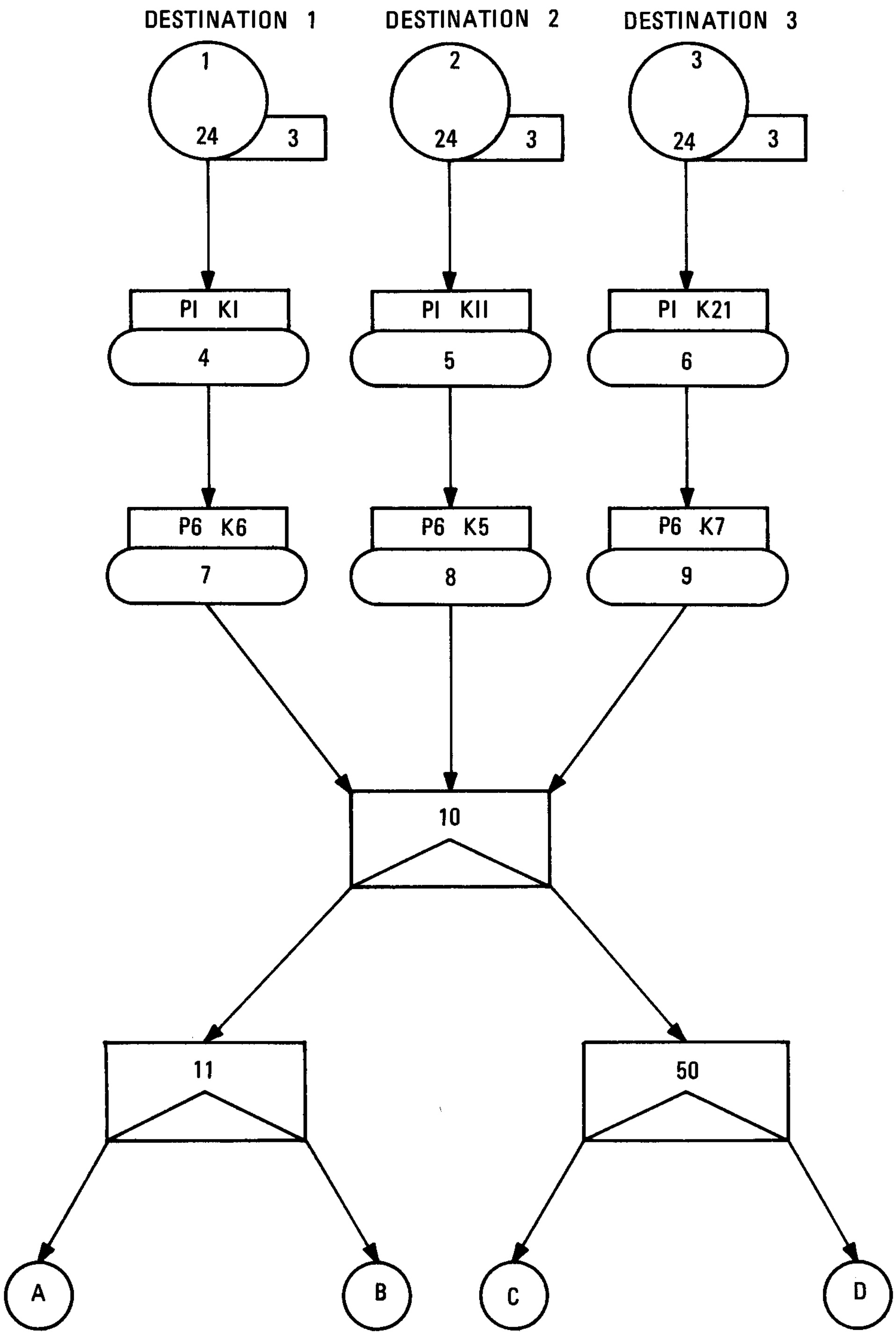


Figure 3. Computer Flow Diagram.

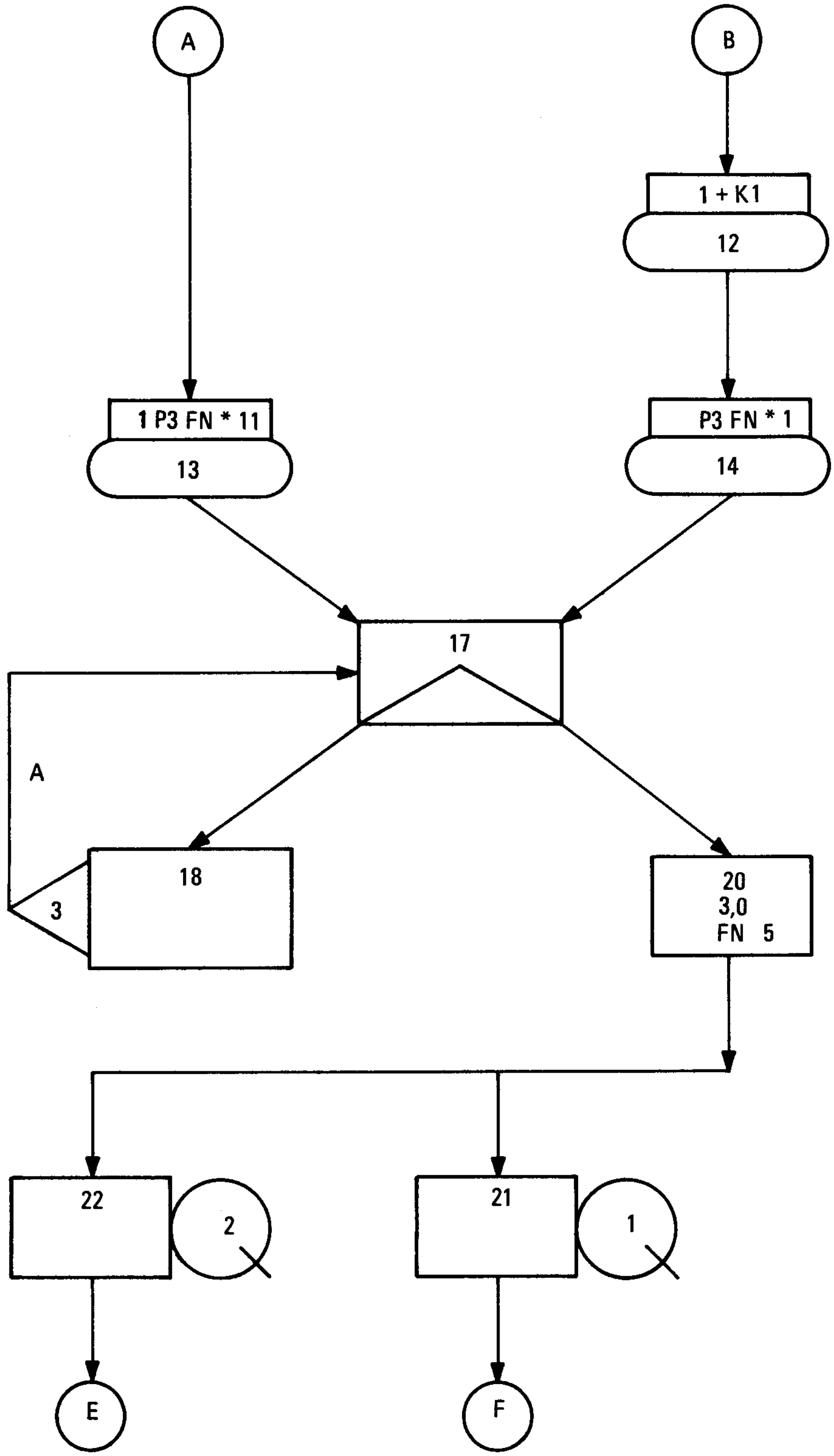
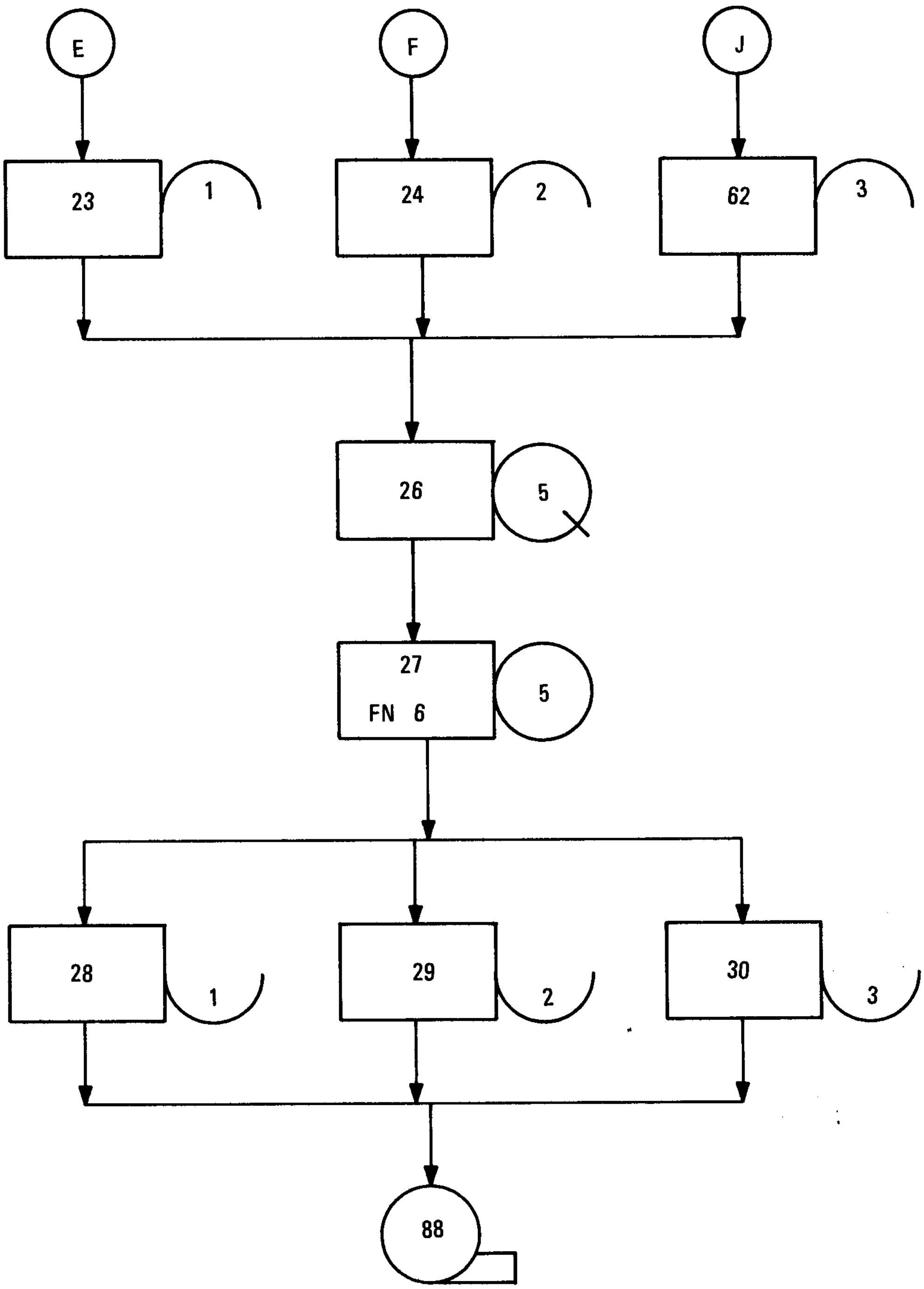


Figure 3 (Continued). Computer Flow Diagram.



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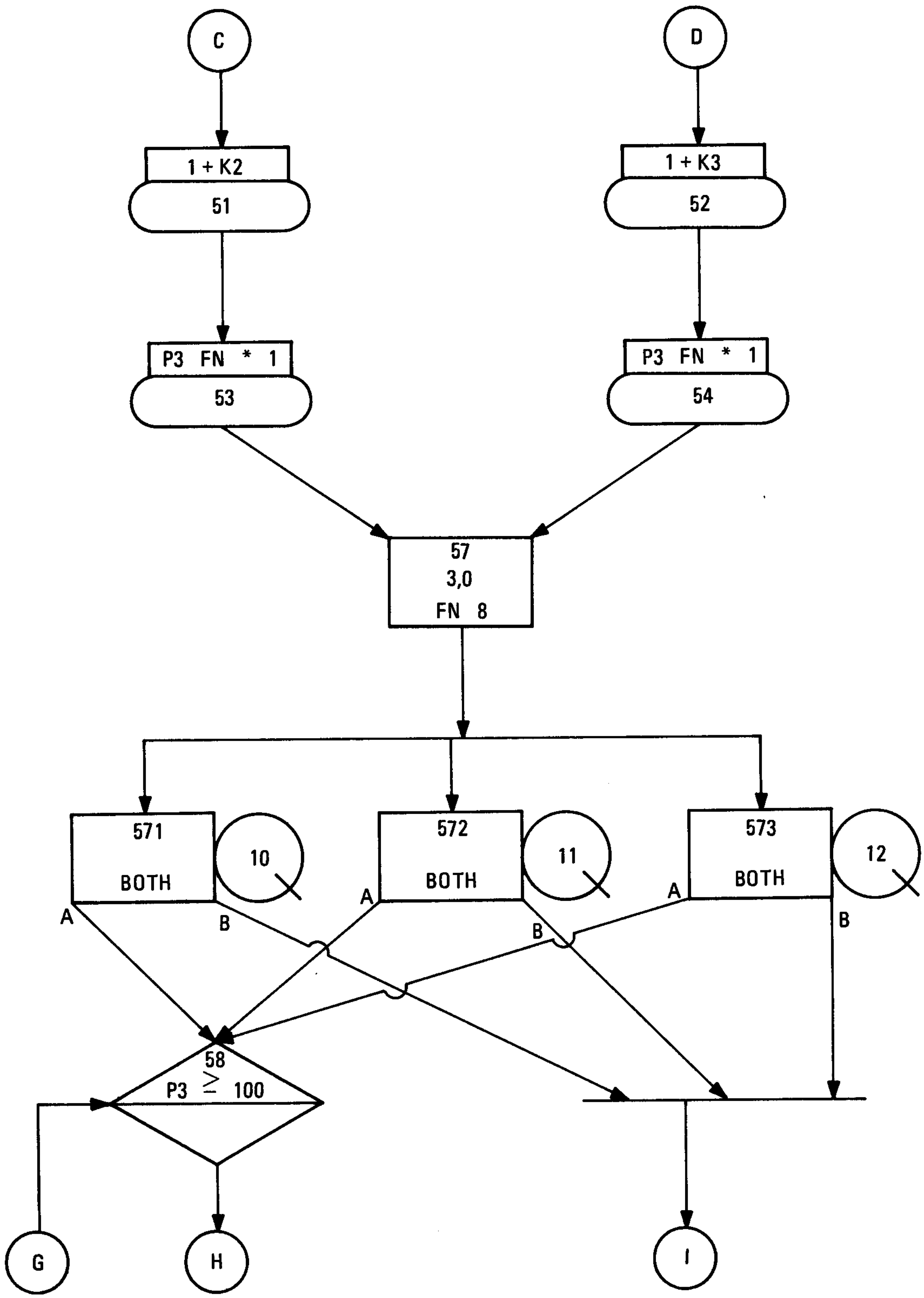

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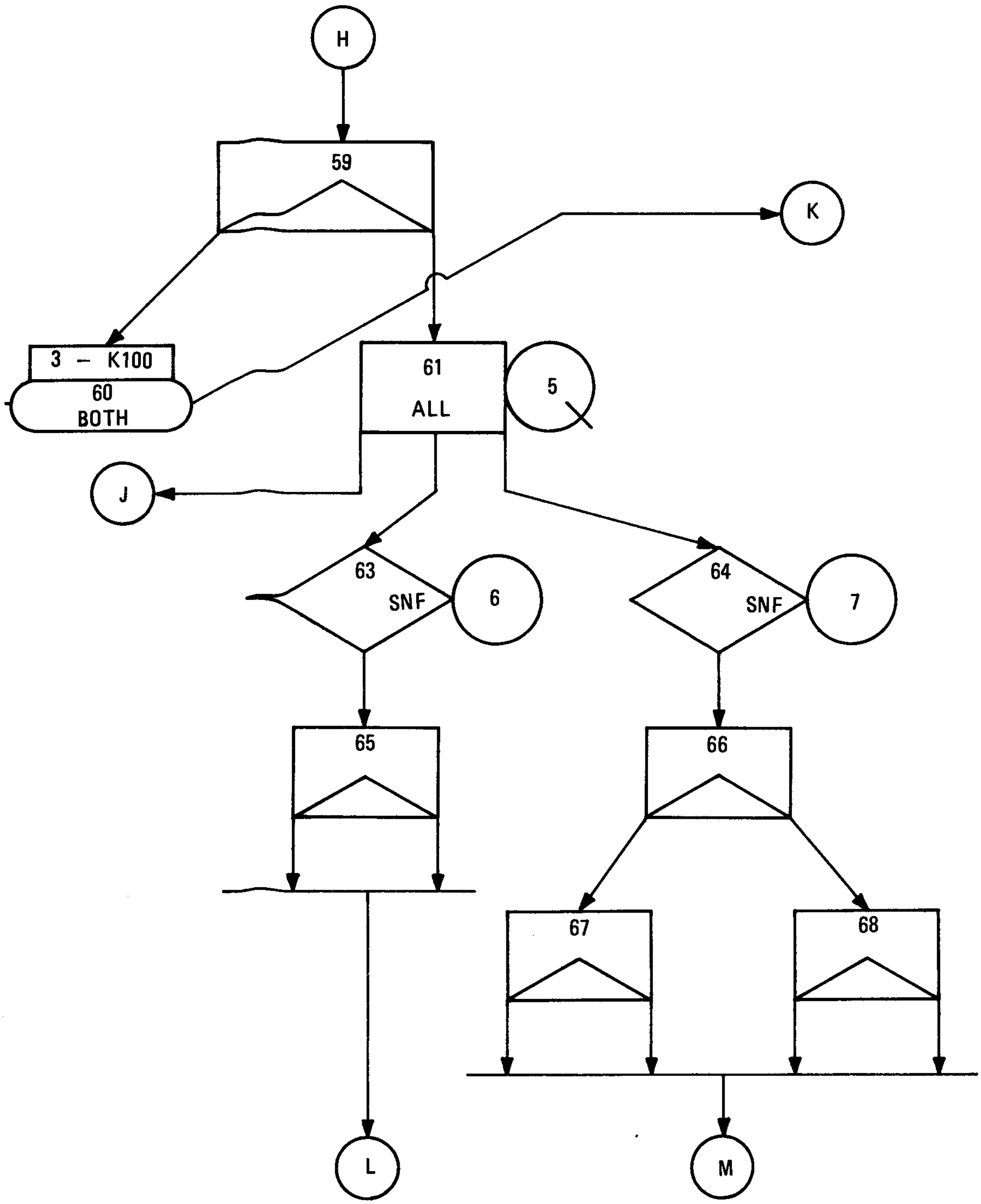

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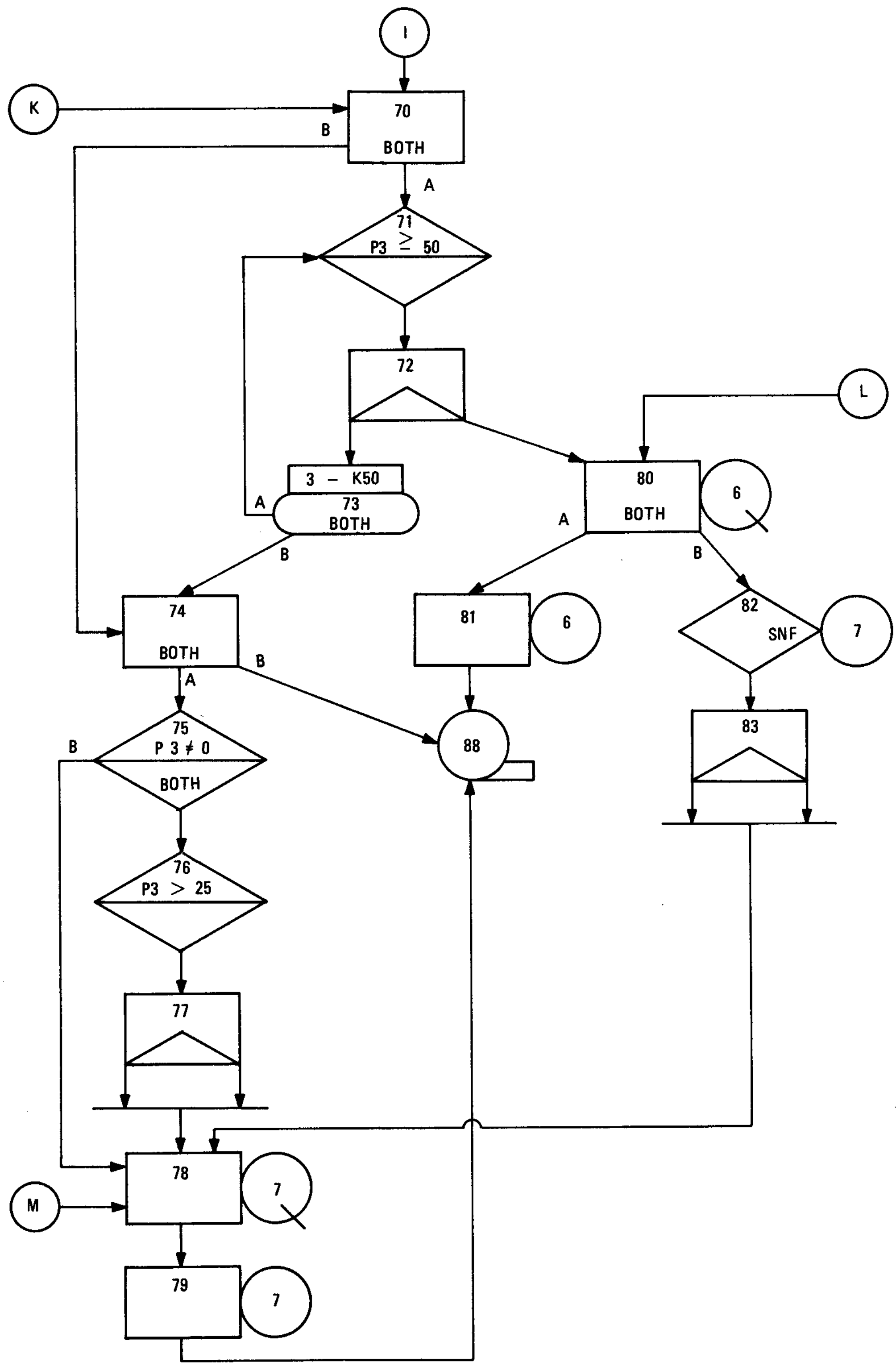


Figure 3 (Continued). Computer Flow Diagram.

three and four.

ASSIGN blocks 13, 14, 53 and 54 assign values obtained from the functions indirectly specified by parameter one to parameter three. Now since the fuel input functions are numbered 1, 11, and 21, parameter three will contain the fuel requirements for that day. The same argument can be applied to the refrigerated, dry cargo and ammunition paths.

SPLIT block 17 creates a duplicate transaction, one going to block 18 and the other block 20.

LOOP block 18 serves to control the number of times a transaction will pass through a section of the block diagram. The value contained in parameter three (loads required for fuel and refrigerated cargo) is used to count the loops which are executed. When parameter three is decremented to zero the process is terminated by TERMINATE block 88.

ADVANCE block 20 accepts the number of transactions that is controlled by the LOOP block. It holds all transactions for three time units and then routes them according to function 5. This function will route the transactions, dependent upon whether it is a fuel or refrigerated requirement.

ADVANCE block 57 accepts the number of transactions that are in paths three (dry cargo) and four (ammunition). The block will hold the transactions for three time units and then route them according to function 8. Function 8 routes with respect to node origination.

QUEUE blocks 21 and 22 signal the program that statistics should be maintained at this point. This indicates the required quantity of fuel and refrigerated cargo respectively, that has been generated for that time period and whether or not it was fulfilled.

QUEUE blocks 571, 572 and 573 maintain statistics of the transactions that are originated by each node.

ENTER blocks 23, 24 and 62 represent the usage of respective storages by a transaction. The capacity of a storage is defined by a CAPACITY control card in the program. These three storages represent the amount of "type" semi-trailers available to move the fuel, refrigerated cargo, dry cargo and ammunition. Transactions are not permitted to enter a storage which is full or lacks sufficient unused space to meet the transactions needs. Statistics are maintained by the program which supply the utilization factors of the storages.

QUEUE block 26 maintains statistics on the number of transactions at this point in the program. It will depict the number of semi-trailers that will require tractor power and whether or not the requirement was fulfilled.

STORE block 27 represents the usage of a storage by a transaction. This block functions in the same manner as the ENTER block. This storage is the location of all tractive power. If there are tractors available, transactions will be permitted to enter this block, if not transaction will be queued in the previous block. Again transactions enter according to their respective priorities. After holding the transaction for 18 hours, depicting a day's work, the tractors are released to the storage. After releasing the tractors, the trailers are routed by type to their respective storage.

LEAVE blocks 28, 29 and 30 release the occupied storage of semi-trailers.

This makes the trailers available for the following days' requirements. Transactions enter the storages by priority.

All transactions flowing through paths three (dry cargo) and four (ammunition) attempt to enter COMPARE block 58. This block tests the relationship between two system variables, parameter three and the constant 100. If parameter three is not greater than 100, the transaction will not be permitted to enter this block. In this case, the transaction enters block 70. However, if the relationship is satisfied, the transaction will enter this block.

SPLIT block 59 creates a duplicate transaction -- one going to block 60 and the other to block 61. The transaction represents the requirement for one stake and platform trailer.

ASSIGN block 60 reduces the value of parameter three by 100. At this point, if the value of the transaction contained in parameter three satisfies the relationship in block 58, it will continue to cycle until the relationship is not satisfied. If not satisfied the transaction is routed to block 70.

QUEUE block 61 queues all dry cargo and ammunition transactions and simultaneously, maintaining continuous statistics. At this point, routing of transactions to transport modes is accomplished. By the block selection mode ALL, the transaction will first attempt to enter block 62; if the store is not fully occupied, the transaction will enter. If block 62 is full, the transaction will attempt to enter block 63. If the transaction is unable to enter block 63, it attempts to enter block 64. If the transaction is unable to enter any of the blocks, it will queue in block 61. From blocks 62, 63, and 64, paths are followed which represent three transport modes; namely, stake and platform (10 ton), 5-ton cargo (5-ton) and 2-1/2 ton cargo (2-1/2 ton). The tonnage capabilities of the modes are enclosed in the above parentheses.

GATE block 63 is used to test the status of a simulator logical condition. This block operates by refusing entry to transactions unless a specified test is passed. In this case, the block tests the status of the 5-ton cargo storage. If not full, the transaction will enter.

SPLIT block 65 creates a duplicate transaction. This is done to provide the necessary carrying capability. That is, since a stake and platform can carry 10 tons, two transactions representing 5 tons each must be created.

GATE block 64 is used to test the status of the 2-1/2 ton storage. If it is not full a transaction can enter.

SPLIT blocks 66, 67, and 68 provide the same function as block 65. However, instead of two transactions, four transactions representing 2-1/2 tons each must be created. Again, this is because of the hauling capabilities.

ADVANCE block 70 accepts all transactions attempting to enter. This block provides a choice of exit paths either to block 71 or 73.

COMPARE block 71 provides the similar function as block 58 -- the exception being that parameter three is compared with the constant 50.

SPLIT block 72 and ASSIGN block 73 provide the same loop as does blocks 59 and 60. Block 72 exits a transaction representing one requirement for a 5-ton truck.

QUEUE block 80 provides the queueing function for the 5-ton cargo mode.

A choice of paths is given to the transaction. If transport capability is available, it goes to block 81; if not available the transaction attempts to enter block 82.

STORE block 81 represents the storage of a transaction. The storage is accompanied by a CAPACITY control card denoting the number of 5-ton cargo trucks available. As does block 27, this store will hold its transactions for 18 hours prior to releasing them.

GATE block 82 and SPLIT block 83 provide similar functions to blocks 63 and 65 -- the exception being that the 2-1/2 ton is being investigated instead of the 5-ton store.

ADVANCE block 74 provides the transaction with a choice of paths. If it can not enter block 75, the transaction will go to block 88.

COMPARE block 75 tests parameter three against the constant 0. Since the transaction is not zero (if entry permitted), it is given a choice of paths.

Since the value of transaction contained in parameter 3 is between 0 and 50, it must be determined to be either greater or less than 25. If greater than 25, two transactions must be created representing the requirement for two 2-1/2 ton trucks. This sequence is accomplished by COMPARE block 76 and SPLIT block 77. If the value contained in parameter three of the transactions less than 25, only one transaction, representing one 2-1/2 ton truck, is required.

QUEUE block 78 and STORE block 79 provide the similar function as do blocks 80 and 81 respectively -- the exception being for the 2-1/2 ton instead of the 5-ton mode.

TERMINATE block 88 removes all transactions from the block diagram. It is used to represent the completion of a path of flow in the system.

Transportation Planner Design

This portion of the model development describes how the transportation planner can adapt the master flow diagram to a given situation. By adjusting or changing certain blocks of the flow diagram, the analyst may expand or contract the model according to his particular needs. The primary modifications are discussed below:

Origination of Requirements. - The model is designed for a maximum of three destinations per program run. If more than three destinations are required multiple runs, with three or less nodes, may be programmed. If less than three destinations are desired for a particular run, the appropriate number of ORIGINATE blocks should be eliminated from the program. For example, if two nodes are to be supported, extract ORIGINATE card 3 from the program.

Priority by Destination. - The model is presently constructed with the following priority by destination: destination 3, destination 1, and destination 2. The systems analyst may adjust the node priority in one of two ways: (1) the input functions should be arranged according to the present priority structure or (2) by adjusting blocks 7, 8, and 9 of the flow diagram or renumbering program cards 7, 8 and 9.

Supply Categories. - Present design of the model encompasses four supply categories: bulk petroleum, refrigerated cargo, dry cargo, and ammunition. Additional or fewer categories can be made by modifying either block 11 or 50. Each SPLIT block creates a duplicate transaction; therefore, the addition or deletion of a SPLIT block will accomplish the desired modification in the program.

Priority of Cargo Transporters. - In the present construction of the model, dry cargo and ammunition are transported in the following manner: (1) stake and platform semitrailers, (2) 5-ton cargo trucks, and (3) 2-1/2-ton cargo trucks. If it is desired to revise the present order of transport, the renumbering of blocks or cards 62, 63, and 64 can accomplish same.

Capacities of Cargo Transporters. - The cargo carriers are designed to carry their nominal loads. In other words, the stake and platform semitrailers can carry ten short tons; the 5-ton cargo truck can carry five short tons; and the 2-1/2-ton cargo truck can carry two and a half short tons. These capacities may be modified by constructing ratios of one carrier to the other. For example, presently the ratio of the 5-ton truck to the 2-1/2 ton truck is two to one. Therefore, if a 5-ton vehicle is not available, two 2-1/2 ton trucks are required to accomplish the same task. In the model, this is done by SPLIT BLOCK 83. By constructing the desired ratio of mode carrying capacities, SPLIT blocks can be employed to model the desired ratio.

Modification of the model according to the desires of the transportation planner is a relatively simple task. Significant changes in the simulation model and its results can be induced by renumbering, interchanging, deleting or adding of standard GPSS II flow diagram blocks.

CHAPTER IV

EXPERIMENTATION

General

Prior to conducting experiments, the model must be programmed into the computer language from the flow diagram. With the model constructed, a syntax run must be completed to verify the correctness of the program. A complete program listing, including output data, is shown in the Appendix.

Five basic experiments, with three variations of each, were designed with specific considerations. This plan of experiments is shown in Table 2.

Basic experiments No. 1 and No. 2 are utilized in the validation of the model. Experiment No. 1 is designed to supply a supported force which is three times larger than the force of experiment No. 2. Basic experiments No. 3 and No. 5 are utilized to test the maximum and minimum size of supported force. A field army consisting of eight divisions is supported in experiment No. 3 and two task forces consisting of battalion size units is supported in experiment No. 5. Basic experiment No. 4 is designed to determine transport requirements for a force of six divisions.

In conducting the fifteen experiments, multiple runs per experiment are necessary to determine the transport requirements for each supported force. These transport requirements must satisfy two acceptance criteria; namely, the average utilization factor and the percentage of queued requirements.

Table 2. Plan of Experiments Showing Types of

Units Supplies and Roundtrip Factors

	NODE 1	NODE 2	NODE 3
	Experiment No. 1		
Supported Force	Infantry Division	Airmobile Division	Airborne Division
R/T (a)	1	1	1
(b)	2	0	1
(c)	1.5	1	0
	Experiment No. 2		
Supported Force	Infantry Brigade	Airmobile Brigade	Airborne Brigade
R/T (a)	1	1	1
(b)	2	0	1
(c)	1.5	1	0
	Experiment No. 3		
Supported Force	2 Infantry & 1 Mechanized Divisions	2 Airmobile Divisions	2 Mechanized and 1 Infantry Division
R/T (a)	1	1	1
(b)	2	0	1
(c)	1.5	1	0
	Experiment No. 4		
Supported Force	Infantry and Mechanized Divisions	Airmobile and Infantry Divisions	2 Airborne Divisions
R/T (a)	1	1	1
(b)	2	0	1
(c)	1.5	1	0
	Experiment No. 5		
Supported Force	TF"A"*	TF"B"**	
R/T (a)	1	1	
(b)	2	1	
(c)	1.5	.5	

* Task force (TF) "A" consists of 1 infantry and 1 airmobile battalion.

** Task Force (TF) "B" consists of 1 mechanized battalion.

The random selection of tonnage per combat posture precludes a 100 percent utilization of modes. In the experiments conducted in the study the average utilization criterion per mode is set at a minimun of 97 percent. In general, the higher the value of the average utilization factor, the greater the number of computer runs required to meet the specified standard.

The percentage of queued requirements per mode must be less than two percent. This percentage is determined by dividing the total number of entries of each QUEUE block into the current value of the block when the computer run is terminated. In general, the lower the value of the calculated queued factor, the greater the number of computer program runs required to meet the specified standard.

The output of the program runs can readily be compared against the above acceptance criteria. When the standards are met by each mode, the experiment is terminated. An example of a completed experiment which has met the specified standards is shown in the computer program output in the Appendix.

Having reached the acceptance criteria, the quantity of each transport mode will be multiplied by a factor of 1.33. This is due to the planning guidance set by current military doctrine that transportation units will operate on a 75 percent utilization of assigned capability (9). Therefore, the quantity of transport medium is first determined by the simulation model and then modified to reach a planning operational criterion of 75 percent.

The daily resupply factors for each division per posture are shown in Table 3. The resupply factors are shown in short tons (S/T) for each of the four

Table 3. Resupply Factors per Day

Unit (Divisional)	Posture	Bulk S/T*	Petr Tanks	Refrigerated S/T	Refrigerated Vans	Dry Cargo S/T	Ammunition S/T
Infantry	Attack	308	21	5	1	128	421
	Defense	285	19	20	3	114	447
	Pursuit	304	20	5	1	111	91
	Inactive	193	13	30	4	106	176
Mechanized	Attack	376	25	5	1	163	457
	Defense	315	21	20	3	128	466
	Pursuit	383	26	5	1	124	95
	Inactive	254	17	30	4	123	193
Airborne	Attack	211	14	5	1	86	268
	Defense	195	13	20	3	84	298
	Pursuit	189	12	5	1	82	51
	Inactive	116	8	30	4	78	106
Airmobile	Attack	1054	70	5	1	155	304
	Defense	937	62	20	3	145	281
	Pursuit	943	62	5	1	148	91
	Inactive	483	32	30	4	115	111

*S/T = Short Ton

categories of supply. For bulk petroleum and refrigerated cargo the tonnage is further subdivided into the number of required semitrailers; namely, tanks are used for bulk petroleum and vans are used for refrigerated cargo. The respective conversion factors are as follows:

(a) 327.8 gallons per S/T of fuel.
5,000 gallons per tanker.

(b) 7-1/2 S/T per refrigerated van.

By utilizing the above conversion factors the tabular mode results were obtained.

The initial run of each experiment is devised to determine transport requirements on maximum required resupply factors from the input functions. Depending on utilization percentages per transport mode, the capacities will be modified in an attempt "to bracket" the desired quantity of each node. Subsequent runs will be made to meet the acceptance criteria if required.

The experiments run on the computer are primarily dependent on turn-around time. Therefore, the inputs (resupply factors) to the various experiments will be adjusted according to the parameter. The input functions to the model are derived from Tables 2 and 3.

The input functions are discrete with a random number selection mode. Therefore, the input is a random variable with uniform distribution between 0 and 1. The output is a random variable with a distribution controlled by the discrete function. Through this random variate process, a daily posture is determined which dictates the appropriate resupply factors.

The development of the discrete functions further emphasize the necessity of a typical military situation which predicates the posture of the different divisions.

The posture in turn dictates the requirements per day to the supported force.

Experiment No. 1

Experiment No. 1 is designed to determine the truck transportation requirements for the forces shown in Table 4. An infantry division is located at Node 1; an airmobile division is located at Node 2; and an airborne division is located at Node 3. Experiment No. 1 is further divided into subexperiments 1(a), 1(b) and 1(c). These three experiments are predictated on the number of roundtrips (R/T) that the transport units can accomplish from origin to destination and return to origin.

Table 4. Experiment No. 1

Supported Forces	NODE 1 Infantry Division	NODE 2 Airmobile Division	NODE 3 Airborne Division
R/T (a)	1	1	1
R/T (b)	2	0	1
R/T (c)	1.5	1	0

In subexperiment 1(a), one roundtrip is accomplished to each node from the transportation origin. In subexperiment 1(b), two roundtrips are made to Node 1, zero to Node 2, and one to Node 3. In subexperiment 1(c), one and a half roundtrips are accomplished to Node 1, one to Node 2, and zero to Node 3.

The input functions for these experiments are shown in Figures 4-7. Functions 1, 11, and 21 depict the fuel requirements for destinations 1, 2, and

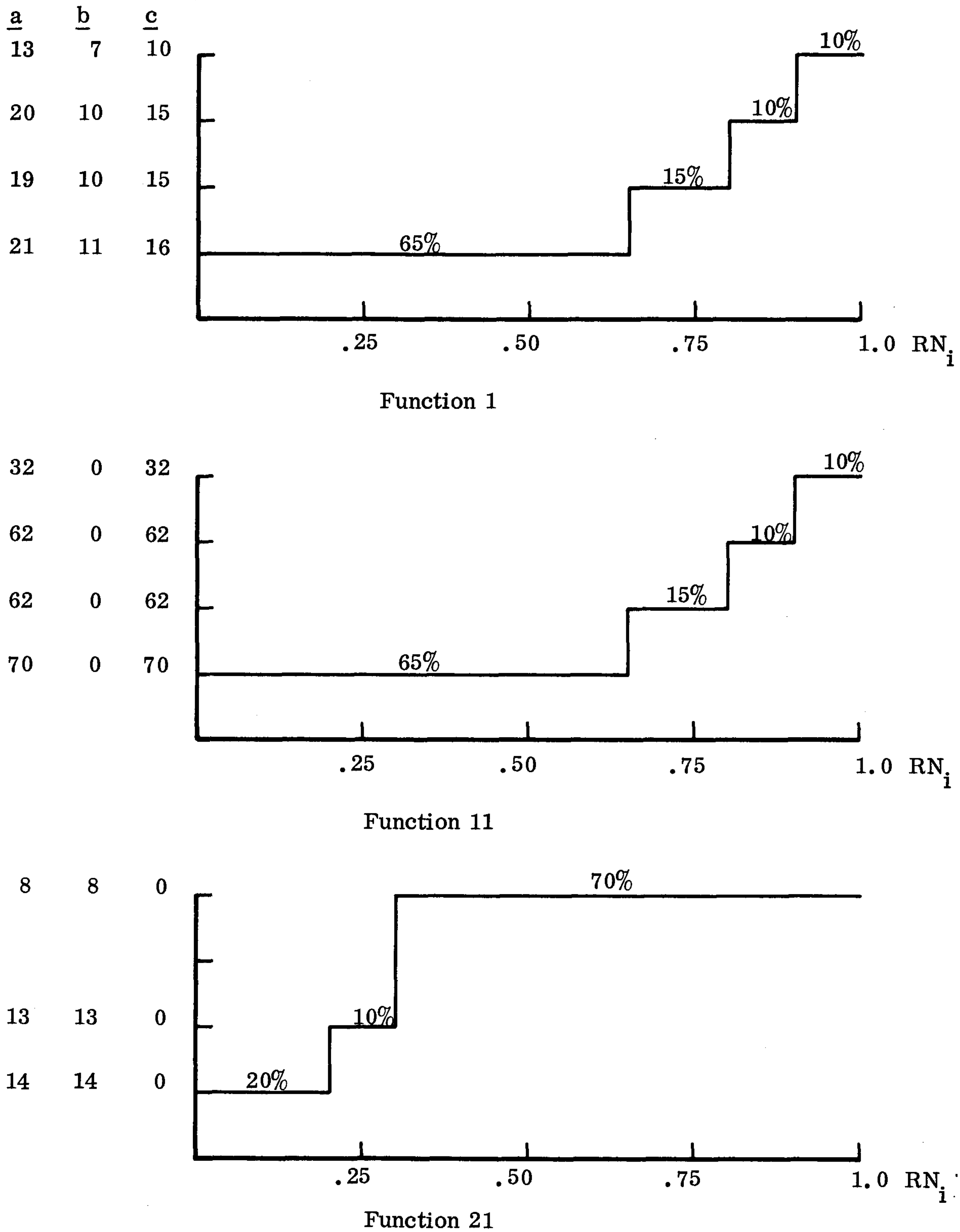
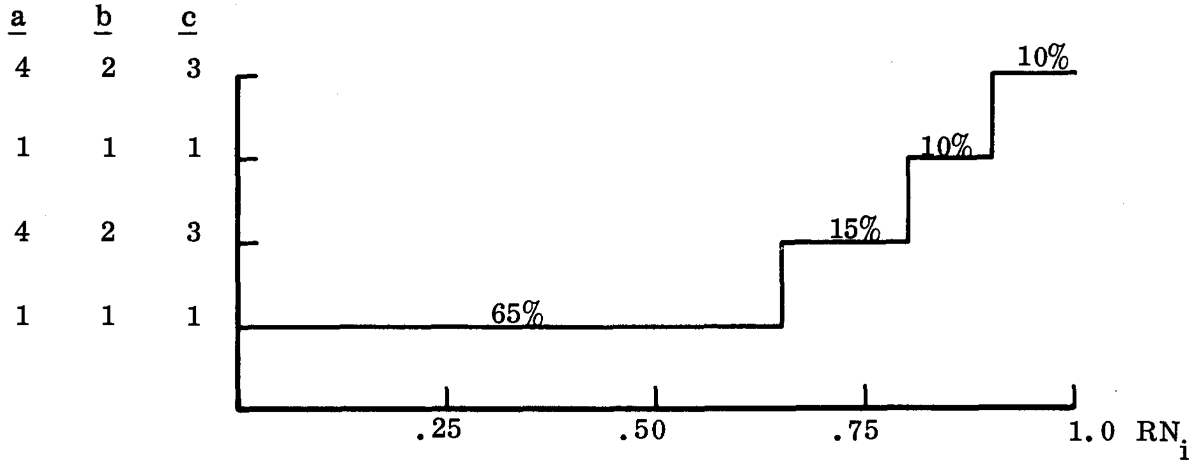
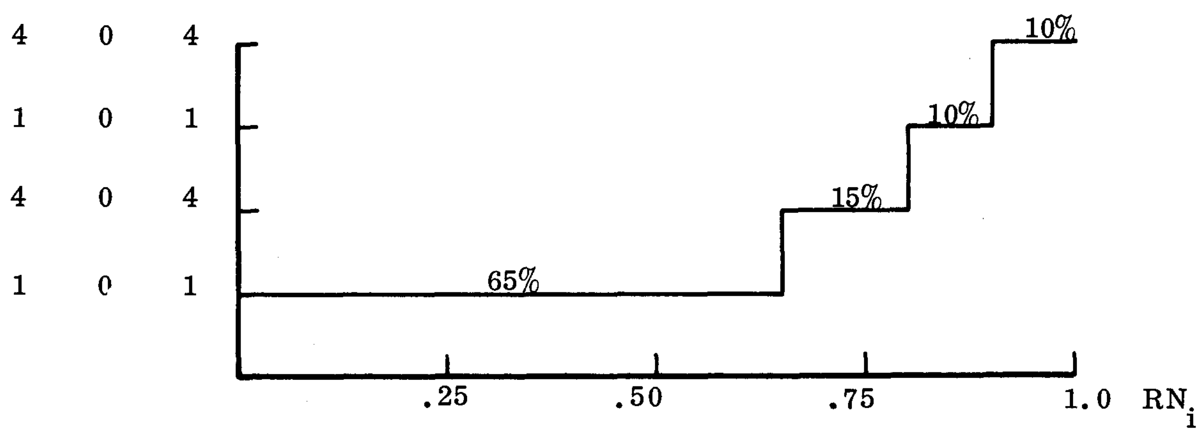


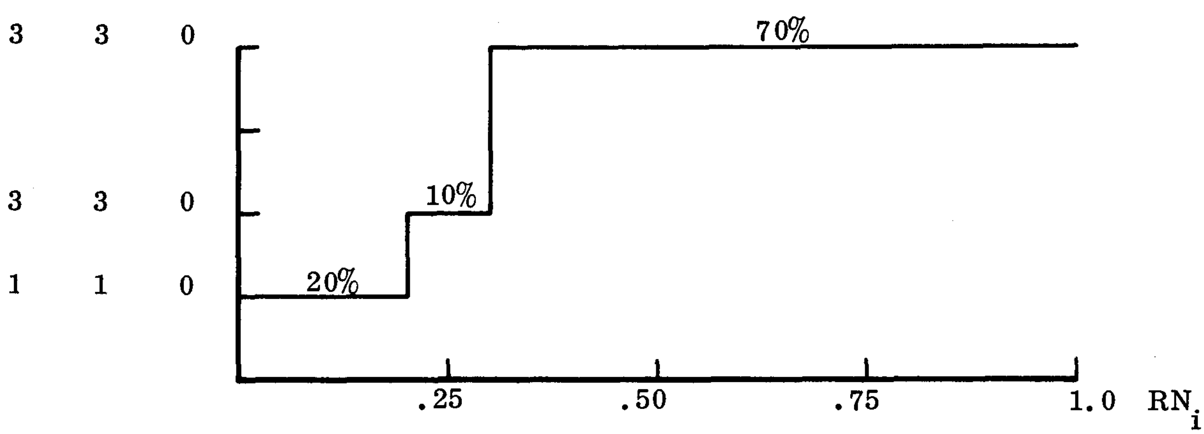
Figure 4. Fuel Input Functions for Experiments 1(a), 1(b), and 1(c).



Function 2



Function 12



Function 22

Figure 5. Refrigerated Cargo Input Functions

for Experiments 1(a), 1(b) and 1(c).

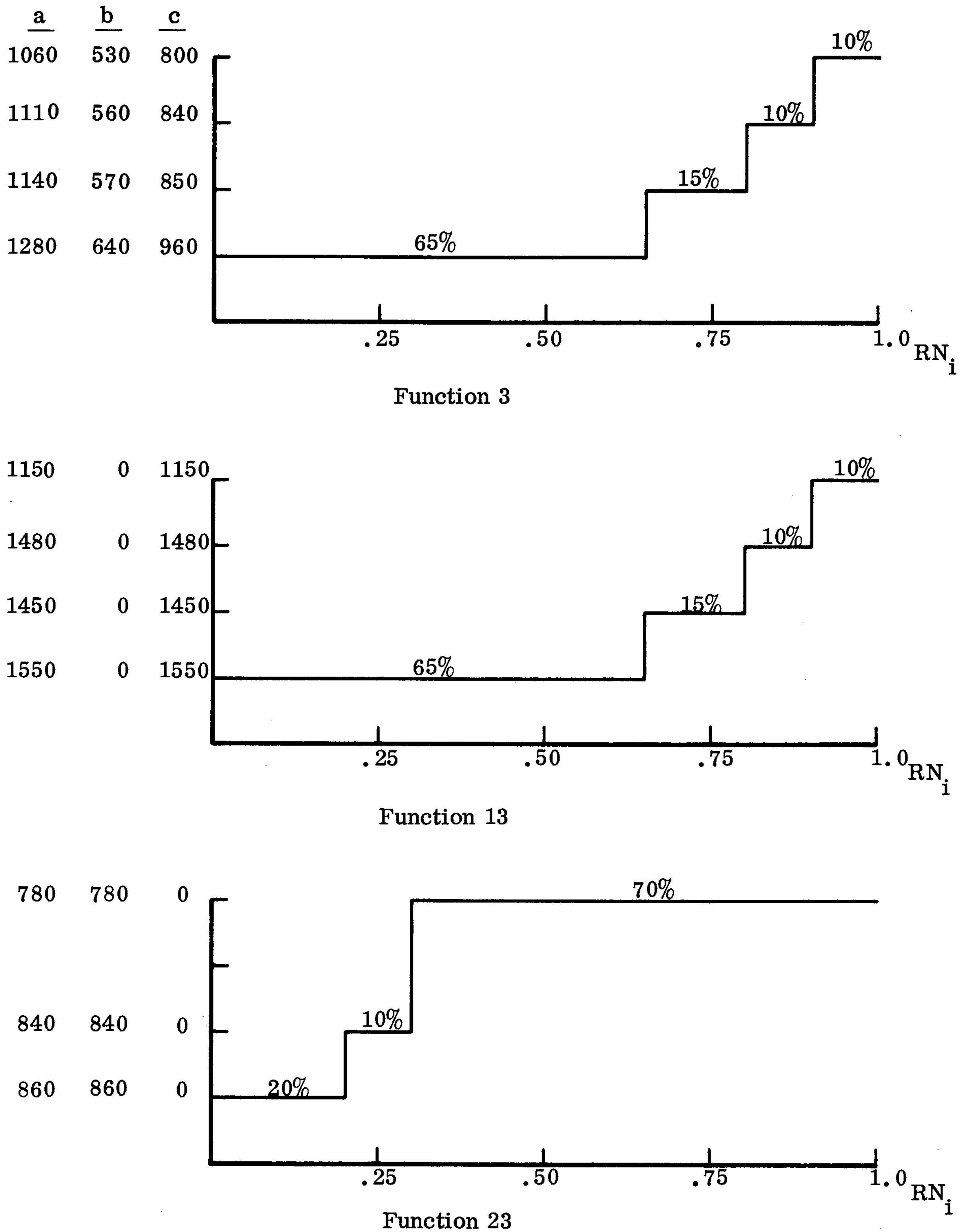
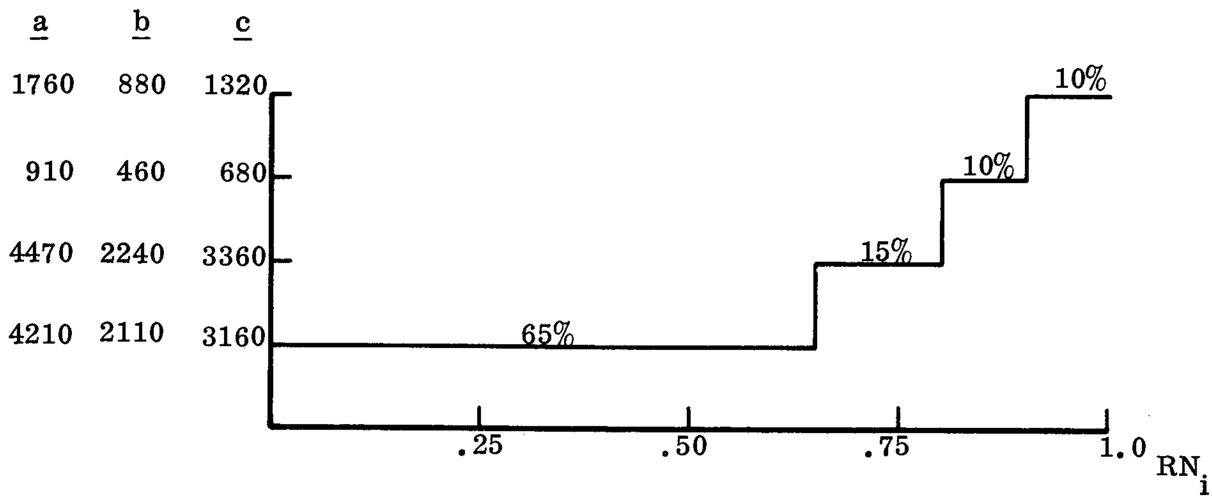
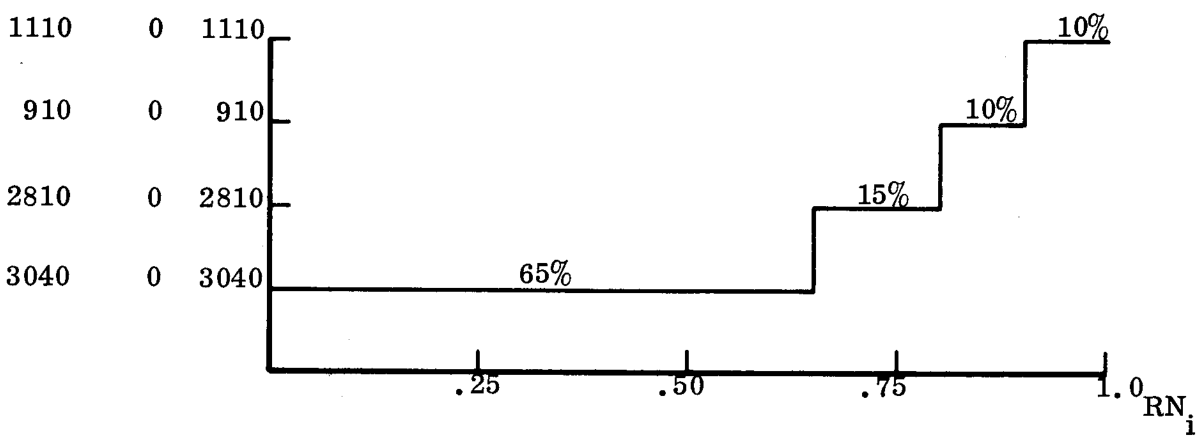


Figure 6. Dry Cargo Input Functions for

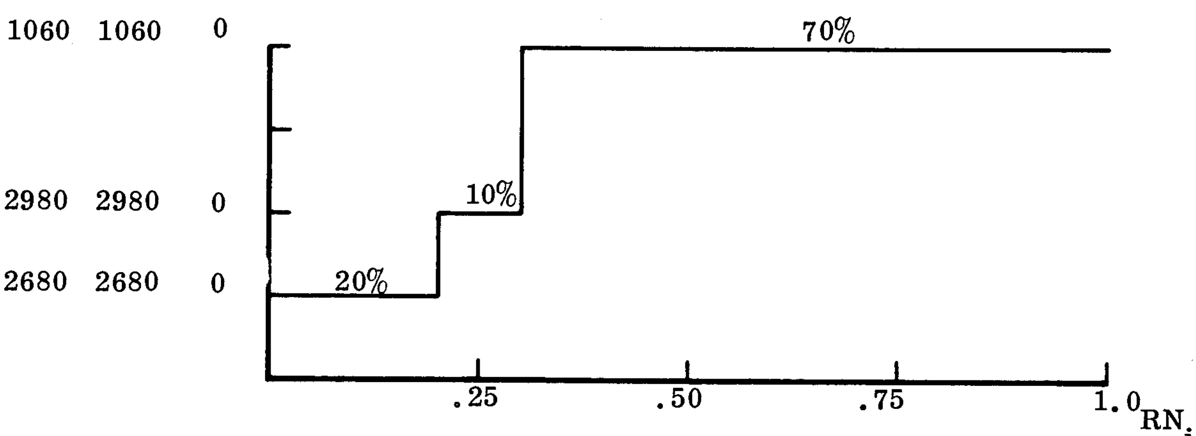
Experiments 1(a), 1(b), and 1(c).



Function 4



Function 14



Function 24

Figure 7. Ammunition Input Functions for

Experiments 1(a), 1(b), and 1(c).

3 respectively; functions 2, 12, and 22 show refrigerated cargo requirements; functions 3, 13, and 23 refer to dry cargo requirements; and functions 4, 14, and 24 ammunition requirements.

Experiment No. 2

Experiment No. 2 is designed to determine the truck transportation requirements for the forces shown in Table 5. An infantry brigade is located at Node 1; an airmobile brigade is located at Node 2; and an airborne brigade is located at Node 3. Experiment No. 2 is further divided into subexperiments 2(a), 2(b), and 2(c). These experiments are predicated on the number of roundtrips that the transport units can accomplish from origin to destination and return to origin.

Table 5. Experiment No. 2

Supported Forces	NODE 1 Infantry Brigade	NODE 2 Airmobile Brigade	NODE 3 Airborne Brigade
R/T (a)	1	1	1
R/T (b)	2	0	1
R/T (c)	1.5	1	0

In subexperiment 2(a), one roundtrip is accomplished to each node from the transportation origin. In subexperiment 2(b), two roundtrips are made to Node 1, zero to Node 2, and one to Node 3. In subexperiment 2(c), one and a half roundtrips are accomplished to Node 1, one to Node 2, and zero to Node 3.

The input functions for these experiments are shown in Figures 8-11.

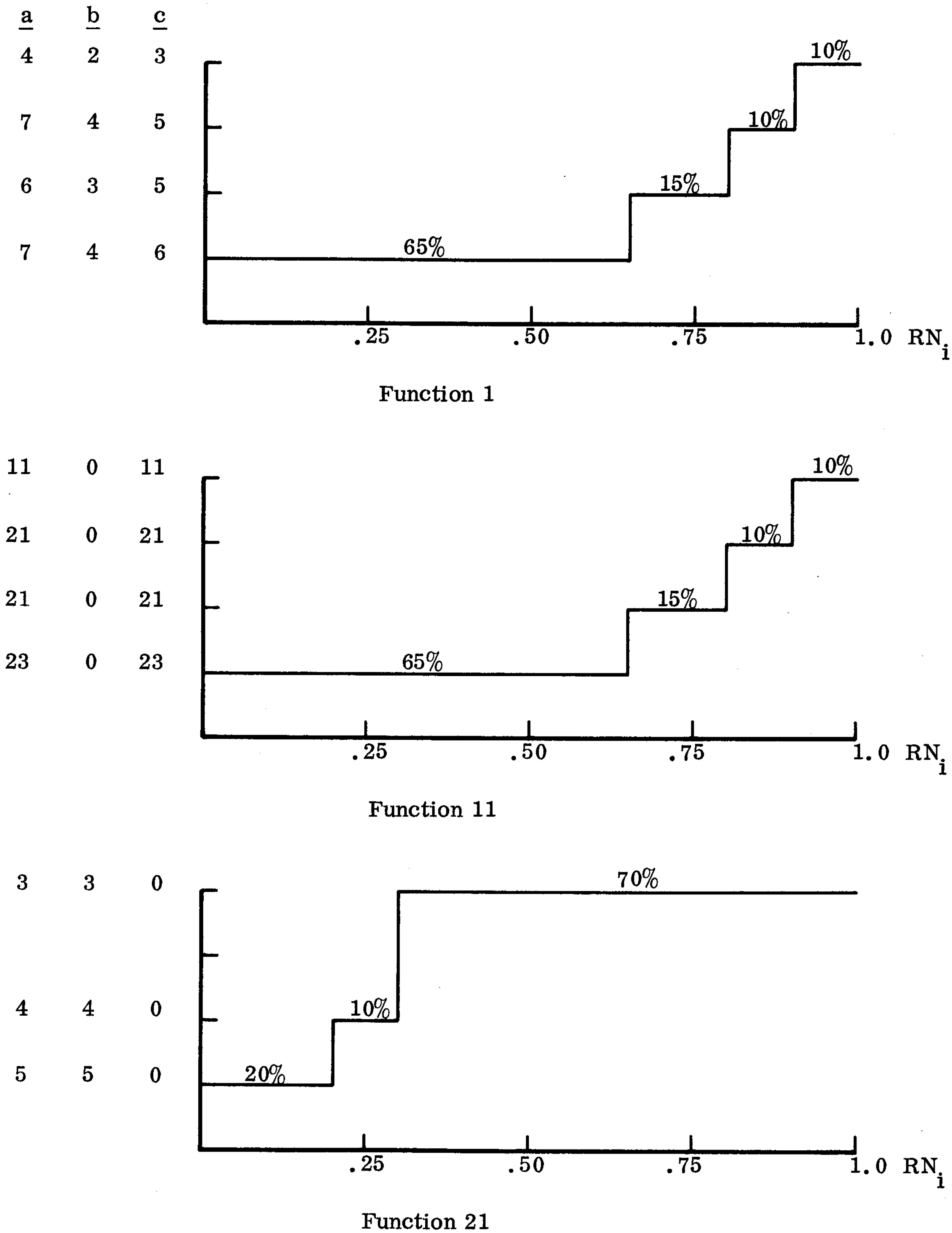


Figure 8. Fuel Input Functions for Experiments 2(a), 2(b), and 2(c).

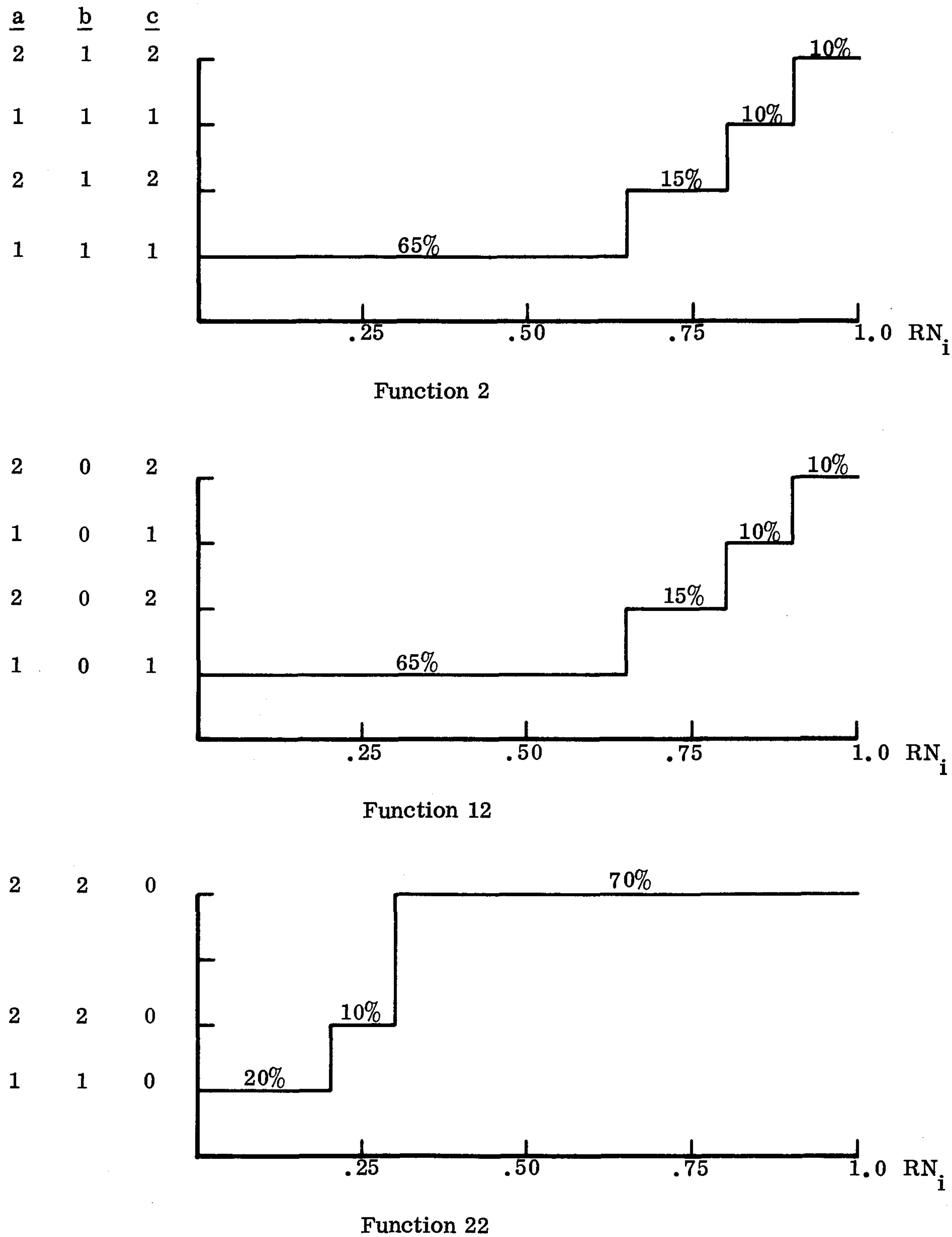
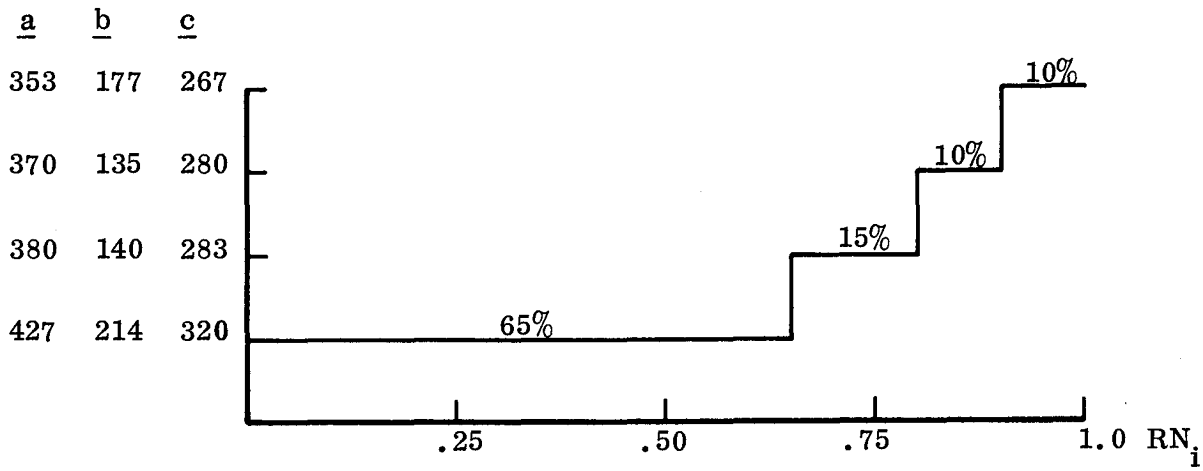
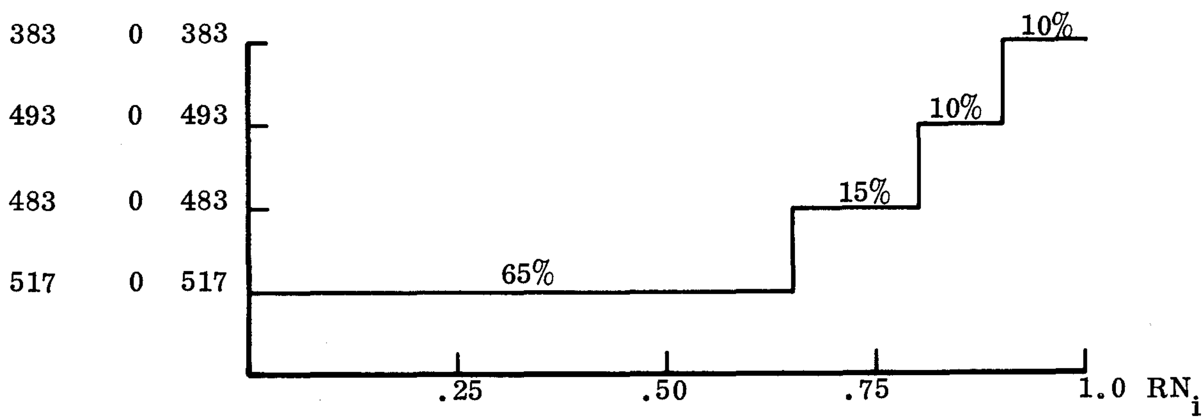


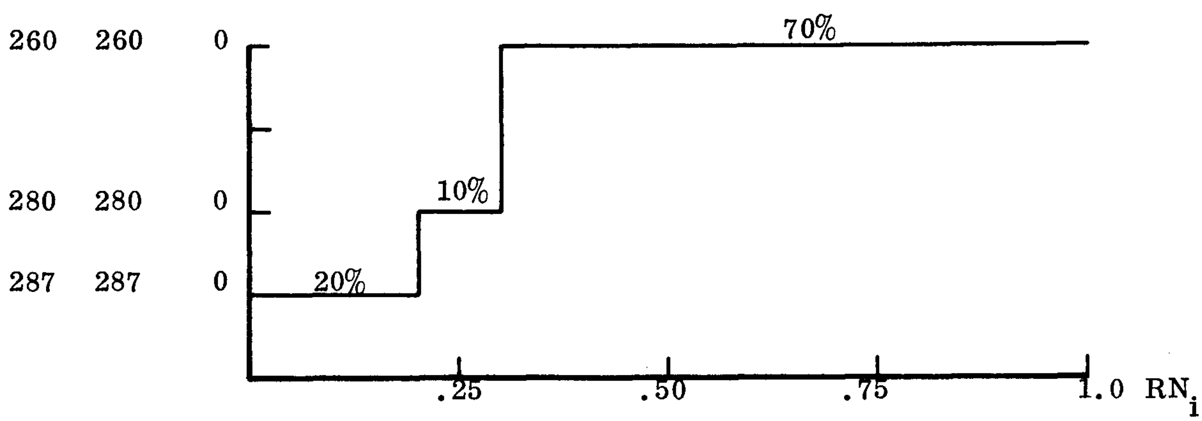
Figure 9. Refrigerated Cargo Input Functions for Experiments 2(a), 2(b), and 2(c).



Function 3



Function 13



Function 23

Figure 10. Dry Cargo Input Functions for Experiments 2(a), 2(b), and 2(c).

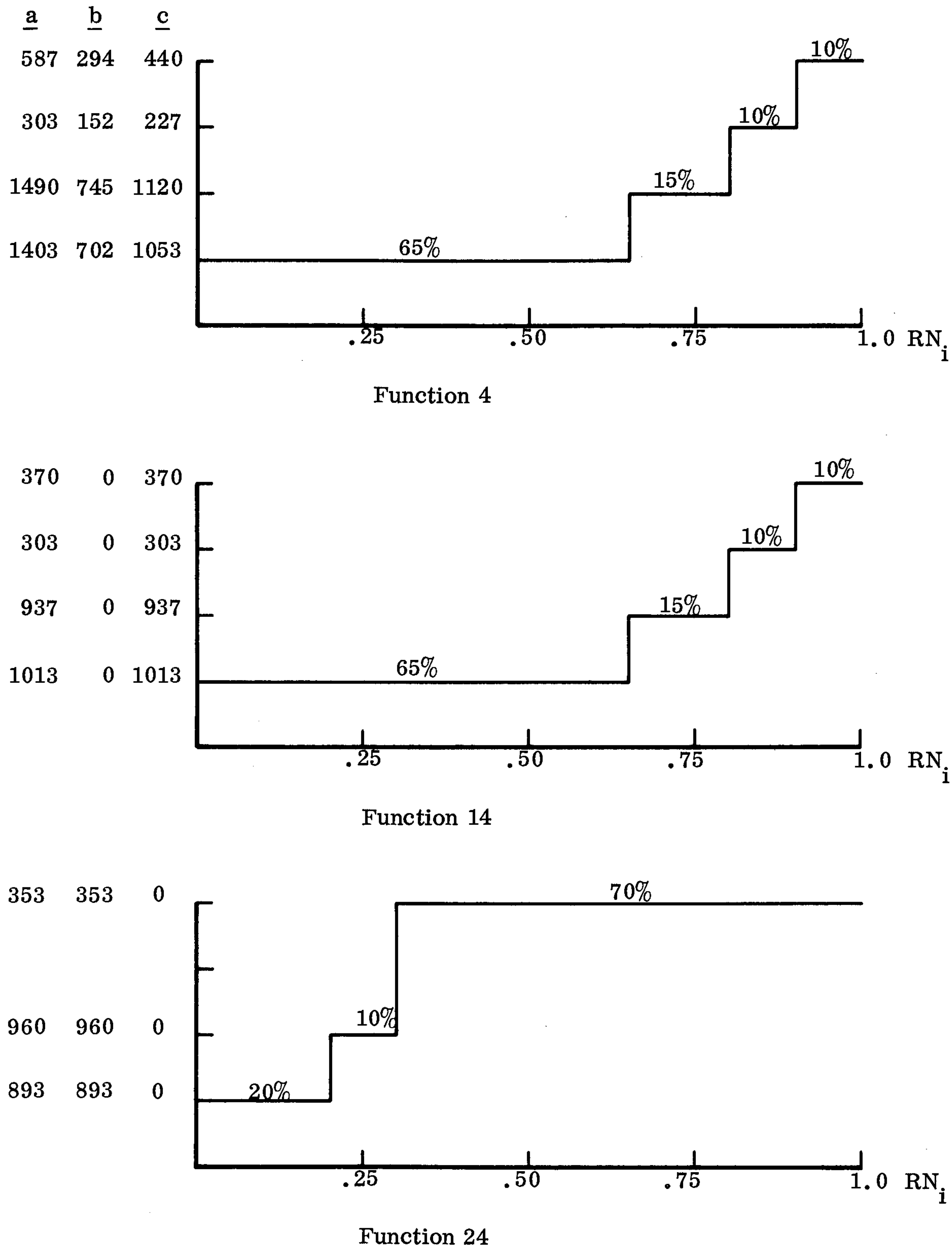


Figure 11. Ammunition Input Functions for Experiments 2(a), 2(b), and 2(c).

Functions 1, 11, and 21 depict the fuel requirements for destinations 1, 2, and 3 respectively; functions 2, 12, and 22 show refrigerated cargo requirements; 3, 13, and 23 refer to dry cargo requirements; and functions 4, 14 and 24 show ammunition requirements.

In addition to determining the transport requirements for the supported forces, experiment 2 has an additional purpose. In conjunction with experiment 1, this experiment will hopefully confirm the validity of the simulation model. The validation criteria will be that of comparing experimental results. Since three brigades constitute a division, experiment No. 1 is supplying three times the force as is experiment No. 2. Therefore, since the input to the respective models has a three to one ratio, the determined transport requirements should maintain this proportionality.

Experiment No. 3

Experiment No. 3 is designed to determine the truck transportation requirements for the forces shown in Table 6. Two infantry divisions and one mechanized division are located at Node 1; two airmobile divisions are located at Node 2; and two mechanized divisions and one infantry division are located at Node 3. Experiment No. 3 is further divided into subexperiments 3(a), 3(b), and 3(c). These three experiments are predicated on the number of roundtrips that the transport units can accomplish from origin to destination and return to origin.

In subexperiment 1(a), one roundtrip is accomplished to each node from the transportation origin. In subexperiment 3(b), two roundtrips are made to Node 1, zero to Node 2, and one to Node 3. In subexperiment 3(c), one and a half

Table 6. Experiment No. 3

Supported Forces	NODE 1 2 Infantry Divisions 1 Mechanized Division	NODE 2 2 Airmobile Divisions	NODE 3 2 Mechanized and 1 Infantry Divisions
R/T (a)	1	1	1
R/T (b)	2	0	1
R/T (c)	1.5	1	0

roundtrips are accomplished to Node 1, one to Node 2, and zero to Node 3.

The input functions for these experiments are shown in Figures 12-15. Functions 1, 11, and 21 depict the fuel requirements for destinations 1, 2, and 3 respectively; functions 2, 12, and 22 show refrigerated cargo requirements; and functions 4, 14, and 24 show ammunition requirements.

In addition to determining the transport requirements for the field army consisting of eight divisions, will hopefully test the GPSS II program to its maximum. That is, if too many transactions are created, the program will "bomb out." If this occurs, an alternative method must be utilized to determine transport requirements.

Experiment No. 4

Experiment No. 4 is designed to determine the truck transportation requirements for the forces shown in Table 7. One infantry division and one mechanized division are located at Node 1; one airmobile division and one infantry division are located at Node 2; and two airborne divisions are located at Node 3. Experiment

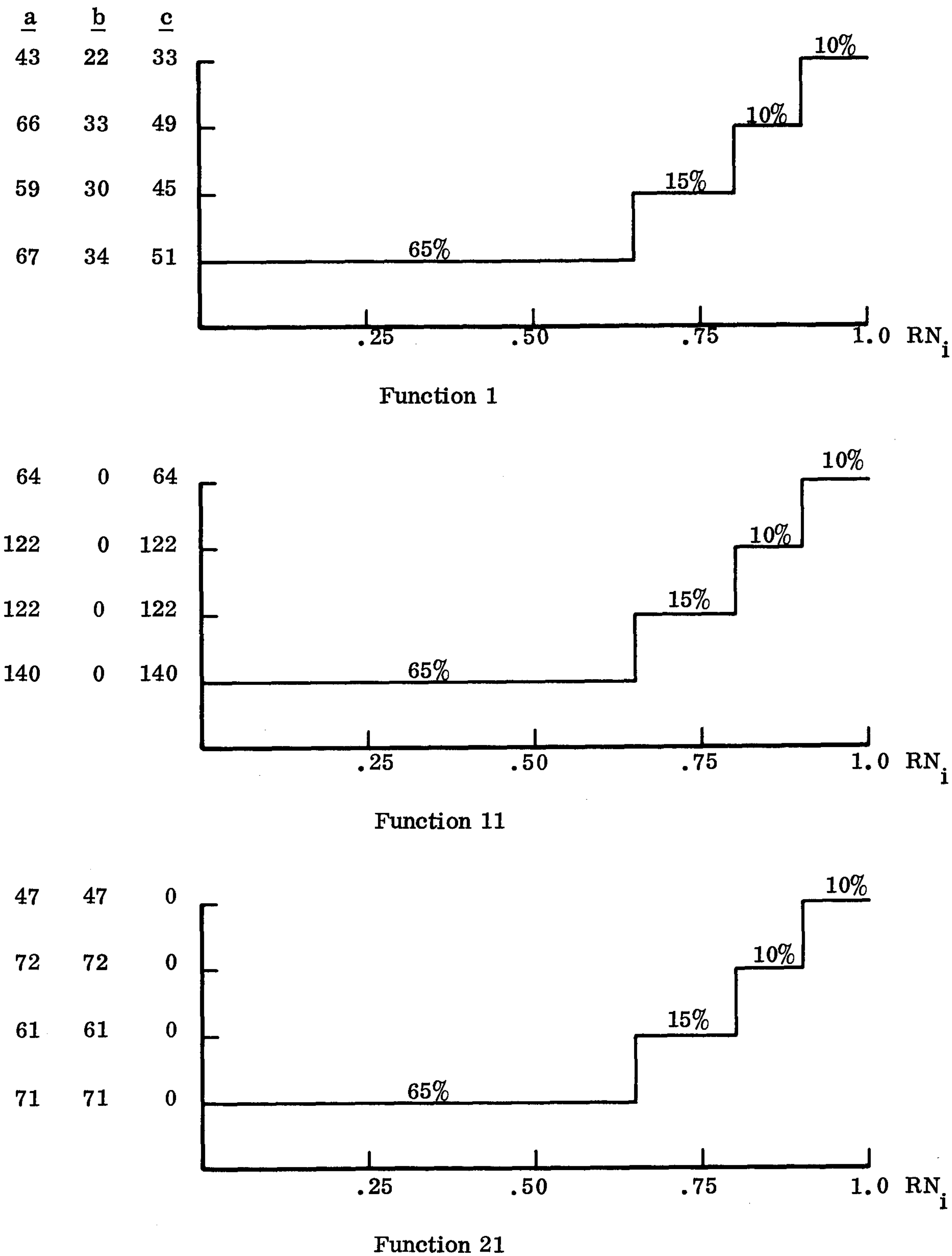
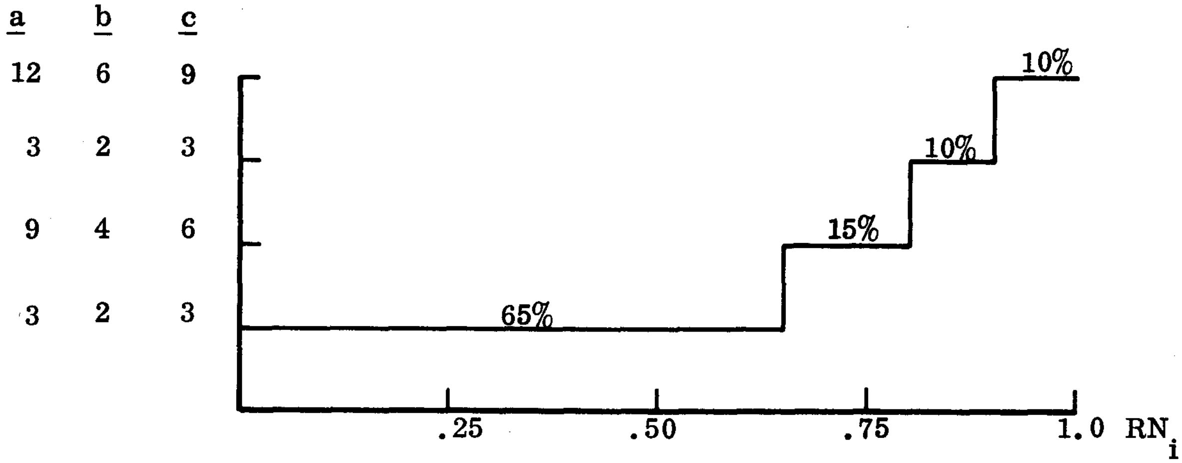
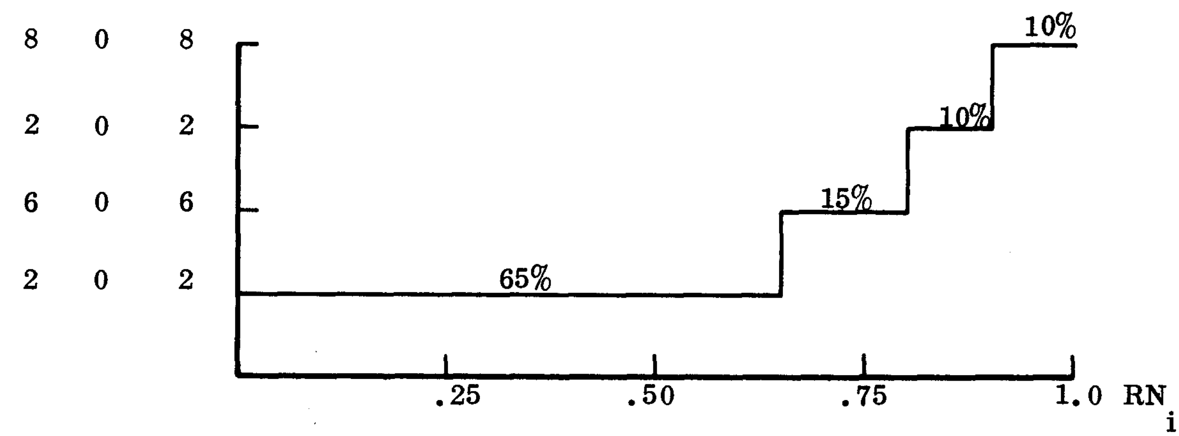


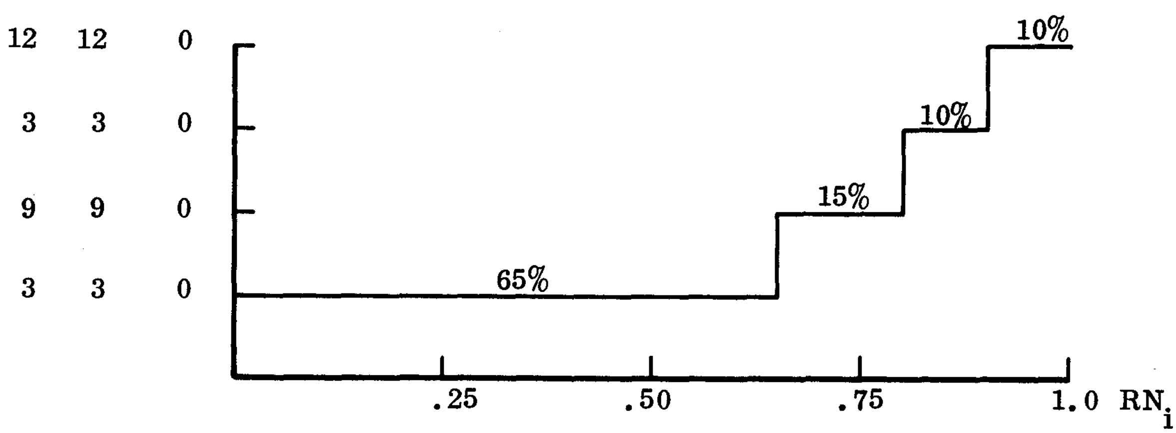
Figure 12. Fuel Input Functions for Experiments 3(a), 3(b), and 3(c).



Function 2



Function 12



Function 22

Figure 13. Refrigerated Cargo Input Functions

for Experiments 3(a), 3(b), and 3(c).

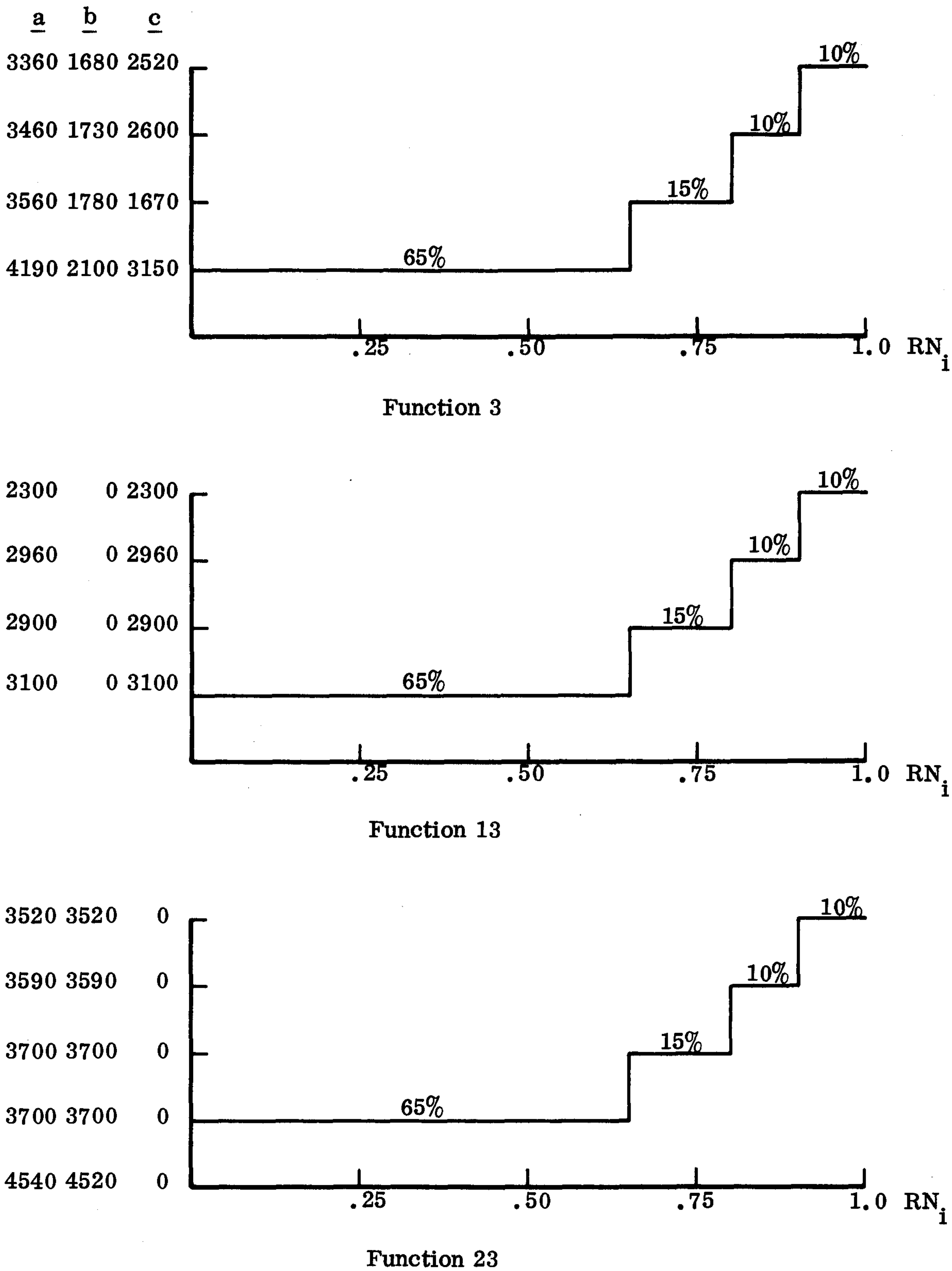
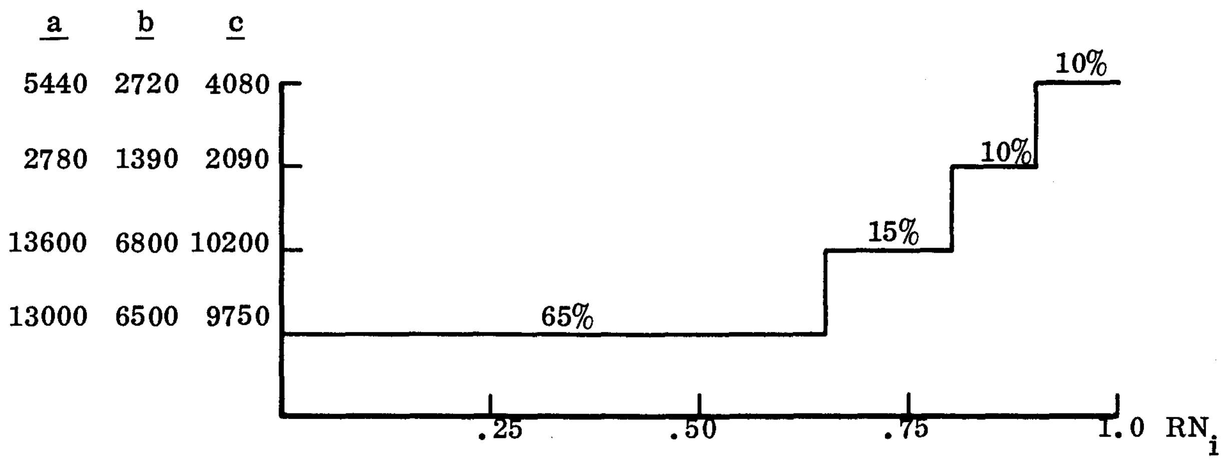
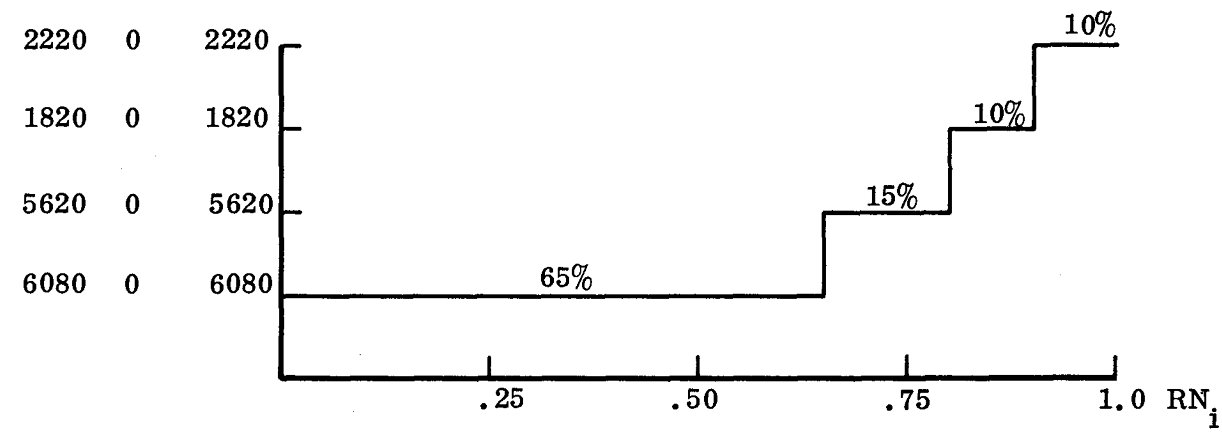
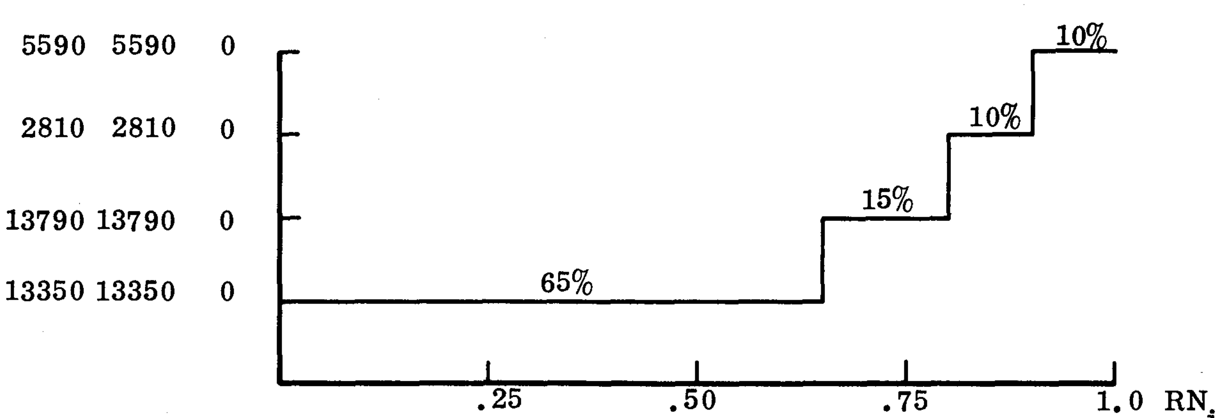


Figure 14. Dry Cargo Input Functions for Experiments 3(a), 3(b), and 3(c).



Function 4





Function 24

Figure 15. Ammunition Input Functions for Experiments 3(a), 3(b) and 3(c).

No. 4 is further divided into subexperiments 4(a), 4(b), and 4(c). These three experiments are predicated on the number of roundtrips that the transport units can accomplish from origin to destination and return to origin.

Table 7. Experiment No. 4

	NODE 1	NODE 2	NODE 3
Supported Forces	Infantry Division Mechanized Division	Airmobile Division Infantry Division	2 Airborne Divisions
R/T (a)	1	1	1
R/T (b)	2	0	1
R/T (c)	1.5	1	0

In subexperiment 4(a), one roundtrip is accomplished to each node from the transportation origin. In subexperiment 4(b), two roundtrips are made to Node 1, zero to Node 2, and one to Node 3. In subexperiment 4(c), one and a half roundtrips are accomplished to Node 1, one to Node 2, and zero to Node 3.

The input functions for these experiments are shown in Figures 16-19. Functions 1, 11, and 21 depict the fuel requirements for destinations 1, 2, and 3 respectively; functions 2, 12, and 22 show refrigerated cargo requirements; functions 3, 13, and 23 refer to dry cargo requirements; and functions 4, 14, and 24 show ammunition requirements.

Experiment No. 5

Experiment No. 5 is designed to determine the truck transportation

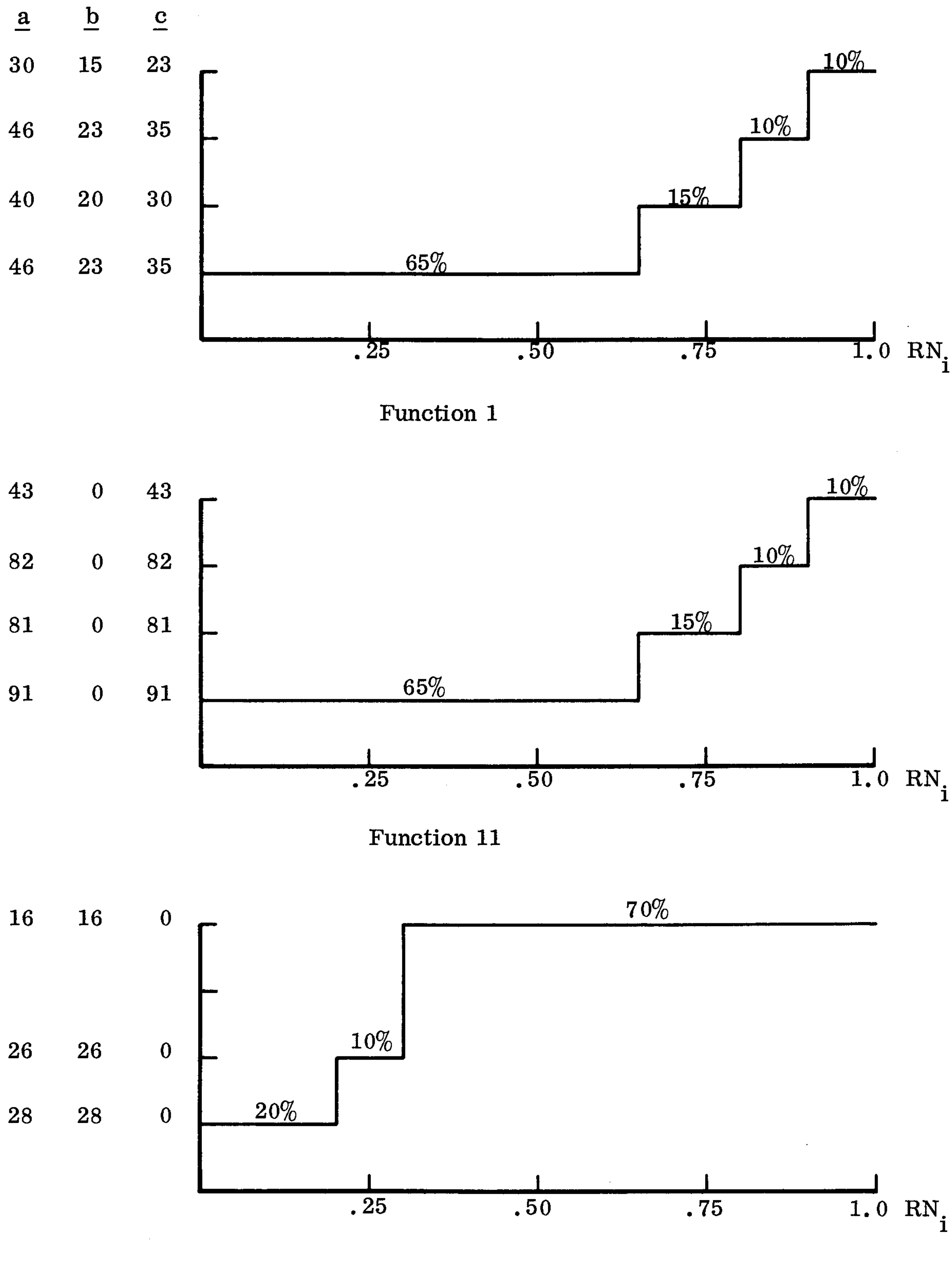
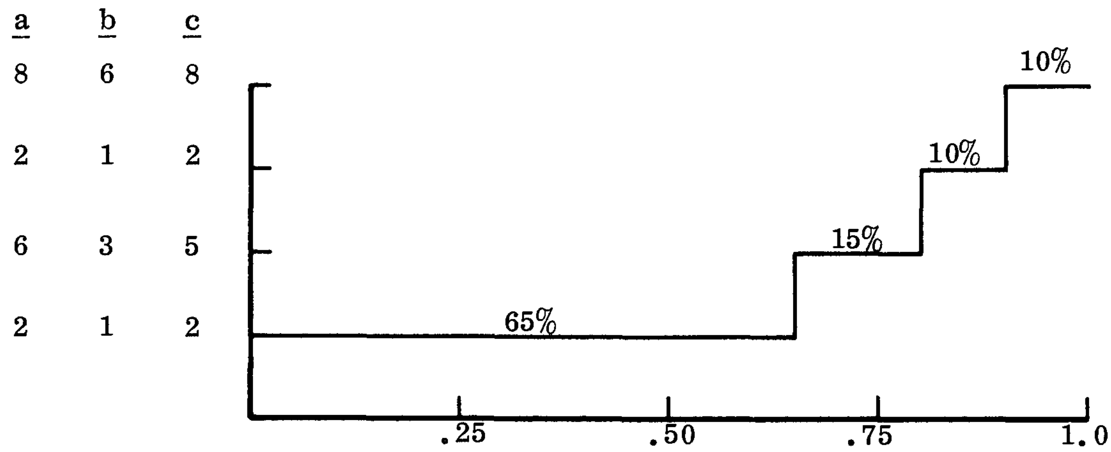
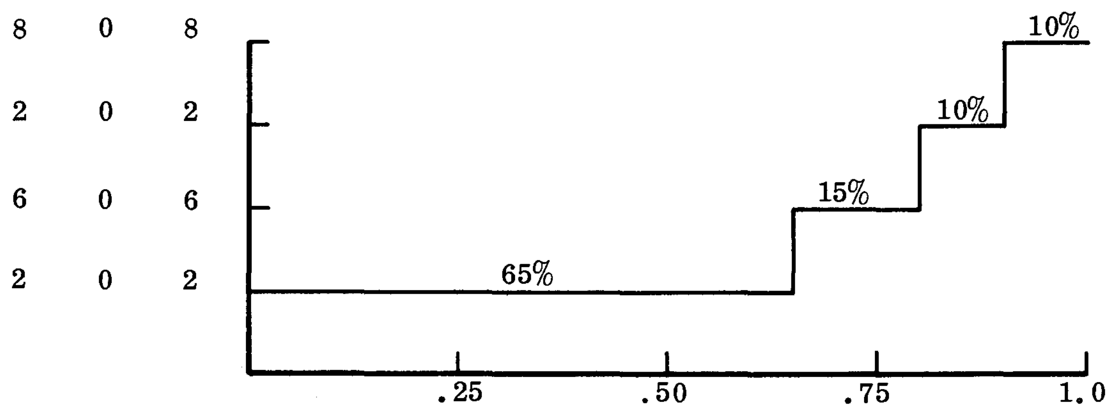


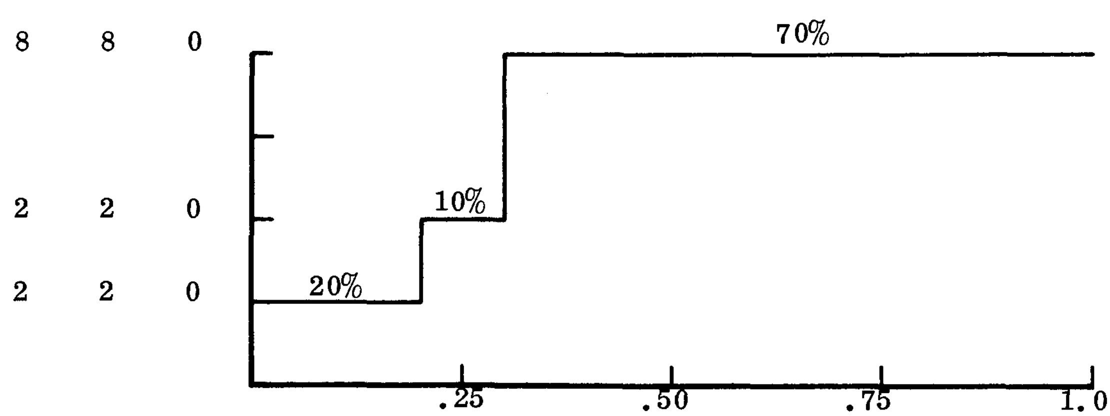
Figure 16. Fuel Input Functions for Experiment 4(a), 4(b) and 4(c).



Function 2



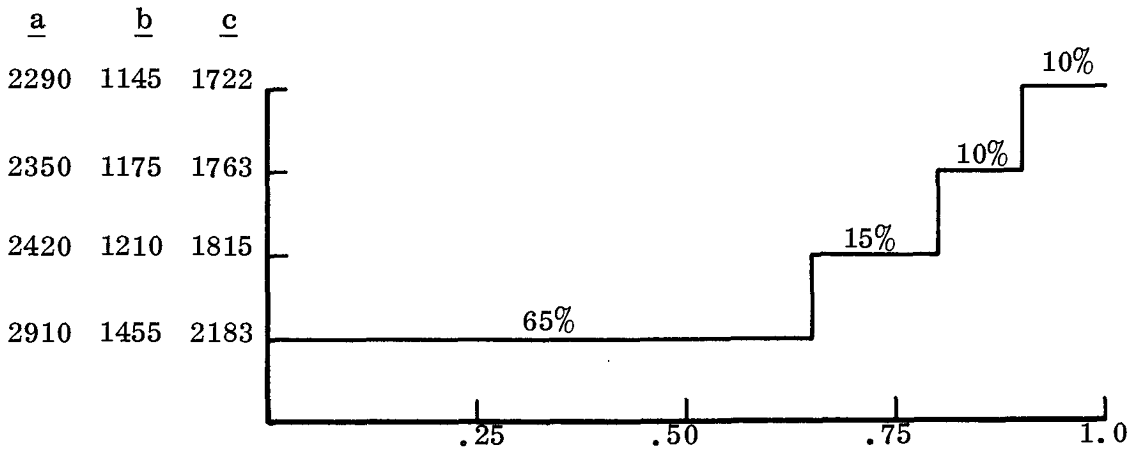
Function 12



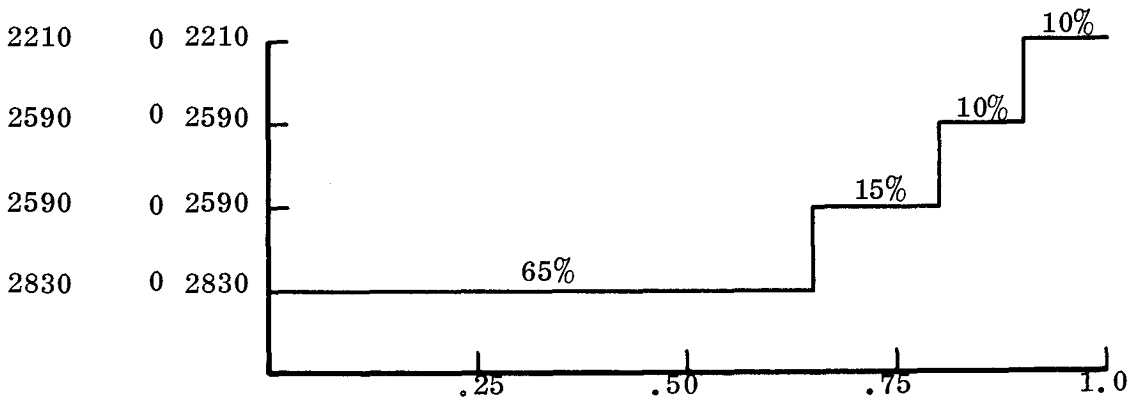
Function 22

Figure 17. Refrigerated Cargo Input Functions for

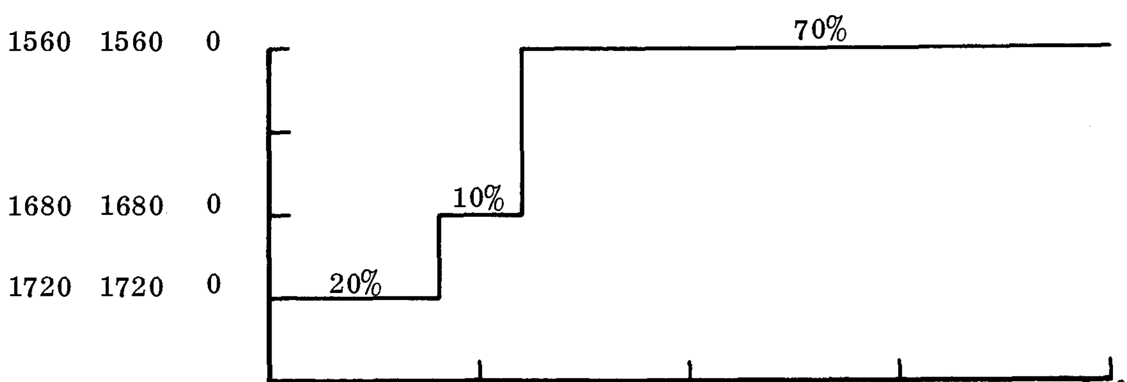
Experiments 4(a), 4(b), and 4(c).



Function 3

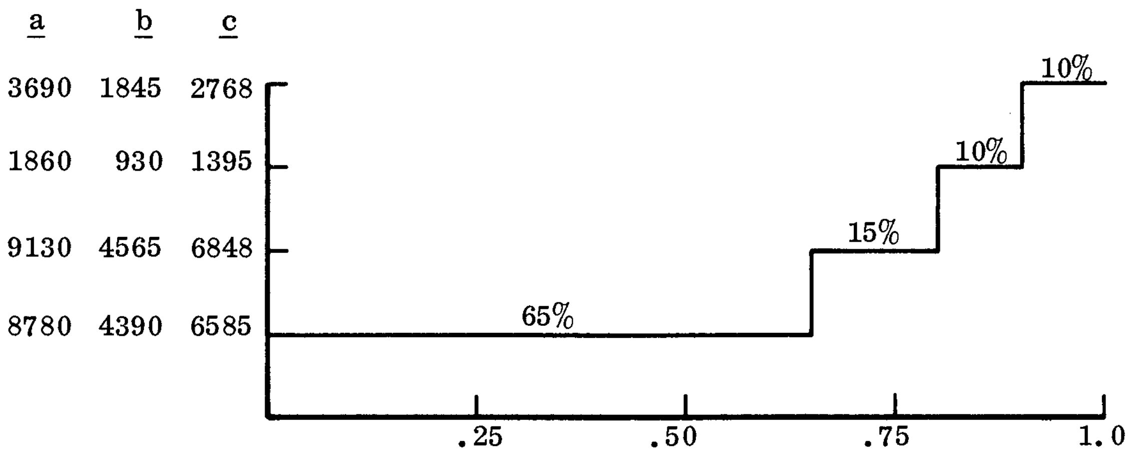


Function 13

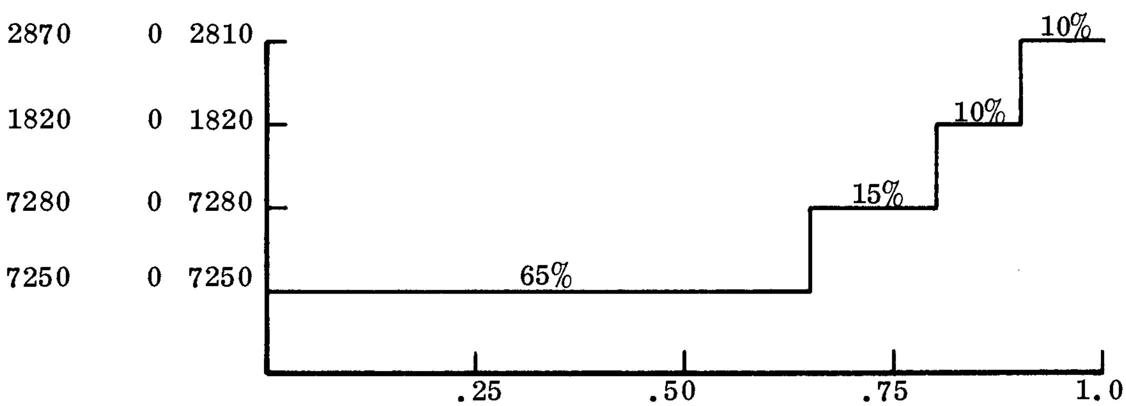


Function 23

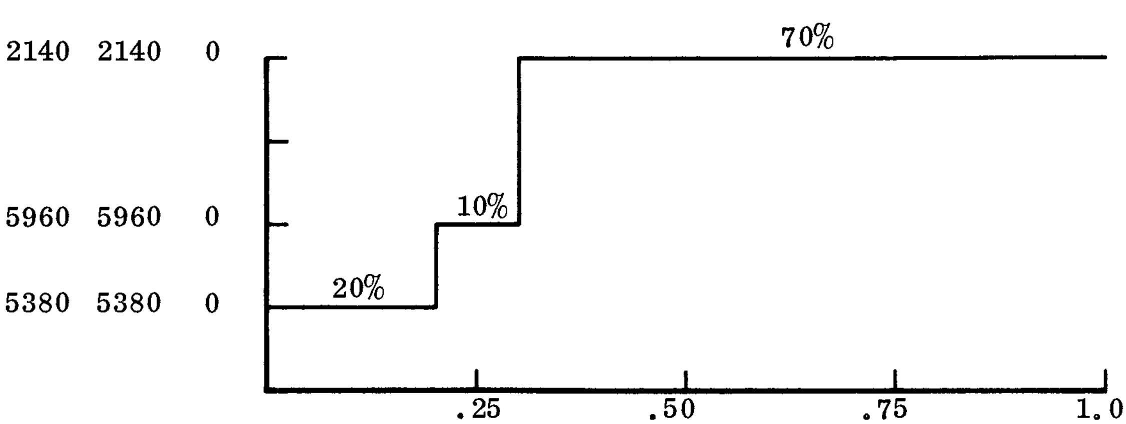
Figure 18. Dry Cargo Input Functions for Experiments 4(a), 4(b), and 4(c).



Function 4



Function 14



Function 24

Figure 19. Ammunition Input Functions for Experiments 4(a), 4(b), and 4(c).

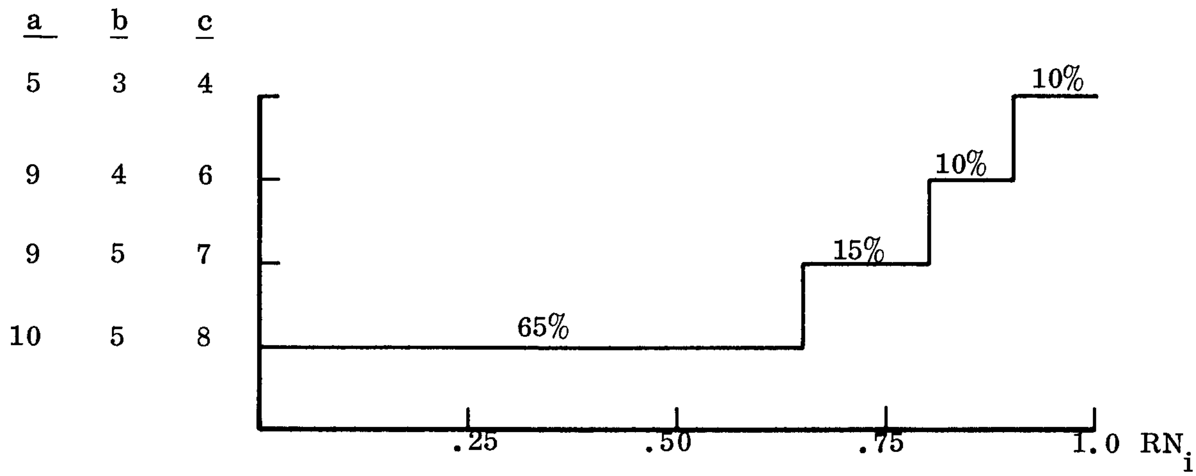
requirements for the forces shown in Table 8. Task Force (TF)"A" consists of an airmobile and an infantry battalion and is located at Node 1; task force "B" consists of a mechanized battalion and is located at Node 2; and there are no forces at Node 3. Experiment No. 5 is further divided into subexperiments 5(a), 5(b), and 5(c). These three experiments are predicated on the number of round-trips that the transport units can accomplish from origin to destination and return to origin.

Table 8. Experimental Design No. 5

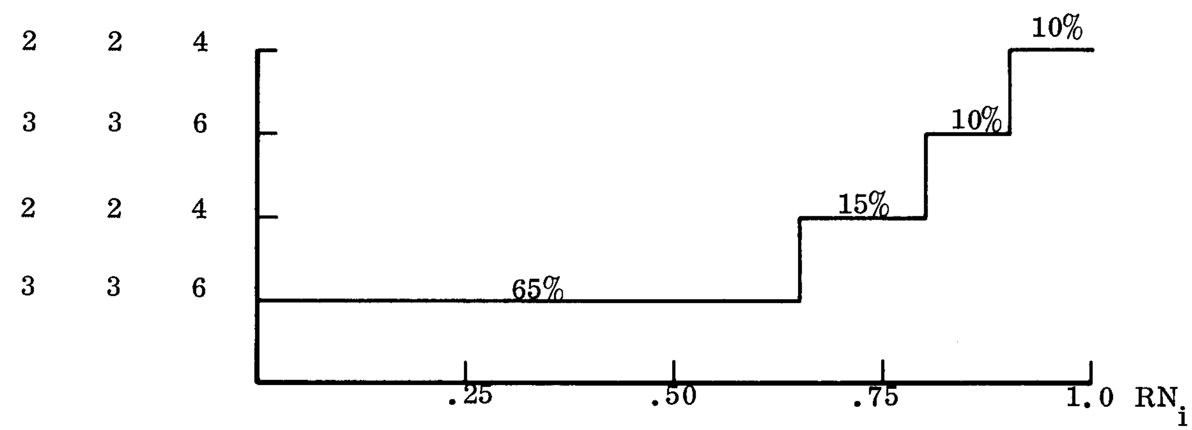
		NODE 1	NODE 2
		TF"A"	TF"B"
R/T	(a)	1	1
R/T	(b)	2	1
R/T	(c)	1.5	.5

In subexperiment 5(a), one roundtrip is accomplished to each node from the transportation origin. In subexperiment 5(b), two roundtrips are made to Node 1 and one to Node 2. In subexperiment 5(c), one and a half roundtrips are accomplished to Node 1 and one half to Node 2.

The input functions for these experiments are shown in Figures 20-23. Functions 1, 11, and 21 depict the fuel requirements for destinations 1, 2, and 3 respectively; functions 2, 12, and 22 show refrigerated cargo requirements; functions 3, 13, and 23 refer to dry cargo requirements; and functions 4, 14, and 24 show ammunition requirements.

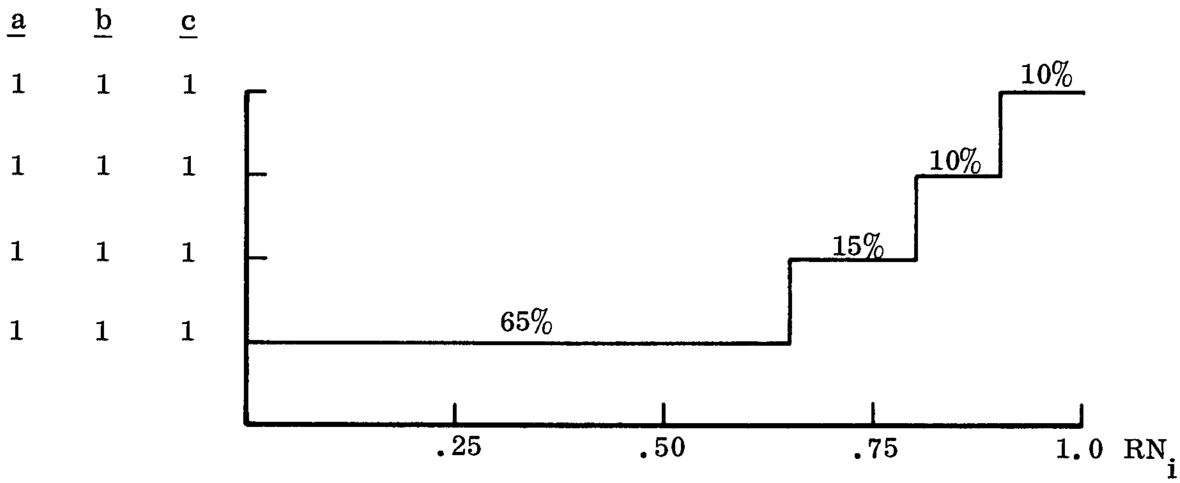


Function 1

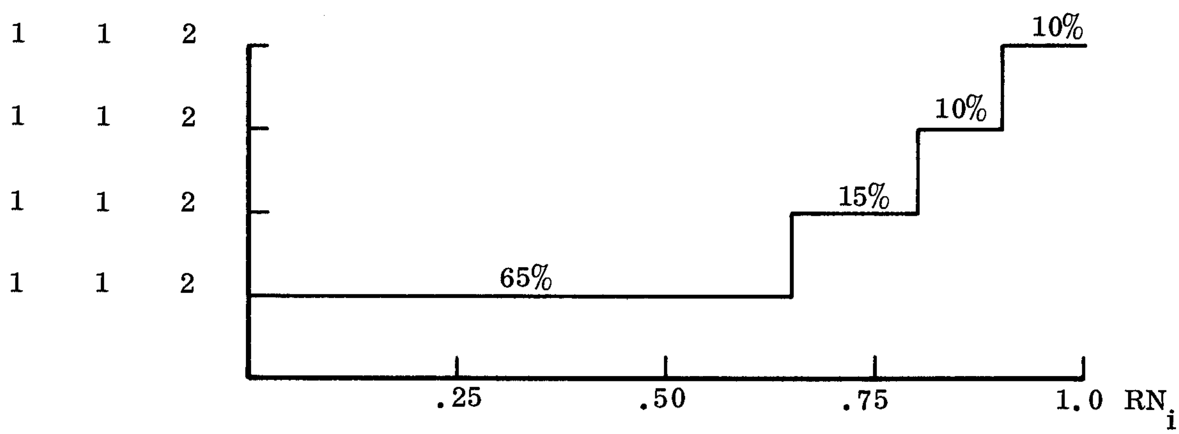


Function 11

Figure 20. Fuel Input Functions for Experiments 5(a), 5(b), and 5(c).

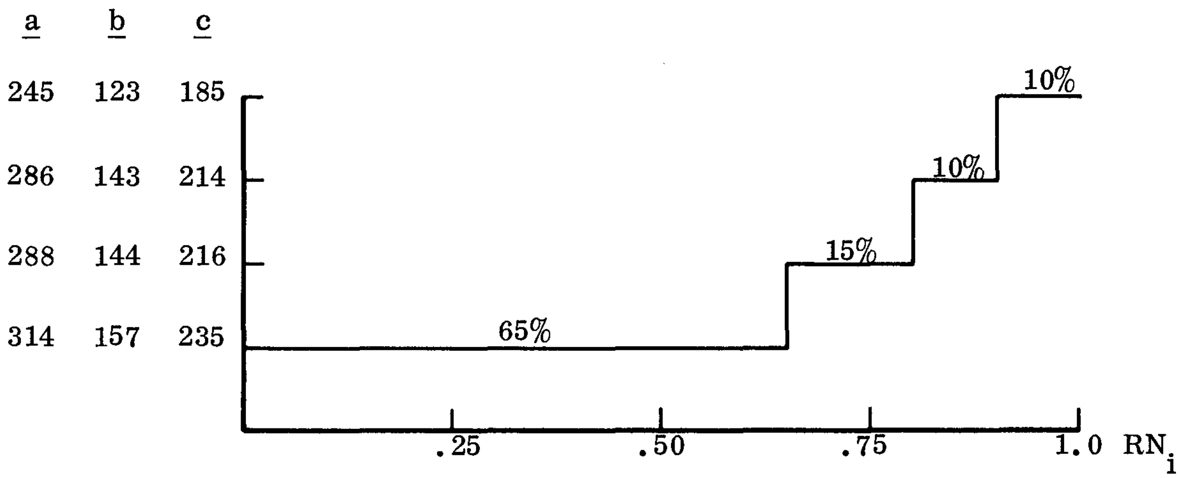


Function 2

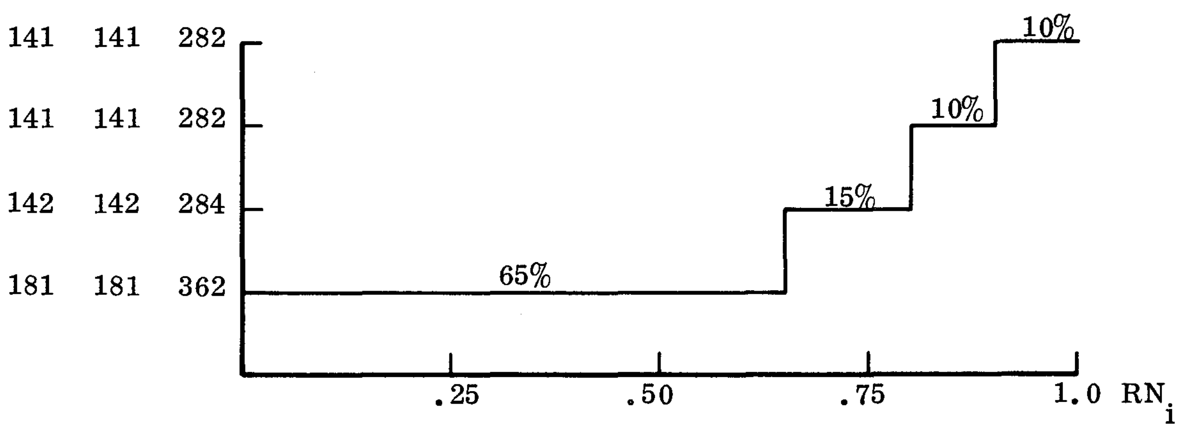


Function 12

Figure 21. Refrigerated Cargo Input Functions for Experiments 5(a), 5(b), and 5(c).

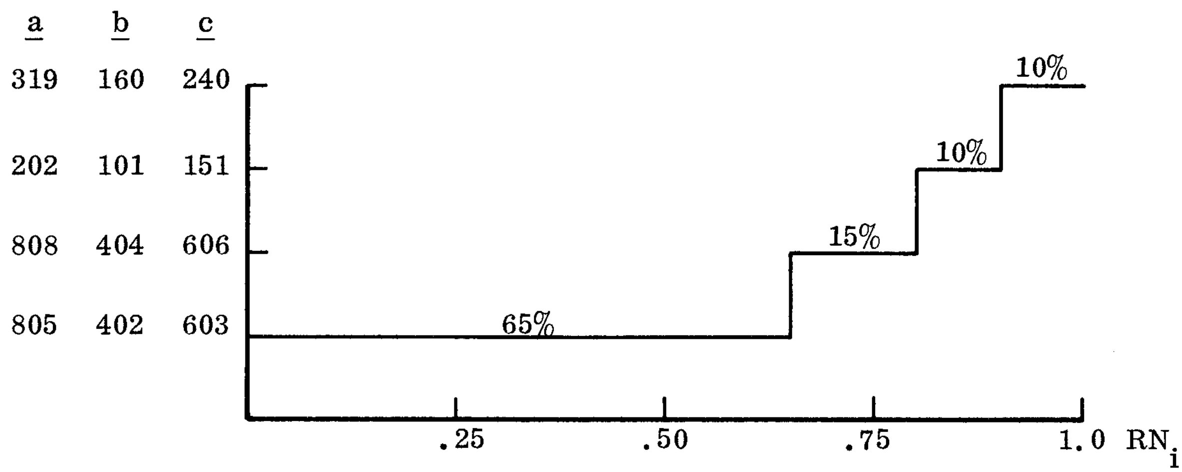


Function 3

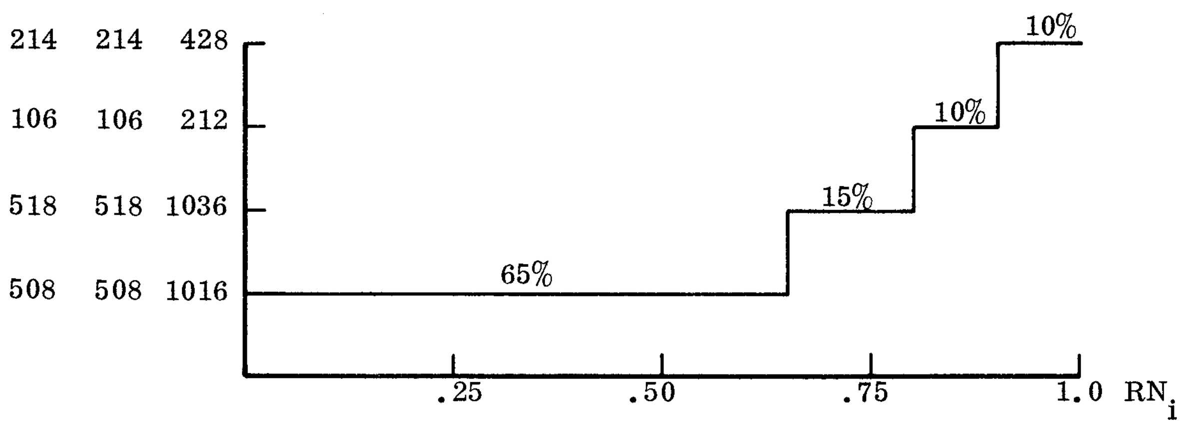


Function 13

Figure 22. Dry Cargo Input Functions for Experiments 5(a), 5(b), and 5(c).



Function 4



Function 14

Figure 23. Ammunition Input Functions for

Experiments 5(a), 5(b), and 5(c).

CHAPTER V

RESULTS

General

The first objective of this research was to develop a computer simulation assignment model of resources to a line haul transportation system. This purpose has been accomplished. The results of the second objective, i.e., conducting experiments designed to establish truck transportation requirements for given supported combat forces, shall be shown in this chapter. The results are directly correlated with the experiments designed in Chapter IV.

Tables showing computer program results, modified by the proportional constant of 1.33 will be constructed for each experiment. The resulting quantity, by transport mode, will be the amount of trucks required to operate on the planning guidance of 75 percent available capability.

From these quantities, transportation units will be organized to fulfill the support requirements by the guidelines established in Department of Army Field Manual 55-35, Motor Transport Operations and Motor Transport Units. Generally, stake and platform trailers are assigned on a 2-for-1 required basis. This is due to the nature of operations with this medium. For these organized units, only the required stake and platform trailers will be specified. Furthermore, to transport the dry cargo and ammunition, an equal number of stake and platform trailers, 5-ton cargo and 2-1/2 ton trucks will be utilized as nearly as possible. With known terrain, predominant (heavy or light) loads, etc., the quantity of different media can easily be modified to satisfy a given situation.

Experiment No. 2

Table 9. Results of Experiment 1(a)

	Computer Results		75% Available
Fuel Tankers	94	x 1.33	= 125
Refrigerated Vans	6	x 1.33	= 8
Stake & Platforms	65	x 1.33	= 86
Tractors	165	x 1.33	= 219
5-Ton Cargo	60	x 1.33	= 80
2-1/2 Ton Cargo	60	x 1.33	= 80

Six computer program runs were required to obtain the above results.

The transportation battalion is capable of command and control of from four to seven transportation companies. Therefore, a transportation battalion will be organized to fulfill this mission as follows:

Unit Organization for Experiment 1(a)

Unit	TOE	Task Vehicles
Headquarters and Headquarters detachment	55.16	
Two Transportation Medium Truck Companies Equipped with 5,000 gallon tank Semitrailers	55.18	(1) 63 Semitrailers with tractors. (2) 62 Semitrailers with tractors.

Unit Organization for Experiment 1(a) (Continued)

Unit	TOE	Task Vehicles
One Transportation Medium Truck Company Equipped with Stake and Platform Semitrailers	55-18	66 Semitrailers with tractors
One Transportation Composite Truck Company	55-18	8 Refrigerated vans with tractors 20 S&P's w/tractors 20 5-ton trucks 20 2-1/2 ton trucks
One Transportation Light Truck Company Equipped with 5-Ton Cargo Trucks	55-17	60 5-ton cargo trucks
One Transportation Light Truck Company Equipped with 2-1/2 ton cargo Trucks	55-17	60 2-1/2-ton Cargo Trucks.

Table 10. Results of Experiment 1(b)

	Computer Results			75% Available
Fuel Tankers	20	x 1.33	=	27
Refrigerated Vans	4	x 1.33	=	6
Stake & Platforms	26	x 1.33	=	35
Tractors	50	x 1.33	=	68
5-Ton Cargos	26	x 1.33	=	35
2-1/2 Ton Cargos	26	x 1.33	=	35

Five computer runs were required to obtain the above results.

Two transportation companies will be organized to support the combat forces of this experiment. The companies may be attached to the appropriate staff transportation officer. The units are organized as follows:

Unit	TOE	Task Vehicles
One transportation medium composite truck company	55-18	27 5,000 gallon semi-trailers 6 refrigerated vans 35 stake and platform trailers 68 tractors
One transportation light composite truck company	55-17	35 5-ton trucks 35 2-1/2 ton trucks

Table 11. Results of Experiment 1(c)

	Computer Results			75% Available
Fuel Tankers	80	x 1.33	=	107
Refrigerated Vans	3	x 1.33	=	4
Stake & Platforms	45	x 1.33	=	60
Tractors	128	x 1.33	=	171
5-Ton Cargos	40	x 1.33	=	54
2-1/2 Ton Cargos	40	x 1.33	=	54

Four runs were required to obtain the above results.

A transportation battalion will be organized to support the combat forces of this experiment.

Unit	TOE	Task Vehicles
Headquarters and Headquarters Detachment	55-16	
One Transportation Medium Truck Company Equipped With 5,000 Gallon Semitrailers	55-18	60 Semitrailers with tractors
One Transportation Medium Truck Company Equipped With Stake and Platform Semitrailers	55-18	60 S&P Semi-trailers with Tractors
One Transportation Medium Composite Truck Company Equipped with Refrigerated Vans, and 5,000 Gallon Semitrailers	55-18	47 5,000 Gallon Semitrailers With Tractors 4 Refrigerated Vans
One Transportation Light Truck Company Equipped With 5-Ton Cargo Trucks	55-11	54 5-Ton Cargo Trucks
One Transportation Light Truck Company Equipped With 2-1/2 Ton Cargo Trucks	55-17	54 5-Ton Cargo Trucks

Experiment No. 2

Table 12. Results of Experiment 2(a)

	Computer Results			
Fuel Tankers	32	x 1.33	=	43
Refrigerated Vans	4	x 1.33	=	6
Stake and Platforms	23	x 1.33	=	30
Tractors	59	x 1.33	=	79
5-Ton Cargos	21	x 1.33	=	30
2-1/2 Ton Cargos	21	x 1.33	=	28

Four computer program runs were required to obtain the above results.

Two transportation companies will be organized to support the combat forces of this experiment. The medium composite company will have an additional platoon (20 trailers with tractors) attached to it. The overstrength of a company will present no overwhelming hardship on this unit. For example, this author commanded a transportation company from 1966 to 1967 with a total of 100 task vehicles. The companies may be attached to the appropriate staff transportation officer. The units are as follows:

Unit	TOE	Task Vehicles
One Transportation Medium Composite Truck Company	55-18	43 5,000 gallon fuel tankers 6 refrigerated vans 31 stake and platform semitrailers 80 tractors.
One Transportation Light Composite Truck Company	55-17	28 5-ton cargo trucks 28 2-1/2 ton cargo trucks.

Table 13. Results of Experiment 2(b)

	Computer Results			75% Available
Fuel Tankers	7	x 1.33	=	10
Refrigerated Vans	3	x 1.33	=	4
Stake and Platforms	9	x 1.33	=	12
Tractors	19	x 1.33	=	26
5-Ton Cargos	8	x 1.33	=	11
2-1/2 Ton Cargos	8	x 1.33	=	11

Three computer runs were required to obtain the above results.

One composite transportation company minus will be organized to support these two brigades. Company minus meaning that the company is approximately one platoon (20 trucks) short of company TOE strength. This unit will be assigned to the appropriate staff transportation officer.

Unit	TOE	Task Vehicles
One Transportation Composite Truck Company	55-18	10 5,000 gallon semitrailers 4 refrigerated vans 12 stake and platform semi-trailers 26 tractors 11 5-ton cargo trucks 11 2-1/2 ton cargo trucks.

Table 14. Results of Experiment 2(c)

	Computer Results			75% Available
Fuel Tankers	27	x 1.33	=	36
Refrigerated Vans	3	x 1.33	=	4
Stake and Platforms	14	x 1.33	=	19
Tractors	42	x 1.33	=	59
5-Ton Cargos	13	x 1.33	=	17
2-1/2 Ton Cargos	13	x 1.33	=	17

Four computer runs were necessary to obtain the above results.

An overstrength company assigned to the appropriate transportation staff officer will be organized to support this experimental force. The unit is as follows:

Unit	TOE	Task Vehicles
One Composite Transportation Truck Company	55-18 55-17	36 5000 gallon semitrailers 4 refrigerated vans 19 stake and platform semi-trailers 59 tractors 17 5-ton cargo trucks 17 2-1/2 ton cargo trucks

Experiment 3

Table 15. Results of Experiment 3(a)

	Computer Results			75% Available
Fuel Tankers	262	x 1.33	=	349
Refrigerated Vans	14	x 1.33	=	19
Stake and Platforms	220	x 1.33	=	293
Tractors	496	x 1.33	=	661
5-Ton Trucks	220	x 1.33	=	293
2-1/2 Ton Trucks	215	x 1.33	=	286

Nineteen computer program runs were required to obtain the above results.

This experiment did test the GPSS II program beyond its maximum. The program "bombed out" due to an excess of transactions. To obtain the above results, two alternatives were available; (1) to scale down the input data and conversely the output, (2) to run each node independently and collate the results. The latter course of action was chosen even though three independent runs were necessary. The random number generator operated with the same "seed" each run, so randomness will not affect the collation of the results.

A motor transport command will be organized into two transport groups consisting of five transport battalions commanding and controlling 21 transport companies. The type units are as follows:

Unit	TOE	Task Vehicles
Headquarters and Headquarters Company, Transportation Motor Transport Command	55-11	
Two Headquarters and Headquarters Detachments, Transportation Truck Group	55-12	
Five Headquarters and Headquarters Detachments, Transportation Truck Battalion	55-16	
Six Transportation Medium Truck Companies Equipped with 5,000 Gallon Semitrailers	55-18	(5) 58 5000 gallon semitrailers with tractors (1) 59 5000 gallon semitrailers with tractors
Five Transportation Composite Medium Truck Companies Equipped with Stake and Platform Trailers and Refrigerated Vans	55-18	(3) -59 stake and platform semitrailers 4 refrigerator vans (3) 63 tractors (2) 58 stake & platform semitrailers (2) 4 refrigerated vans (2) 62 tractors
Five Transportation Light Truck Companies Equipped with 5-ton Cargo Trucks	55-17	(3) -59 cargo trucks (2) -58 cargo trucks
Five Transportation Light Truck Companies Equipped With 2-1/2 Cargo Trucks	55-17	(3) -57 cargo trucks (2) -56 cargo trucks

Table 16. Results of Experiment 3(b)

	Computer Results			75% Available
Fuel Tankers	100	x 1.33	=	133
Refrigerated Vans	8	x 1.33	=	11
Stake & Platforms	133	x 1.33	=	177
Tractors	241	x 1.33	=	321
5-Ton Trucks	132	x 1.33	=	176
2-1/2 Ton Trucks	131	x 1.33	=	175

Eleven computer program runs were required to obtain the above results. This program initially "bombed out" as did the previous experiment due again to excessive transactions. Since only two nodes are being resupplied, two independent runs were conducted using the same random "seed" each time.

A motor transport group will be organized into two battalions consisting of six and five companies. The type units are as follows:

Unit	TOE	Task Vehicles
Headquarters and Headquarters Detachment, Transportation Truck Group	55-12	
Two Headquarters and Headquarters Detachments, Transportation Truck Battalion	55-16	
Two Transportation Medium Truck Companies Equipped With 5,000 Gallon Semitrailers	55-18	(1) 67 5000 gallon semi-trailers with tractors (1) 66 5000 gallon semi-trailers with tractors

Unit	TOE	Task Vehicles
Headquarters and Headquarters Detachment, Transportation Truck Group	55-12	
Three Headquarters and Headquarters Detachments, Transportation Truck Battalions	55-16	
Four Transportation Medium Truck Companies Equipped With 5,000 Gallon Semitrailers	55-18	(2) 60 5,000 gallon semi-trailers with tractors (2) 61 5,000 gallon semi-trailers with tractors
Two Transportation Medium Truck Companies Equipped With Stake and Platform Trailers	55-18	(2) 60 stake and platform semitrailers with tractors
One Transportation Composite Medium Truck Company (Minus) Equipped with Stake and Platform Semitrailers and Refrigerated Vans	55-18	30 stake and platform semitrailers with tractors 11 refrigerated vans with tractors
Two Transportation Light Truck Companies Equipped With 5-ton Cargo Trucks	55-18	(2) 60 5-ton cargo trucks
Two Transportation Light Truck Companies Equipped With 2-1/2 ton Cargo Trucks	55-18	(a) 60 2-1/2 ton cargo trucks
One Transportation Composite Light Truck Company Equipped With 5-ton and 2-1/2 ton Cargo Trucks	55-18	30 5-ton cargo trucks 30 2-1/2 ton cargo trucks

Three Transportation Composite Medium Truck Companies Equipped with Stake and Platform Semitrailers and Refrigerated Vans	55-18	(3) 59 Stake and Platform Semitrailers with tractors (3) 4 refrigerated vans
Three Transportation Light Truck Companies Equipped with 5-Ton Cargo Trucks	55-17	(2) 59 5-Ton Cargo Trucks (1) 58 5-Ton cargo trucks
Three Transportation Light Truck Companies Equipped With 2-1/2 Ton Cargo Trucks	55-17	(2) 58 2-1/2 Ton Cargo Trucks (1) 59 2-1/2 Ton Cargo Trucks

Table 17. Results of Experiment 3(c)

	Computer Results			
Fuel Tankers	182	x 1.33	=	242
Refrigerated Vans	8	x 1.33	=	11
Stake & Platforms	113	x 1.33	=	150
Tractors	303	x 1.33	=	403
5-Ton Trucks	113	x 1.33	=	150
2-1/2 Ton Trucks	113	x 1.33	=	150

Thirteen computer program runs were required to obtain the above results.

The results of this experiment were collated from two independent runs; that is, resupplying one node at a time.

A motor transport group will be organized into three battalions consisting of twelve companies. The type units are as follows:

Experiment No. 4

Table 18. Results of Experiment 4(a)

	Computer	Results		75% Available
Fuel Tankers	130	x 1.33	=	173
Refrigerated Vans	12	x 1.33	=	16
Stake & Platforms	135	x 1.33	=	180
Tractors	277	x 1.33	=	369
5-Ton Cargos	130	x 1.33	=	173
2-1/2 Ton Cargos	130	x 1.33	=	173

Fourteen computer program runs were required to obtain the results in Table 18.

This experiment pushed the GPSS II program beyond its maximum. The program was sub-divided into two runs and the above results collated from these runs.

A motor transport group will be organized into three battalions consisting of twelve transportation companies. The type units are as follows:

Unit	TOE	Task Vehicles
Headquarters and Headquarters Detachment Transportation Truck Group	55-12	
Three Headquarters and Headquarters Detachments, Transportation Truck Battalion	55-16	

Unit	TOE	Task Vehicles
Three Transportation Composite Medium Companies Equipped With 5,000 Gallon Semitrailers and Refrigerated Vans	55-18	(2) 58 5,000 gallon semi-trailers with tractors (2) 5 refrigerated vans with tractors (1) 57 5,000 gallon semi-trailers with tractors (1) 6 refrigerated vans with tractors
Three Transportation Medium Companies Equipped with Stake and Platform Semitrailers	55-18	(3) 60 stake and platform semitrailers
Three Transportation Light Companies Equipped with 5-Ton Cargo Trucks	55-17	(2) 58 5-ton cargo trucks (1) 57 5-ton cargo trucks
Three Transportation Light Companies Equipped with 2-1/2 Ton Cargo Trucks	55-17	(2) 58 2-1/2 ton cargo trucks (1) 57 2-1/2 ton cargo trucks

Table 19. Results of Experiment 4(b)

•	Computer Results			75% Available
Fuel Tankers	31	x 1.33	=	42
Refrigerated Vans	6	x 1.33	=	8
Stake and Platforms	53	x 1.33	=	71
Tractors	90	x 1.33	=	121
5-Ton Cargos	51	x 1.33	=	68
2-1/2 Ton Cargos	51	x 1.33	=	68

Six computer program runs were required to obtain the above results.

One transportation battalion will be organized consisting of four companies to support the divisions at N0025 1 and 3. The battalion will consist of the following units:

Unit	TOE	Task Vehicles
Headquarters and Headquarters Detachment, Transportation Truck Battalion	55-16	
Transportation Composite Medium Company Equipped with 5,000 Gallon Semitrailers, Refrigerated Vans, and Stake and Platform Trailers	55-18	42 5000 gallon semitrailers with tractors 8 refrigerated vans with tractors 10 stake and platform semitrailers with tractors
Transportation Medium Company Equipped with Stake and Platform Trailers	55-18	61 stake and platform trailers with tractors
Transportation Light Company Equipped with 5-ton Cargo Trucks	55-17	68 5-Ton Cargo Trucks
Transportation Light Company Equipped with 2-1/2 ton Cargo Trucks	55-17	68 5-Ton Cargo Trucks

Table 20. Results of Experiment 4(c)

	Computer Results			75% Available
Fuel Tankers	104	x 1.33	=	139
Refrigerated Vans	6	x 1.33	=	8
Stake and Platforms	100	x 1.33	=	133
Tractors	208	x 1.33	=	280
5-Ton Cargos	92	x 1.33	=	124
2-1/2 Ton Cargos	91	x 1.33	=	122

Seven computer program runs were required to obtain the above results.

A transportation truck group will be organized into two transport battalions consisting of nine transportation companies. The type units are as follows:

Unit	TOE	Task Vehicles
Headquarters and Headquarters Detachment, Transportation Truck Group	55-12	
Two Headquarters and Headquarters Detachments, Transportation Truck Battalion	55-16	
Two Transportation Medium Companies Equipped with 5,000 Gallon Semitrailers	55-18	(2) 60 5,000 gallon semitrailers with tractors
Two Transportation Medium Companies Equipped with Stake and Platform Semitrailers	55-18	(2) 60 stake and platform semitrailers with tractors
Transportation Composite Medium Company (Minus) Equipped with 5,000 Gallon Semitrailers, Refrigerated Vans, and Stake and Platform Semitrailers	55-18	19 5,000 gallon semitrailers 6 refrigerated vans 13 stake and platform semitrailers 40 tractors
Two Transportation Light Companies Equipped With 5-Ton Cargo Trucks	55-17	(2) 62 5-ton cargo trucks
Two Transportation Light Companies Equipped With 2-1/2 Ton Cargo Trucks	55-17	(2) 61 2-1/2 ton cargo trucks

Experiment No. 5

Table 21. Results of Experiment 5(a)

	Computer Results			75% Available
Fuel Tankers	12	x 1.33	=	16
Refrigerated Vans	2	x 1.33	=	3
Stake and Platforms	9	x 1.33	=	12
Tractors	23	x 1.33	=	31
5-Ton Cargos	9	x 1.33	=	12
2-1/2 Ton Cargos	9	x 1.33	=	12

Table 22. Results of Experiment 5(b)

	Computer Results			75% Available
Fuel Tankers	7	x 1.33	=	10
Refrigerated Vans	2	x 1.33	=	3
Stake and Platform	7	x 1.33	=	9
Tractors	16	x 1.33	=	22
5-Ton Cargos	6	x 1.33	=	8
2-1/2 Ton Cargos	6	x 1.33	=	8

Table 23. Results of Experiment 5(c)

	Computer Results		75% Available	
Fuel Tankers	13	x 1.33	=	18
Refrigerated Vans	3	x 1.33	=	4
Stake and Platforms	12	x 1.33	=	16
Tractors	28	x 1.33	=	38
5-Ton Cargos	12	x 1.33	=	16
2-1/2 Ton Cargos	11	x 1.33	=	15

Thirteen complete program runs were required to obtain the above results for experiments 5(a), 5(b), and 5(c).

These experiments were conducted in order to confirm the model could produce results for a supported force of three battalions or one brigade. Generally speaking, this small a force would not be committed into an area for an extended period of time; thus support forces would not be committed to sustain the operation. However, if required, this model is quite capable of producing the necessary transportation requirement.

One transportation composite company (plus or minus) could be organized to support the forces in each of the three experiments. The company would consist of the number of each type mode in the respective tables. The company would be assigned under the appropriate transportation staff officer.

Validation

By comparing experiments 1(a) with 2(a), 1(b) with 2(b), and 1(c) with 2(c), the obtained computer results are approximately three times as great with the one exception of the number of refrigerated vans required. This may be explained in the size and spread of the input data considering the random process. Also, by analyzing experiments 1(b) and 1(c), one can readily surmise that the proportionality of input data to output results is consistent.

Furthermore, a manual validation, in conjunction with an uniform input, to determine fixed capacities was undertaken to further validate the model. The manual capacity determinants proved to be the same as the computer results.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

General Comments

Logistical operations are conducted to assure that the quantity and quality of supplies needed by the combat forces are delivered in the time and condition needed to successfully fulfill the operational mission. However, logistics systems are generally complex, and are characterized by uncertainty, diversity of operations and considerable magnitude in scope. These factors greatly limit the scope of analysis by analytical techniques.

The purpose of this research is to provide the logistician with an alternative tool in developing line haul truck transportation requirements to support a given combat force. Thus, the specific objective is two-fold; (1) to develop a computer simulation assignment model of a line haul truck transport system and (2) to conduct experiments to validate the model and to determine truck transportation resource requirements.

Digital simulation in GPSS II provides a ready means to study this transport system. Model formulation and programming are relatively easy tasks, once the system flow diagram is complete. Furthermore, the output generated by GPSS II eliminates the difficulties of quantitative analysis.

Conclusions

1. It is felt that a specific military situation must be developed due to the nature of the comsumption data. With the situation established, functional input (resupply factors) was designed based on the posture of the supported force. It should be emphasized that the approach taken is not necessary to the success of the model and its outputs. The results obtained from the model are only as good as the input. It is felt the best available input was utilized in the foregoing experiments.

2. It is felt that this simulation model will provide the logistician with an alternative tool in determining truck transportation requirements for a given supported force. Requirements were determined for supported forces in fifteen difference experiments in this study. In addition, this method can provide a "check system" on existing techniques in determining truck transportation requirements.

3. GPSS II is a very appropriate language for this type of endeavor. The primary limitation encountered was the language's memory capacity. The program "bombed out" because of this factor in Experiments 3(a), 3(b), 3(c) and 4(a). However, subprograms can easily be run and the output results collated to obtain the desired results. Even with this limitation, this computer program perhaps can be best utilized when the support requirements are to be determined for large supported forces.

4. The model provides wide flexibility to the logistician. As shown in Experiment 5, the smallest supported units' requirements can be determined. In

Experiment 3, a field army's transport support requirements were obtained. Furthermore, with supported force and turnaround time known, transport requirements may be determined from any number of origins to any number of destinations. This fact is exemplified by experiments No. 3 and No. 4(a). Multiple runs were necessary in each of these experiments and the results of each subexperiment collated. When the supported force exceeded four divisions, the above procedure was necessary to obtain the truck transport requirements.

5. The computer program was run approximately one hundred times. The number of runs could have been reduced considerably if the acceptance criteria of the results had been less than stated; i.e., if the average utilization of transport mode was less than 97 per cent, and if the queued percentage factor was increased above two per cent.

6. Validation of the computer model is the most elusive and least pronounced topic in the art of simulation. However, by the direct treatment of the output results as Koopmans suggests, the model developed in this study is valid. From the results of experiments No. 1 and No. 2, the output is both proportional and consistent. Furthermore, the manual validation performed adds substance to the validity of the model.

Recommendations

1. This study should be extended in scope to encompass all resupply transport modes to include air (both Army and Air Force), inland waterway, and rail. The recommended approach is to build a family of simulation models of each remaining transport capability. This logically leads to an aggregated simulation

model of the entire transport system.

2. It is recommended that a study be undertaken as to the adaptability of this simulation model to the commercial truck industry. One application, providing input data was available, would be the determination of an initial truck fleet for a new transport business firm.

3. This research should be extended to include a historical study of division postures. For example, extensive historical reports are available on type divisional activities from World War II and the Korean conflict. With this information, division posture percentages can be determined. This in turn will more accurately reflect the nature of a type division's activities and unit posture will not have to be assumed.

4. Another research extension of this effort would be the construction of a dynamic model of the sub-parameters which comprise the primary parameter turnaround time. Random fluctuations of the sub-parameters should be modeled and the resulting value of turnaround time be utilized as the determinant for input tonnages. The random fluctuations should encompass the maximum and minimum effect of each sub-parameter upon turnaround time.

A Look Into the Future of Simulation

In June, 1968, J. P. Haverty of the Rand Corporation published a paper called "Grail/GPSS: Graphic On-Line Modeling" (16). In this paper a new dimension is added to the art of simulation. Essentially, this technique inputs the flow diagram directly into the computer. In this manner, the analyst is interacting directly with the model, thus eliminating key punching, punched cards, batch processing, etc.... Although this system is at its infant stage, the innovation takes a giant step forward in terms of time, effort and cost. This is especially true when large complex systems are being modeled.

Simultaneously, this on-line approach presents a problem of the first magnitude in computer software. Additional software capabilities must be programmed in conjunction with those supporting the input/output terminal.

APPENDIX

```
LOC  NAME          X      Y      Z      SEL    NBA    NBB    MEAN   MOD    REMARKS    E

     JOB
*
* TRUCK TRANSPORTATION REQUIREMENTS - SIMULATION MODEL
*  EXPERIMENT    #2B
* INPUT PHASE
*
* FUNCTION 1 - FUEL FOR DESTINATION 1
 1   FUNCTION     RN1    D4
.65  4      .80   3      .90    4      1.0    2
* FUNCTION 2 - REFRIGERATED CARGO FOR DESTINATION 1
 2   FUNCTION     RN1    D4
.65  1      .80   1      .90    1      1.0    1
* FUNCTION 3 - DRY CARGO FOR DESTINATION 1
 3   FUNCTION     RN1    D4
.65  214    .80   190    .90    135    1.0    177
* FUNCTION 4   AMMUNITION FOR DESTINATION 1
 4   FUNCTION     RN1    D4
.65  702    .80   745    .90    152    1.0    294
* FUNCTION 11- FUEL FOR DESTINATION 2
 11  FUNCTION     RN1    D4
.65  6      .80   4      .90    6      1.0    4
* FUNCTION 12- REFRIGERATED CARGO FOR DESTINATION 2
 12  FUNCTION     RN1    D4
.65  2      .80   2      .90    2      1.0    2
* FUNCTION 13- DRY CARGO FOR DESTINATION 2
 13  FUNCTION     RN1    D4
.65  362    .80   284    .90    282    1.0    282
* FUNCTION 14- AMMUNITION FOR DESTINATION 2
 14  FUNCTION     RN1    D4
.65  1016   .80   1036   .90    212    1.0    428
* FUNCTION 21- FUEL FOR DESTINATION 3
 21  FUNCTION     RN1    D3
.20  5      .30   4      1.0    3
* FUNCTION 22- REFRIGERATED CARGO FOR DESTINATION 3
 22  FUNCTION     RN1    D3
.20  1      .30   2      1.0    2
* FUNCTION 23- DRY CARGO FOR DESTINATION 3
 23  FUNCTION     RN1    D3
.20  287    .30   280    1.0    260
* FUNCTION 24  AMMUNITION FOR DESTINATION 3
 24  FUNCTION     RN1    D3
.20  893    .30   960    1.0    353
*REQUIREMENTS FOR DESTINATION 1
 1   ORIGINATE    3                           4             24
*REQUIREMENTS FOR DESTINATION 3
 3   ORIGINATE    3                           5             24
 4   ASSIGN       1      K1                   7
 5   ASSIGN       1      K11                  8
 6   ASSIGN       1      K21                  9
 7   ASSIGN       6      K6                   10
 8   ASSIGN       6      K5                   10
 9   ASSIGN       6      K7                   10
 10  SPLIT                                    11     50
 11  SPLIT                                    13     12
```

```
  12    ASSIGN     1+     K1                  14
  13    ASSIGN     3      FN*1                17
  14    ASSIGN     3      FN*1                17
  17    SPLIT                                 18    20
  18    LOOP       3                          17    19
  19    TERMINATE
  20    ADVANCE                        FN     5           3
  21    QUEUE      1                          23
  22    QUEUE      2                          24
  23    ENTER      1                          26
  24    ENTER      2                          26
  26    QUEUE      5                          27
  27    STORE      5                   FN     6           24
  28    LEAVE      1                          88
  29    LEAVE      2                          88
  30    LEAVE      3                          88
  88    TERMINATE
  62    ENTER      3                          26
  50    SPLIT                                 51    52
  51    ASSIGN     1+     K2                  53
  52    ASSIGN     1+     K3                  54
  53    ASSIGN     3      FN*1                57
  54    ASSIGN     3      FN*1                57
  57    ADVANCE                        FN     8           3
  571   QUEUE      10                  BOTH   58    70
  572   QUEUE      11                  BOTH   58    70
  573   QUEUE      12                  BOTH   58    70
  58    COMPARE    P3     GE     K100         59
  59    SPLIT                                 60    61
  60    ASSIGN     3-     K100         BOTH   58    70
  61    QUEUE      5                   ALL    62    64
  63    GATE       SNF6                       65
  64    GATE       SNF7                       66
  65    SPLIT                                 80    80
  66    SPLIT                                 67    68
  67    SPLIT                                 78    78
  68    SPLIT                                 78    78
  70    ADVANCE                        BOTH   71    74
  71    COMPARE    P3     GE     K50          72
  72    SPLIT                                 73    80
  73    ASSIGN     3-     K50          BOTH   71    74
  74    ADVANCE                        BOTH   75    88
  75    COMPARE    P3     NE     K0    BOTH   76    78
  76    COMPARE    P3     G      K25          77
  77    SPLIT                                 78    78
  78    QUEUE      7                          79
  79    STORE      7                          88          24
  80    QUEUE      6                   BOTH   81    82
  81    STORE      6                          88          24
  82    GATE       SNF7                       83
  83    SPLIT                                 78    78
*     ROUTING FUNCTIONS
  5     FUNCTION   P1     D6
1       21    2    22     11     21    12     22    21    21    22    22
  6     FUNCTION   P1     D12
1       28    2    29     3      30    4      30    11    28    12    29
13      30    14   30     21     28    22     29    23    30    24    30
  8     FUNCTION   P1     D6
```

3 571 4 571 13 572 14 572 23 573 24 573
*AVAILABLE FUEL TANKERS
1 CAPACITY 9
*AVAILABLE REFRIGERATED VANS
2 CAPACITY 3
*AVAILABLE STAKE AND PLATFORM TRAILERS
3 CAPACITY 12
*AVAILABLE 5-TON TRACTORS
5 CAPACITY 24
*AVAILABLE 5-TON CARGO TRUCKS
6 CAPACITY 11
*AVAILABLE 2-1/2 TON TRUCKS
7 CAPACITY 11
START 2160

CLOCK TIME REL 2160 ABS 2160

TRANS COUNTS	BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL
	1	0, 90	2	0, 0	3	0, 90	4	0, 90	5	0, 90
	6	0, 0	7	0, 90	8	0, 90	9	0, 0	10	0, 180
	11	0, 180	12	0, 180	13	0, 180	14	0, 180	15	0, 0
	16	0, 0	17	0, 1092	18	0, 1092	19	0, 360	20	13, 1092
	21	19, 812	22	0, 267	23	0, 793	24	0, 267	25	0, 0
	26	0, 2124	27	24, 2124	28	0, 784	29	0, 264	30	0, 1052
	46	0, 0	47	0, 0	48	0, 0	49	0, 0	50	0, 180
	51	0, 180	52	0, 180	53	0, 180	54	0, 180	55	0, 0
	56	0, 0	57	4, 360	58	0, 1624	59	0, 1624	60	0, 1624
	61	23, 1624	62	0, 1064	63	0, 482	64	0, 55	65	0, 482
	66	0, 55	67	0, 55	68	0, 55	69	0, 0	70	0, 356
	71	0, 139	72	0, 139	73	0, 139	74	0, 356	75	0, 356
	76	0, 116	77	0, 116	78	7, 986	79	11, 979	80	3, 1103
	81	11, 953	82	0, 147	83	0, 147	84	0, 0	85	0, 0
	86	0, 0	87	0, 0	88	0, 4010	89	0, 0	90	0, 0
	571	0, 178	572	0, 178	573	0, 0	574	0, 0	575	0, 0

STORAGE NR	CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRANS	CURRENT CONTENTS
1	9	8.80	.9776	793	23.97	9
2	3	2.96	.9875	267	23.97	3
3	12	11.81	.9838	1064	23.97	12
5	24	23.57	.9819	2124	23.97	24
6	11	10.57	.9612	953	23.97	11
7	11	10.86	.9875	979	23.97	11

QUEUE NR	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
1	19	8.02	812	301	37.1	21.33	0	19
2	1	.00	267	267	100.0	.00	0	0
5	26	9.53	3748	2008	53.6	5.49	0	23
6	12	5.71	1103	245	22.2	11.18	0	3
7	37	11.81	986	41	4.2	25.88	0	7
10	1	.00	178	178	100.0	.00	0	0
11	1	.00	178	178	100.0	.00	0	0

FUTURE RANDOM NUMBER SEED IS (OCTAL) 242120764065

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