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DESIGN OF A SIMULATION PACKAGE
FOR AUTOMATED GUIDED VEHICLE
SYSTEMS /

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Master of Science

by
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—
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CHAPTER 1

INTRODUCTION

Background

The purpose of this project is to design, program and test an interactive software package that will simulate Automated Guided Vehicle (AGV) systems. The simulation results may be used as an aid in evaluating the performance of AGV systems with different design configurations and control policies. This interactive package reduces the task of programming each design configuration and allows the user to concentrate on the design of the AGV system.

Analytical methods for the design optimization of AGV systems are not well defined. Although the designer has some tools to determine the required number of vehicles and appropriate operating policies, these methods ignore or approximate the dynamic elements of the system. For design problems such as determining the layout of the track, location of stations, and the dispatching of idle vehicles, the designer has only general guidelines. Simulation is the only adequate means of evaluating a proposed AGV system design. Unfortunately, developing a simulation is a time consuming process. To evaluate several design configurations, a different program may have to be developed

for each of the configurations. As an alternative to this design process, a general, interactive simulation package is developed. This package, entitled ASP for AGVS Simulation Package, enables several design alternatives to be simulated quickly.

Problem and Objectives

Figure 1, modified from Maxwell and Muckstadt (39), illustrates a typical AGV system. In this small example, four vehicles serve eight stations. Idle vehicles reside in the parking zone(s) or if the parking zone(s) capacity is full, an idle vehicle will remain in the last station visited. When a vehicle is requested for service, the control system determines which vehicle to send and the route it should take to its destination. While the vehicle is traveling, the control system monitors the progress of the vehicle to prevent collisions. After the vehicle arrives at a pickup station, it is loaded. The vehicle may carry a load to one or several stations depending on the type of task requested. After a vehicle completes the assigned task, the control system determines the next, if any, assignment for the vehicle. The vehicle is sent to an appropriate parking zone if there are not any demands for service waiting.

The two major objectives of this project are:

1. to develop a general simulation model of AGV systems. The model should be capable of simulating different types of AGV system configurations and operating policies.

S - STATIONS
 P - PARKING ZONES
 I - INTERSECTIONS
 V - VEHICLES

FIGURE 1 MODIFIED MAXWELL PROBLEM

2. to develop an interface between the simulation model and the user. This interface should allow the user to quickly and easily enter a design alternative.

CHAPTER 2

LITERATURE

General Description of AGV Systems

In an article commenting on the need for systems integration in the design of material handling systems, White and Apple (63) have noted that there is an increasing demand on industry to raise the productivity of its operations and the quality of its products. In addition, there is an accelerating rate of change in market demand that requires flexibility in product design, product mix and product volume. Industry has responded to these pressures by automating. Automation of single operations or sets of operations without establishing a "systems" concept has created "islands of automation". The lack of integration in these "islands of automation" has reduced the benefits that can be derived from automation. White (64) has further commented that "an obvious vehicle that can be used to physically 'build bridges that join together the islands of automation' is the material handling system." The traditional view of material handling systems, according to White and Apple, has tended to be myopic in nature, focusing on the transportation of goods from one specific point to another. In response to the demand for integration, the

traditional myopic view has been expanded to a "systems" view. This view examines the affect that the total material handling system has on the "utilization of production equipment and direct labor". (63) Tompkins (61) discusses the need for facilities to be designed as integrated manufacturing environments. He states that an integrated manufacturing environment should be comprised of:

- 1) Integrated manufacturing equipment
- 2) Integrated material handling equipment
- 3) Integrated computer control
- 4) Integrated manufacturing, material handling and computer control equipment
- 5) Integrated islands of automation

The need for automation, flexibility and a systems approach to material handling has caused the rapid development of Automated Guided Vehicle (AGV) systems. Kulwiec (34) states that AGV systems are viewed as the "key link in integrating individual operations in overall factory systems" especially automated systems. According to the Automated Guided Vehicle Product Section of the Material Handling Institute (MHI) (16), automated guided vehicles are defined as follows:

A vehicle equipped with automatic guidance equipment, either electromagnetic or optical. Such a vehicle is capable of following prescribed guide paths and may be equipped for vehicle programming and stop selection, blocking and any other special functions required by the system.

According to the MHI, AGV's were first introduced in a grocery warehouse in 1953 as a modified towing truck with a trailer. An overhead wire provided guidance. Gunsser (27) traces the effect that advances in electronics have had on

AGV systems. By 1965 wire guidance was imbedded in the floor and relays were used for control logic. In the early 1970's semi-conductors had replaced relays and by the end of the 1970's microprocessors were being installed on the vehicles. Today, there are many types of vehicles, applications, guidance techniques and control systems in use. AGV systems "can vary in size from a short, pick-up and delivery arrangement, to a complex layout with computer controlled vehicles automatically interfacing with an automated storage/retrieval system". (16)

The potential benefits of installing an AGV system are varied. Although the cost of each vehicle is high, the cost of the guidance facilities and system installation are relatively low. Some of the benefits as listed by Kulwiec(34), Modern Material Handling (6) and the MHI (16) are:

- 1) Automatic Interfacing - The interface between the vehicle and pickup/delivery points is unmanned. Vehicles may be equipped with forks for pickup/delivery from the floor or for pickup/delivery from above the floor by a hydraulic lift platform or conveyor section.
- 2) Elimination of Congested Elevator Staging Areas - Elevators may be used without unloading and loading the vehicles. This eliminates the need for staging areas and reduces travel time.
- 3) Economic Justification - Despite the high cost of the vehicles, a return on investment of 3 years can be expected for an appropriate application.
- 4) Flexible System Capacity - As material handling activity increases and decreases, vehicles may be easily added or removed from the system.
- 5) Tighter Material Control - When the system is

controlled by computer, the exact location of all material in transit is known and may be monitored.

- 6) Increased Productivity - Since labor is reduced, productivity is improved.
- 7) Flexible Use of Vehicles - Vehicles may be easily programmed to new or different assignments.
- 8) Easy Modification and Expansion of the Track Layout - The track is generally a wire imbedded in the floor or an optical marking on the floor. Installation of the track causes minimum interruption to daily operation.
- 9) Efficient Use of Floor Space - The amount of floor space required for the system is less than that required by floor-installed conveyors (but more than that required by monorails or overhead conveyors).
- 10) Easily Adapted for Automation - Vehicles may be easily interfaced with automatic equipment.
- 11) Ease of Installation - Installation causes little interruption and the system may be easily adapted to existing facilities.

In 1980, there were over 1000 AGVS installations according to the MHI (16). According to Kulwiec (34), in 1984 four times as many systems were installed as in 1983. As the functions and control of vehicles and systems become more sophisticated, the systems are applied to new areas. Bischoff (11) has categorized the applications areas as:

1. Warehousing/Distribution Applications
2. Production Applications
3. Institutional Applications (e.g. offices and hospitals)

AGV systems can perform a wide range of functions in these application areas. In any one application, vehicles may be used for one or more functions. Muller (43) lists these functions as:

1. Supplying and collecting material
2. Order picking
3. Production integrated applications (e.g. transport assembly through a set of operations)
4. Interfacing with automated storage and retrieval systems (AS/RS)

Appendix F is a list of AGV system installations, some characteristics of these systems and the source of the information. Muller has compiled an extensive list of AGV system installations in Europe.

There are five basic types of vehicles employed in AGV systems. These categories, compiled from Kulwiec (34) and the MHI (16), are:

1. automated towing vehicles. These trucks may pull from 1 to 6 trailers in a train and are capable of pulling loads up to 50,000 pounds. The vehicles can automatically hitch to and release the trailers.
2. pallet trucks. These trucks may be loaded manually or automatically. If loading/unloading is automatic, the vehicles are equipped with forks so that loads can be picked up from the floor or from a programmed height.
3. unit load carriers. These have a deck surface that may be flat, equipped with a conveyor section or especially fixtured to hold assemblies.
4. automatic fork lift trucks. These trucks are similar to pallet trucks except that a mast is installed so that loads may be lifted and deposited at heights up to 15 feet.
5. specialty trucks. These are for unusual applications. Some types of specialty trucks are light load carriers for loads of less than 50 pounds, sideloading trucks which can load/unload without turning, and heavy load carriers equipped with air bearing casters which allow loads up to 10 tons to be transported.

There are three forms of vehicle guidance. The most common method is to guide the vehicles by signals emanating

from wire(s) embedded in the floor. The vehicle is equipped with sensors to receive the signals that are sent from a control station or another vehicle. A second method is optical guidance. A pattern of fluorescent material is applied to the floor. The vehicle is equipped with optical sensors that determine the location and interpret the meaning of these patterns. Soft programmed guidance is the third and least common method of guidance. This approach does not require a physical track so that vehicles that normally travel on a track may be programmed to leave the track for a given distance and direction. This type of guidance is under development.

Control philosophies for AGV systems vary depending on the intelligence of the control equipment installed on the vehicles. Kulwiec (34) describes two levels of system control: vehicle traffic management and system management. Vehicle traffic management prevents collisions and determines the path that the vehicles should travel. There are two basic approaches to vehicle traffic management and many combinations of them may be found in practice.

1. Zone Control - The guide path is divided into zones. Only one vehicle is permitted within a zone. When a vehicle leaves the zone, another vehicle may enter the zone. This method is also referred to as block control.
2. Sensor Control - Optical, physical contact and/or sonar sensors are placed on the vehicle to avoid collisions. This type of control performs best on straight sections of the guide path and generally maintains a specified distance between vehicles.

System management, the second type of control,

determines the order in which the tasks are to be performed and assigns vehicles to appropriate tasks. Gunsser (27) discusses two basic approaches to system management control, dispatching and pre-planning. The primary difference between the approaches is timing. Dispatching allocates the resources (vehicles) to tasks at the time that the tasks are required. Pre-planning assigns a list of expected tasks to each vehicle at the beginning of a work period.

There are three levels of system management control according to Kulwiec (34). Any combination of the three levels, given below, may be implemented.

1. On-board dispatching is performed by an operator who enters the appropriate codes on the vehicle to dispatch it to one or more stations.
2. Remote terminal dispatching is also performed by an operator who enters the appropriate codes from a remote terminal to send the vehicle to one or more stations.
3. Central computer dispatching is performed by a dedicated computer or by a computer which supports other components of production (e.g. AS/RS)

If a central computer is used, the computer must constantly communicate with the vehicles. If traffic management control is distributed to computers on-board the vehicles, these computers must have a means of communicating with each other. Modern Material Handling (7) lists three different means, given below, for a microprocessor on-board a vehicle to communicate with a host computer and/or a microprocessor installed on another vehicle. Any combination of the three may be implemented.

1. Magnetic or optical switches along the track.
2. In-floor communications by means of additional wires embedded in the floor with the guidance wire.
3. Radio frequency transmission

New forms of AGV systems and components are emerging.

Modern Material Handling (44) describes a vehicle that is not battery operated. The vehicle is powered by rails in the floor similar to a street trolley. Although not currently used in the U.S., a mail-order company in England is currently operating such a system.

Modern Material Handling (1) describes an overhead system which is another new form of AGV systems. Similar to a monorail system, this system is faster than floor systems, but generally not as flexible. Such systems provide an added challenge to designers because a third spatial dimension is added to an already difficult layout problem.

Other new developments discussed by Warnecke (62), Premi and Besant (50) and Elbrecht and Pfeiffer (24) are systems with robots installed on the vehicles. Mobile robots integrate the handling function of the robot with the transport function of the AGV. These systems are proving ideal for handling applications that do not require a dedicated robot. Two or more handling tasks in different locations may be assigned to the same robot. The significance of traffic congestion increases in these systems. If an AGV with a robot is blocked, both the AGV and the robot are hindered. This increases the cost of congestion. Other applications of mobile robots are

transportation between work stations, assembly work, removal of material, and computer controlled exchange of defective robots.

Design Techniques for AGV Systems

Design techniques for AGV systems are not well established. The design procedure is an iterative process comprised of (1) preliminary analytical calculations to estimate some of the design parameters and (2) digital simulation to test the design configuration. The necessary input to the design process is well defined and Kulwiec (34) provides the following summary.

- 1) Material flow patterns and flowpaths are generally defined in FROM/TO charts. These charts list the origin and destination of each load.
- 2) Throughput or the number loads per hour for each origin and destination are also given in the FROM/TO chart.
- 3) Load schedules define when the loads in the FROM/TO chart are to occur.
- 4) Load attributes describe the dimensions, weight, and stability of the loads.
- 5) Physical conditions, such as clearances, special environmental conditions, and other traffic such as personnel and manned lift trucks, that will affect the system.
- 6) Maintenance plan describes the type and frequency of preventive maintenance tasks.

Sharp, et al (55) list the design parameters of AGV systems shown in Figure 2. Generally the designer can manipulate the layout of the network, the existence and length of spurs and the control system. The number of

1. Network Topology
 - A. Location and configuration of path
 - B. Existence of spurs
 - C. Length of spurs

2. Operating Characteristics
 - A. Speed
 - B. Number of vehicles
 - C. Load/unload times
 - D. Control System
 1. Priority disciplines
 2. Path selection
 3. Dispatch of empty vehicles

FIGURE 2 DESIGN PARAMETERS

vehicles is defined by the amount of activity in the system and must be determined. Control policies must also be selected.

The layout problem of determining the optimal orientations of the aisles in the network has been considered by Malik (36). Given that all aisles are one way, he formulates a mixed integer program to determine the optimal travel direction for each aisle. Assuming the location of the pickup and delivery stations, the problem minimizes the total travel distance of the vehicles. Unfortunately, the required number of vehicles is implicitly assumed by the formulation of the problem. Malik (37) has also shown that the problem is NP-complete.

Due to the lack of problem solving techniques for designing the layout of the network, several guidelines have been developed. Maxwell and Muckstadt (39) give the following guidelines for planning the track layout for an AGV system:

- 1) To minimize empty travel distance, locate dropoff stations with respect to pickup stations such that on any track segment the dropoff activity is greater than or equal to the pickup activity.
- 2) Delivery stations should precede pickup stations on a track segment.
- 3) Aisles should be designated as transit aisles or work aisles.
- 4) The work load of the track segments should be balanced. Both total work time (travel time and load/unload time) and the number of vehicles that work or travel on a segment are a measure of work load.

Muller (43) states that "since every network represents a special applications problem in itself only general guidelines can be given for planning networks and avoiding bottlenecks". He suggests the following iterative procedure and set of guidelines to improve the design of an AGV network.

- 1) Determine the local bottlenecks.
- 2) Attempt to improve the capacity of these bottlenecks by following these general guidelines:
 - A) Use appropriate priority rules at intersections.
 - B) Use one way traffic. Allow bi-directional travel for specific cases only (e.g. spurs).
 - C) Avoid merging high flow rate secondary aisles with high flow rate main loops. When such a merge can not be avoided, reduce the size of the control zone around the intersection to a minimum.
 - D) Minimize the length of the first control zone of a secondary lane if there is a high rate of traffic flow on the main aisle.
 - E) Place frequently used pickup/dropoff stations on secondary aisles, not main aisles.
- 3) Simulate the system to examine the dynamic and stochastic behavior of the system.

The total cost of an AGV system is greatly affected by the number of vehicles the system requires. In most systems the optimal number of vehicles can not be determined. The required number of vehicles is a function of travel time, load/unload time, empty travel time and blocked time. Blocked time and empty travel time can not be predicted in a stochastic system. The required number of vehicles may be estimated more accurately if there is little variance in the

system.

Maxwell (38) determines a lower bound for the required number of vehicles as a function of the total travel time and load/unload time. Since block time is difficult to estimate, it is assumed to be zero.

Empty travel time (deadheading) is the amount of time a vehicle is traveling without a load. Empty travel time is a function of the order of dispatching the vehicles. One method to estimate empty travel time is suggested by Beisteiner (10). He defines the upper limit for the number of empty trips as the number of loaded trips. The lower limit is the number of trips required to maintain the conservation of flow at each station. Beisteiner estimates the empty travel time per trip as the average travel time per load multiplied by the estimated number of empty trips.

Maxwell and Muckstadt (39) have developed an integer program to determine a lower bound for empty travel time. Their formulation minimizes empty travel time subject to the conservation of flow. After the lower bound for empty travel time has been determined, the required number of vehicles may be estimated. Assuming that the loads between a specific pickup and dropoff point may be scheduled evenly over a shift, a deterministic simulation may be used to estimate the blocked time. This estimate of blocked time is added to the total required time to determine if additional vehicles are required.

Kulwiec (34) suggests some general guidelines for

determining the required number of vehicles. When the total travel time has been determined, multiply the total travel time by a traffic congestion factor of .85 to account for interference between vehicles. If the loaded travel time is known, divide this time by a factor of .6 or .8 to account for empty traveling time. The system should be simulated to determine if the estimated number of vehicles is sufficient.

There are three types of operating strategies which are generally implemented in a system. One strategy determines which vehicles have the right of way at intersections. Another operating strategy selects a waiting task to be assigned to a vehicle. The third strategy determines which waiting vehicle is assigned a task.

Egbelu and Tanchoco (21) suggest the following rules for assigning priority at an intersection:

- 1) FCFS - first come first served
- 2) Relaxed FCFS - first come first served for vehicles going to the same arc immediately after the intersection
- 3) Activity control - priority assigned according to the type of task which the vehicle is performing
- 4) Train routing - a function of the distance between vehicles on the preceding arcs.

If more than one vehicle is available when a transport task is requested, Egbelu and Tanchoco (21,22,23) suggest the following rules for selecting a vehicle:

- 1) Select the vehicle randomly from the set of available vehicles.
- 2) Select the vehicle which has the shortest travel time to the pickup station.

- 3) Select the vehicle which has the longest travel time to the pickup station.
- 4) Select the vehicle that has been idle the longest since its last task.
- 5) Select the least utilized vehicle.

If more than one task is waiting when a vehicle becomes available, the following rules are suggested by Egbelu and Tanchoco (21,22,23):

- 1) Select the task randomly.
- 2) Select the task that is waiting in the station that has the maximum on-hand outgoing queue size.
- 3) Select the task that is waiting in the station which is the closest to the vehicle.
- 4) Select the task that is waiting in the station which is the farthest from the vehicle.
- 5) Select the task that is waiting in the station that has the smallest remaining outgoing queue capacity.
- 6) Select the task that has been waiting the longest from a subset of waiting tasks. This subset allows only one task from each station to be waiting.

Egbelu and Tanchoco (21) have developed a simulation package for AGV systems, evaluated the described rules and reported on the results. Their results indicate that dispatching rules based on a measure of distance may perform poorly if the layout of the facility and locations of the stations are not carefully designed. They have also demonstrated the effect of dispatching rules on other elements of the system such as the size of buffers at stations.

Blair and Vasquez (12) discuss a pre-planning method

that schedules tasks to vehicles. They consider a static problem defined by the FROM/TO matrix and schedule a fixed number of vehicles to a fixed number of move orders during a fixed time period. The objective function is to minimize the elapsed time required to execute all tours simultaneously. This will also minimize the duration of the longest route. The formulation is that of the multiple traveling salesmen problem with a modified objective function. Complete enumeration is the only optimal solution technique known for this formulation. Blair and Vasquez have developed a heuristic that employs a swap algorithm combined with a solution procedure for the multiple traveling salesmen problem.

Cyrus and Kusiak (17) have considered the same problem. They formulate the scheduling problem with several different objective functions including:

1. Minimize the number of vehicles required for the set of tasks
2. Minimize the route length. This also minimizes empty vehicle traveling time.
3. Minimize total capital and operating costs.

According to Dwnsnup (19), dispatching idle vehicles is one the most difficult operating issues Kearney and Trecker has encountered in designing AGV systems for flexible manufacturing systems. As Tanchoco and Egbelu describe, idle vehicles may be sent to a parking zone, circulate in a loop or remain in the delivery station. As Dwnsnup states, there are no guidelines for selecting a

parking zone, circulatory loop or for electing to remain in the station. The location of idle vehicles affects empty travel time which, in turn, affects the number of vehicles required.

Sharp, et al (55) propose a two phase approach for designing AGV systems. The objectives of the first phase are two-fold: (1) to minimize the cost of the network and (2) to minimize vehicle time subject to the required throughput and the maximum permissible delay. Phase I determines the location and configuration of the path including the use of spurs and estimates the number of vehicles. Phase II validates the implicit assumptions required to solve Phase I and determines detailed characteristics of the design. The length of the spurs, the number of vehicles and the operating strategies such as priority disciplines at intersections, path selection and the dispatching of empty vehicles are established in Phase II.

Modeling AGV Systems

Maxwell (38) states that "the current challenge [of material handling problems] is to develop models that simultaneously address spatial orientation and timing". The design of AGV systems is encompassed in this category. Maxwell suggests that one approach is to use computer graphics and to include a designer in an iterative solution process.

Wilson (65) and Maxwell and Wilson (40) discuss a "methodology for the analysis of the flow dynamics of proposed industrial unit load material handling systems with fixed path movement". This methodology, dynamic network flow modelling, may be used to determine the throughput capacity and examine the queueing characteristics of a proposed system. Three advantages of this methodology are that it:

1. allows analysis of dynamic, deterministic flows in addition to steady state flows.
2. is computerized but not as time consuming to develop as a simulation
3. analyzes the interplay between dynamic flow schedules, storage limitations and flow bottlenecks.

This methodology has been successfully applied to conveyors by Kang (32). He draws an analogy between conveyor systems and traffic flow theory and uses linear programming and transportation networks with a method to determine the optimum discrete time units to account for time varying flows.

Wilson (65) has developed a computer package, DYNAFLOW, which utilizes dynamic network flow modeling techniques. The package is written in PL/I and requires 350-400K bytes and a Tektronix 4014 terminal. It is currently installed on an Amdahl computer for use in batch or interactive modes. The package is composed of several micromodels. These micromodels represent different components of material handling systems. Micromodels for

AGV system components have not yet been developed due to several complexities in these systems.

AGV System Simulation

Egbelu and Tanchoco (23) have designed an AGV system simulation model to assist in evaluating the guide path configuration, estimated number of vehicles, unit load sizes, machining center control measures, vehicle management and routing policies. Points of congestion in the network may also be identified. The model, AGVSim, is written in Fortran and designed for input by cards. It is composed of two routines. Routine A reads a description of the system and calculates the shortest paths from all nodes to all other nodes. Routine B consists of the following models:

- 1) load assignment
- 2) vehicle unit load transportation system
- 3) machine center
- 4) job scheduling for work centers
- 5) vehicle management and control
- 6) guide path layout

Check zones are established at each intersection to prevent collisions. These check zones are at least the length of the vehicle. When approaching a check zone, the vehicle checks the status of the zone. If the zone is clear, the vehicle proceeds into the check zone, through the intersection and out of the check zone before another vehicle may enter the check zone for that intersection. Vehicles may travel at one speed only. In actual systems, the speed of the vehicle depends on whether or not the vehicle has a load. For this reason, this model is not

adequate. Data entry for the package is by computer cards which is also undesirable.

At the University of Dortmund, Grosseschallau and Heinzel (26) have developed a planning method for AGV systems which utilizes a computer simulation package with graphics. The process consists of four steps:

- 1) Construction - A description of the AGV system is entered from a terminal with a light pen by selecting graphical constructs from a library.
- 2) Analysis - The deterministic or stochastic load information is entered and analyzed using a material flow algorithm. The results of the algorithm are an estimate of the number of vehicles required, the expected conflict regions of the guide path, and the amount of flow on specified track segments.
- 3) Simulation - The system is simulated. A graphical animation of the simulation may be displayed. The five component models of the simulation model are - tracking course, vehicle control, vehicle dispatching, scheduling, and event listing.
- 4) Evaluation - The simulation results are analyzed.

Cheng (14) has developed a simulation of an FMS (flexible manufacturing system) with an AGV system. The program is written in Pascal. The AGV simulation is part of a larger project to create a design tool for FMS designers that will execute on a microcomputer. This model provides rules for selecting a vehicle from among several idle vehicles but does not provide rules to choose a task from among several tasks. The rules used are the same as those defined by Egbelu and Tanchoco (21,22,23). Systems simulated with this package must be small since the package is designed for use with a microcomputer.

Newton (45) has developed a continuous, static simulation tool for AGV systems. The model is similar to the analysis portion of Grosseschallau and Heinzl's model. The model is static and does not consider vehicle interference. The model forecasts the amount of traffic flow on each arc. Newton uses a transportation problem formulation. The model may be used to determine the series of moves for each vehicle which will minimize empty travel time. Since this model is static and deterministic, it was considered not adequate for research purposes.

AutoSimulations, Inc. (9) markets a simulation package for automated manufacturing that provides extensive modeling capabilities for AGV systems. A model of an AGV system is developed by programming the system using AutoMod, an English-like, high level computer language. AutoMod reduces programming time because each line of code generates 20-30 lines of GPSS/H code. The package is available for \$60000/year for a CPU lease or \$15000 for a single project lease. The language may be installed under IBM's CMS, DEC's VMS or UNIX. Due to the high cost of the package, it was not considered a viable alternative for research purposes.

Shortest Path Algorithms

When a vehicle receives an assignment, the control system must determine the best route for the vehicle to follow. If the shortest route is blocked, then the second shortest route is examined and so on. The paths should not

contain cycles, that is, the path should not visit any station, intersection or parking zone more than once. The context of this problem is a network. The nodes of the network are the stations, intersections and parking zones and the arcs are the track segments. The paths can be determined by a shortest path algorithm. Specifically, an algorithm to determine the Kth shortest paths between all pairs of nodes without cycles is required. There are several algorithms available. Deo and Pang (18) provide an excellent classification of shortest path algorithms and capabilities including Kth shortest path algorithms. Dreyfus (20) also provides a good review of shortest path algorithms.

Pollack (49) reviews three Kth shortest path algorithms. The method of Bock, Kantner and Haynes determines all possible routes between a pair of nodes using a tree structure. When all the paths have been determined, the paths are ranked by distance. This algorithm is limited to small networks. Hoffman and Pavely's method first determines the shortest path. The Kth shortest paths are found by deviating from the shortest path. These routes may have cycles. A general estimate of the number of computations can not be determined due to the nature of the algorithm. The method of Bellman and Kalaba may be applied to larger networks but the problem of loopless paths remains difficult. Pollack suggests a modification to the Bellman and Kalaba algorithm but Dreyfus notes that the

computation of the modification increases significantly with K . Pollack (48) proposes another algorithm that is also only appropriate for small K . This algorithm determines the shortest route between a pair of nodes and then sets one link of the shortest path to infinity and solves the shortest path algorithm again. The algorithm continues until all links have been, in turn, set to infinity.

There are three algorithms designed specifically for paths without cycles. Wongeeslashote (66) suggests an algorithm based on Giffler's Schedule Algebra. Yen (67) suggests an efficient algorithm for finding the K th shortest paths. The number of computations increases linearly with K instead of polynomially. Only the K shortest paths from source to sink may be found. The algorithm of Clarke, Krikorian and Rausen uses a tree-like structure and like the method of Hoffman and Pavey, the number of computations can not be estimated.

The previously cited algorithms determine the K shortest paths for a specific pair of nodes. To determine the K th shortest paths for all pairs in a network, the algorithms must be solved $N*(N-1)$ times where N is the number of nodes in the network. Minieka (42) proposes two algorithms which solve for all paths simultaneously. One algorithm is a modification of Floyd's shortest path algorithm and the other is a modification of Dantzig's shortest path algorithm. Lawler (35) suggests a modification to Minieka's work to improve computational

efficiency and notes that there are other more efficient algorithms which he discusses. Shier (56,57) discusses the Double Sweep method which is based on matrix methods. He provides a coding of the algorithm and discusses the computational aspects of the algorithm. Phillips (47) also provides a coding of this method in his Network Optimization Package and suggests a modification to the code so that only paths without cycles are determined. The Jacobi method and the Gauss-Seidel methods are two other matrix method algorithms discussed by Shier (57).

CHAPTER 3

SYSTEM DESIGN

General Considerations

ASP, the proposed package, was designed to meet the following criteria:

1. The purpose of the package is to relieve the user of programming tasks and allow the user to concentrate on the design of the AGV system. To satisfy this requirement the package should be interactive, using clear, concise conversation and providing reasonable allowances for user error.
2. The user should be able to input different versions of the design quickly. Data that is tedious to enter may be read from a file instead of being interactively entered.
3. The package should be general, that is, capable of modeling a wide range of AGV systems. This requires that as many parameters as possible be defined by the user.

Programming Languages

SIMAN was selected as the language to use for the AGV system simulation model. SIMAN is a simulation language developed by C. Dennis Pegden and supported by Systems Modeling, Inc. (46) The language is written in FORTRAN and is available in source form for main frames and microcomputers. This version is installed on a VAX 751.

A primary reason for selecting SIMAN as the language for the simulation model was to learn and evaluate the

language. A high-level language such as PASCAL or FORTRAN was not used because simulation languages may be programmed more quickly since the data collecting capabilities, established framework and constructs of the simulation language are used. SIMAN is specifically designed for simulating manufacturing problems and has established constructs for material handling equipment, routing sequences and scheduling. SIMAN may be used to model any combination of the three traditional orientations of simulation: block diagram, discrete event or continuous. SIMAN also interfaces easily with FORTRAN subroutines and functions. SIMAN was also chosen for its apparent flexibility.

A model developed with SIMAN may have three files:

Model file	- for block diagram orientations
Experiment file	- for all three orientations
Fortran file	- for all three orientations

The experiment file is required and contains the parameters of the simulation such as probability distribution information. The model file contains the logic of the simulation if a block orientation is used. A Fortran file may contain the logic for discrete event and continuous models. In addition, logic that is too complex to program in the block orientation may be contained in the Fortran file.

This package utilizes the block and discrete event orientations so all three SIMAN files are used. The original plan was to write the experiment file from the user

interface programs and not change the model file and the Fortran file for each simulation problem. As the model grew in scope and complexity, it became necessary to have the user interface programs modify both the model file and the Fortran file in addition to writing the experiment file. A command file was written to control the programs.

The model file contains most of the logic for the simulation. The logic for generating tasks and for the stations, intersections, track segments and parking zones are in this file. The experiment file contains the parameters of the simulation (e.g. distribution parameters, path sequences, distances, vehicle speed). The Fortran file contains several subprograms. The subprograms provide decision logic such as which path a vehicle should take from one station to another, where an idle vehicle should be sent, which task should be assigned to a vehicle, and which vehicle should be assigned to a task.

Two problems in the SIMAN package were encountered while developing this model. The first is in the ALTER block. When the capacity of a resource is decreased it must be decreased by the desired amount plus an additional 0.5. Secondly, if the DETECT block in a continuous model is used a tolerance limit must be specified. If this value is not given a tolerance limit, occasionally a continuous loop may be entered. This problem does not affect the ASP model.

FORTTRAN 77 was used for the user interface programs because it interfaces easily with SIMAN and because of its

availability and transportability.

Description of the Model

The information a user must enter to describe an AGV system is outlined in Figure 2. The following terminology is defined to clarify the discussion of the model. A station is any pickup, delivery or assembly location. A part may may be loaded or unloaded at the station or an operation may be performed while the part is on a vehicle. An intersection is the location where two or more track segments, including spurs, meet. A track segment is any continuous track without intersections, stations or parking zones located anywhere except at the ends of the track segment. Stations, intersections and parking zones will often be collectively referred to as nodes and track segments may be called arcs.

There are basically two types of tasks that a vehicle may perform, PICK/DROP and ASSEMBLY. Only one of these types of tasks may be defined in a particular simulation run. To perform a PICK/DROP task, a vehicle travels to a station, picks up a load, travels to the dropoff station and unloads. The pickup and dropoff station of a particular request will be referred to as a FROM/TO pair. The user will define the FROM/TO pairs and the number of times a trip is made between a particular FROM/TO pair.

The second type of task, the ASSEMBLY task, involves loading at the first station and visiting a sequence of

stations at which an operation(s) is performed. The vehicle is not released at these stations. Instead the vehicle waits until the required work is performed and then travels on to the next station. After completing the sequence of operations, the vehicle carries the load to a delivery station, drops the load and is released.

Network Topology

The user defines the number of stations, intersections, track segments, parking zones and their relative positions. The configuration of the network is defined by entering the beginning and ending point of each track segment and the length of the track segment. This is unlike other AGV system simulations which require that the XY co-ordinates of each node be defined. Other simulation models require that the model identify changes in direction and adjust distance to consider curves. The ASP model assumes that the user has included any curve distances in the track length. This greatly simplifies the information the user must enter. The disadvantage of this method is that the user must carefully define the track lengths around intersections. Intersections like those in Figure 3A are represented accurately. In other intersections like that in Figure 3B, some distance will be either added or subtracted depending on how the user defines the track lengths. For example, in Figure 3B, consider the distance of each track segment to be defined to the center of the intersection. When a vehicle

FIGURE 3A INTERSECTIONS ACCURATELY
REPRESENTED BY MODEL

FIGURE 3B INTERSECTION NOT ACCURATELY
REPRESENTED BY MODEL

travels from T1 to T2 the actual distance and the modeled distance are the same. If the vehicle travels from T1 to T3 the modeled distance is less than the actual distance. Other schemes may be used to define the track lengths about an intersection so the user must carefully select a labeling scheme for each type of intersection.

Stations and parking zones may be located directly on the main aisle or off the main aisle by the use of spurs. (Figures 4A and 4B) The ASP system allows only one-way spurs. The situation depicted in Figure 4C may not be used. The number of vehicles which may be located simultaneously in a station or parking zone is user defined.

Track segments may be traveled in one direction only. The direction of travel is assumed to be from the beginning node to the ending node. These nodes are specified by the user.

Vehicle Operating Characteristics

The model assumes that all vehicles have the same traveling speeds and capabilities. That is, all pickups and deliveries may be performed equally by any of the vehicles. The model allows the user to assign different traveling speeds depending on whether the vehicle is loaded or unloaded. The number of vehicles is specified by the user. The SIMAN processor limits the number of vehicles that may be used because of certain array dimensions. The array dimensions have already been increased from the normal SIMAN

FIGURE 4A NO SPUR

FIGURE 4B 1 WAY SPUR

FIGURE 4C 2 WAY SPUR

processor and they may be further increased if necessary. Please see Appendix C for instructions.

The loading and unloading time may be randomly distributed or constant. There are 10 distributions from which the user may choose. The distribution type is the same for unloading/loading and for all stations. The parameters for the distribution may be defined differently for each station.

AGV System Control

The model uses three types of traffic management control. First, the intersections are controlled to prevent collisions. As a vehicle approaches an intersection, a check is made to determine if the intersection is free. If so, the intersection status is set to busy to prevent another vehicle from entering the intersection. Before entering the intersection, a check is also made to ensure that the next track segment is available. If not, the intersection is released and the vehicle waits on the track segment in front of the intersection. If the next track segment is available then the vehicle travels the rest of the track segment before the intersection, through the intersection, onto the next track segment and releases the intersection. If the track segment after the intersection is available, the intersection is entered by the vehicles on a first come, first serve basis. If the next track segment is not available then a vehicle(s) will wait while other

vehicles traveling to other track segments pass through the intersection. For example, Figure 5 illustrates two vehicles approaching an intersection, V1 and V2, and a third vehicle that has just passed through the intersection and is stopped in the first block distance. If V2 is traveling to T3, it will not be allowed to enter the intersection and will wait on T2 until V3 has moved out of the first block distance. If V1 is traveling to T4 it will be allowed to pass through the intersection even though V2 has approached the intersection first. If V1 is traveling to T3, then it will have to wait until V3 has moved to the next block distance and V2 passes through the intersection and the first block distance.

The second type of traffic management control prevents faster vehicles from overtaking and colliding with slower vehicles. This is achieved by either zone or sensor control as defined in the literature review. The user defines the block distance which is the distance that must be maintained between the vehicles. If a track segment is not an integer multiple of the block distance then the last block distance on the segment is one block distance plus the remainder. This can be visualized as zone control if magnetic or optical switches are placed every block distance. This could be implemented as sensor control if the sensors maintained a given distance between each vehicle.

Route selection is the third type of traffic management control effected by the model. Before the simulation

FIGURE 5 INTERSECTION
PRIORITIES

begins, the shortest paths from all nodes to all other nodes are determined and stored in the SIMAN experiment file. If desired the user may specify that the second and/or third shortest paths should also be determined. When a vehicle is assigned a destination, the appropriate path is determined and a limited check is made to determine if the path is blocked. This check includes examining the status of each station and determining whether it is full. If a station along the route is full, a check is made to determine if there is a second path to the destination. If there is a second path, it is checked for blockage. If all paths are blocked, the shortest path is selected. If either the second or third shortest path is not blocked then the vehicle will travel the shortest unblocked path.

The Double Sweep Algorithm discussed by Shier (56,57) and Phillips (47) was the Kth shortest path algorithm selected to be used in the front end programs. This algorithm as modified by Phillips satisfies the criteria of determining loopless paths from one node to all other nodes. Although other algorithms satisfied the criteria, this algorithm was the only algorithm available in coded form. There is some discrepancy in the literature as to the number of operations required by the algorithm. Even the worst case estimation of the number of operations is the same order of magnitude as the other available algorithms and the algorithm need only be executed $N-1$ times (N is the number of nodes) as opposed to most of the other algorithms which

must be executed $N*(N-1)$ times.

There are also three types of system management control. When a vehicle completes its assigned task and no tasks are waiting for a vehicle, and there are no parking zones in the system, the vehicle waits in the station where it just completed a task. If there is more than one parking zone the vehicle selects a parking zone according to the rule selected by the user. The parking zone is selected from the set of available parking zones. The rules available are:

- 1) Select the parking zone randomly.
- 2) Select the parking zone closest to the current location of the vehicle.
- 3) Select the parking zone farthest from the current location of the vehicle.
- 4) Select the parking zone with the largest capacity for vehicles.
- 5) Select the parking zone with the largest available capacity.

When a vehicle completes a task and there is more than one waiting task, the vehicle must select which task to begin. The user may select this rule from the following:

- 1) Select the task randomly.
- 2) Select the task which has waited the longest (FCFS).
- 3) Select the task closest to the vehicle location.
- 4) Select the task farthest from the vehicle location.

The third type of system control must select a vehicle from two or more vehicles and assign it to a task. The user may select this rule from the following list:

- 1) Select the vehicle randomly.
- 2) Select the vehicle closest to the task.
- 3) Select the vehicle farthest from the task.
- 4) Select the vehicle which has been idle the longest since its last task.
- 5) Select the least utilized vehicle.

Simulation Control

There are four methods to define the type of task that is required of the vehicle and the time between arrivals of those tasks. These methods are described below.

- 1) PICK/DROP Task #1 - The number of loads per shift between each FROM/TO pair is defined by the user. The model spreads the loads over a user-defined shift $\pm X$ time units. For example, if the user enters the following information:

FROM/TO pair	Station 1 and Station 5
Shift	420 minutes
Number of Loads	10 loads/shift
Tolerance Band Width (X)	0

Then there is a request for transport every 42 minutes

If the tolerance band width is greater than 0 then the time between arrivals is sampled from a triangular distribution with the mode equal to the length of the shift divided by the number of loads. The minimum and maximum are defined as the mode $\pm$ the tolerance band width X. Returning to the example, if

Tolerance Band Width (X)	5 minutes
--------------------------	-----------

Then there is a request for transport every 42 minutes $\pm$ 5 minutes

Or more specifically, the time between arrivals is sampled from a triangular distribution with a mode of 42 minutes, a minimum of 37 minutes and a maximum of 47 minutes.

- 2) PICK/DROP Task #2 - This is essentially the same as the first method except that the number of loads per shift is not entered. Instead, the user inputs the time between the loads of a particular FROM/TO pair $\pm X$ time units. Requests for transfer of a FROM/TO pair occurs every Y $\pm X$ minutes. Again if X is non-zero, the time between arrivals is sampled from a triangular distribution.
- 3) PICK/DROP Task #3 - The time between arrivals of

requests for transport occur according to a user defined distribution. When a new request is generated, it is assigned a FROM/TO pair according to a discrete distribution defined by the user. For instance, if 60% of requests are for a pickup at station 2 and a dropoff at station 1 then when a request is generated there is a probability of .6 that it will be assigned a pickup at station 2 and dropoff at station 1.

- 4) ASSEMBLY Task - The time between part arrivals occur according to a user defined distribution. When a part arrives, it is assigned a part type according to a user-defined, discrete distribution. Based on the part type, it will also be assigned a sequence of stations to visit. The part will proceed through a series of moves from station to station with the same vehicle.

The user may specify the number of replications in each run and the length of each replication. Between replications there are two options: 1) to discard all observations of the previous replication and 2) to initialize the system after each replication. The user may also specify to run a trace of the simulation.

CHAPTER 4

MODEL PERFORMANCE

Model Testing

As the simulation model was developed, a detailed trace of the simulation was periodically printed to verify that the model was performing correctly. SIMAN provides a trace facility which automatically outputs the result of each model statement, any variables requested by the user and the time of each event. To test the performance of the model, two test problems were defined. The first is modified from Maxwell and Muckstadt (39) and the second is modified from a system installed at the Chicago Regional Shipping Facility of the Keebler Company in Alsip, Illinois.

The configuration of the modified Maxwell/Muckstadt system is shown in Figure 1. Details of the problem are given in Tables 1 and 2. The system was simulated for 150 runs of 8 hours each. After each replication, the observations were discarded but the system was not reinitialized. The results of the simulation are summarized below:

		.95 Confidence			
		Average	Standard	Interval	Min. Max.
		Deviation	Half-Width	Value Value	
Ave System Time	16.04	0.4729	.07569	15.15	17.59
Ave Wait Time	4.174	0.4077	.06525	3.517	5.823

The average time to service a request and the average

TABLE 1

INFORMATION FOR MAXWELL PROBLEM

Number of Vehicles	4
Number of Stations	8
Number of Parking Zones	1
Number of Intersections	5
Number of Track Segments	18
Loaded Vehicle Speed	60 meters/minute
Unloaded Vehicle Speed	80 meters/minute
Shift	480 minutes
PICK/DROP Task #1	

All vehicles initially located in the Parking Zone

Station	Capacity
S1	1
S2	1
S3	1
S4	1
S5	1
S6	1
S7	1
S8	1
Z1	4

FROM/TO Chart Summary

FROM	TO	Loads/Shift	Tolerance
S1	S5	8	1
S1	S6	3	2
S1	S7	3	10
S1	S8	8	3
S2	S1	4	6
S3	S1	3	10
S4	S1	4	8

TABLE 2

NETWORK INFORMATION FOR MAXWELL PROBLEM

Track Number	Beginning Node	Ending Node	Distance (meters)
1	I1	I2	120
2	I2	S7	60
3	S7	S3	120
4	S3	I3	120
5	I3	I5	180
6	I1	S5	60
7	S5	I3	120
8	I5	S2	60
9	S2	I1	60
10	I1	S8	60
11	S8	I4	120
12	I4	I5	180
13	I2	S6	60
14	S6	S4	120
15	S4	I4	120
16	I5	Z1	60
17	Z1	S1	180
18	S1	I5	120

time a request waited for a vehicle was recorded for each replication. This data was analyzed to determine if the system had achieved steady state and to determine if the variance in the system was random. Figure 6 is a plot of the average time to fulfill a request or the average time that a request spends in the system. This average is over an 8 hour period and 150 8 hour periods were observed. The average time that a request must wait for a vehicle is displayed in Figure 7. This time is measured from the time a request is first made for a vehicle until the vehicle is loading the part. From these two plots, the transient phase of the simulation ends around observation number 40. During the transient phase, the time in the system and waiting time are slightly higher. This is to be expected because the system is loaded at time 0 with one request from each FROM/TO pair. After observation number 40 there still appears to be a lot of variation. Figures 8 and 9 are a plot of a three period moving average of the data displayed in Figures 6 and 7, respectively. These plots also indicate that steady state occurs sometime after observation number 40. The average of the data displayed in Figure 6 and 7 are plotted in Figures 10 and 11, respectively. Although this average settles after observation number 40 there is a decreasing trend until about observation 100. Figure 12 represents the time that the vehicle has a load or the work time. A comparison of Figures 6,7 and 12 indicate that most of the variance in the system is a result of requests

Figure 6 Average System Time - Maxwell Problem

Figure 7 Average Wait Time - Maxwell Problem

Figure 8 3 Period Moving Average System Time - Maxwell Problem

Figure 9 3 Period Moving Average Wait Time - Maxwell Problem

Figure 10 Average of Average System Time - Maxwell Problem

Figure 11 Average of Average Wait Time - Maxwell Problem

Figure 12 Average Work Time - Maxwell Problem

waiting for vehicles.

The variance in the system was examined to determine if the variation about the mean time in the system and mean waiting time was random. The autocorrelations of the time in the system and the waiting time were examined after observation number 40. These plots (Figure 13 and 14) show there is a significant correlation between time periods that are one, two and three time periods apart. This is to be expected since the amount of work in the system at the end of a period will affect the time to fulfill a request in the next time period. To determine if the variance in the system was random two tests for randomness were performed, the number of runs up and down and the number of runs above and below the mean. These tests are hypothesis tests for independence where:

H0: Observations are independent
H1: Observations are not independent

If an alpha error of .05 is selected, the test statistic is $Z=2.81$. The results of the test on runs above and below the mean are:

	Z	Reject
Average System Time	-2.35	NO
Average Waiting Time	-3.77	YES

The results of the test on runs up and down are:

	Z	Reject
Average System Time	-2.75	NO
Average Waiting Time	-1.84	NO

Although not ideal results, the tests and the plots indicate that the variance in the system is random and that the

Figure 13 System Time Autocorrelations - Maxwell Problem

Figure 14 Wait Time Autocorrelations - Maxwell Problem

system does reach steady state.

The Keebler Problem is the second problem that was simulated. The Keebler Company has a distribution center in Alsip, Illinois and a larger facility in Cincinnati, Ohio which have AS/RS storage facilities supported by AGV's. The track configuration is displayed in Figure 15. The track layout was modified because the original was too large for some of the data arrays in SIMAN. Station 5 is actually four AS/RS interface stations. Instead of controlling each station separately, Station 5 has a capacity of four. The information for the problem is given in Tables 3 and 4.

The Keebler problem was simulated for 80 runs of 8 hours each. The Keebler system has less variance and reaches steady state approximately 25 observation periods earlier than the Maxwell system. The results of the simulation are summarized below:

		Standard	.95 Confidence	Min.	Max.
	Average	Deviation	Interval	Value	Value
			Half-Width		
Ave System Time	15.45	1.119	.2490	13.93	20.41
Ave Wait Time	3.766	0.850	.1893	2.711	7.883

The average time in the system and average waiting time are plotted in Figure 16 and 17. The three period moving average (Figure 18 and 19) indicates that the time in the system may have cycles with peaks every 20 observation periods. The average of the data in Figures 16 and 17 are plotted in Figures 20 and 21. These figures indicate that there is no trend in the data as expected. Figure 22 shows the average work time.

TABLE 3

INFORMATION FOR KEEBLER PROBLEM

Number of Vehicles	6
Number of Stations	7
Number of Parking Zones	1
Number of Intersections	26
Number of Track Segments	47
Loaded Vehicle Speed	100 feet/minute
Unloaded Vehicle Speed	132 feet/minute
Shift	480 minutes
PICK/DROP Task #1	

Vehicle	Initial Location
1	S1
2	S2
3	S3
4	Z1
5	Z1
6	Z1

Station	Capacity
S1	2
S2	2
S3	2
S4	1
S5	10
S6	1
S7	2
Z1	6

FROM/TO Chart Summary

FROM	TO	Loads/Shift	Tolerance
S1	S4	3	1.0
S1	S5	15	1.0
S1	S6	2	1.0
S2	S4	4	1.0
S2	S5	15	0.5
S2	S6	2	1.0
S3	S4	3	1.0
S3	S5	15	1.5
S3	S6	3	1.0
S5	S7	52	0.0
S6	S5	7	1.0

TABLE 4

NETWORK INFORMATION FOR KEEBLER PROBLEM

Track Number	Beginning Node	Ending Node	Distance (feet)
1	I1	S1	20
2	I1	I2	20
3	S1	I2	20
4	I2	I3	40
5	I3	I4	40
6	I3	I12	25
7	I4	I5	40
8	I5	S2	20
9	S2	I6	20
10	I6	I7	60
11	I5	I6	20
12	I7	I8	20
13	I7	S3	20
14	S3	I8	20
15	I8	I9	30
16	I9	I10	20
17	I9	Z1	20
18	Z1	I10	20
19	I10	I11	160
20	I11	I4	25
21	I11	I12	40
22	I12	I13	120
23	I13	I22	25
24	I13	I14	60
25	I14	I15	20
26	I15	S4	20
27	S4	I16	20
28	I15	I16	20
29	I16	I17	60
30	I17	I20	25
31	I17	I18	20
32	I18	S5	20
33	S5	I19	20
34	I18	I19	200
35	I19	I20	125
36	I20	I21	130
37	I21	I14	25
38	I21	I22	60
39	I22	I23	60
40	I23	S6	20
41	S6	I24	20
42	I23	I24	20
43	I24	I25	40
44	I25	S7	20
45	S7	I26	20
46	I25	I26	20
47	I26	I1	60

FIGURE 15 KEEBLER PROBLEM

Figure 16 Average System Time - Keebler Problem

Figure 17 Average Wait Time - Keebler Problem

Figure 18 3 Period Moving Average System Time - Keebler Problem

Figure 19 3 Period Moving Average Wait Time - Keebler Problem

Figure 20 Average of Average System Time - Keebler Problem

Figure 21 Average of Average Wait Time - Keebler Problem

Figure 22 Average Work Time - Keebler Problem

The variance in this system is not autocorrelated. (See Figures 23 and 24). The results of the runs tests are given below.

	Runs above and below mean		Runs up and down	
	Z	Reject	Z	Reject
Average Time in System	0.67	NO	-1.0	NO
Average Waiting Time	0.31	NO	1.37	NO

Based on this information, the null hypothesis that the observations are independent can not be rejected. This satisfies the independence property of random numbers.

The difference between the results of the two problems is not well understood. There is a parking zone in the Maxwell system and the stations have a vehicle capacity of one. In the Keebler system, there is not a parking zone but most of the stations have capacity for more than one vehicle. These factors are known to affect the time in the system. More research in this area is needed. The two example problems demonstrate that the ASP simulation model works well.

Size of the Model

Run time for the ASP model is dependent on the system being simulated. The Keebler problem required 491K byte of virtual memory and 3 hours and 30 minutes of central processing unit time to execute. The Maxwell problem required 491K bytes of virtual memory and 1 hours and 47 minutes of central processing unit time to execute. The

Figure 23 System Time Autocorrelations - Keebler Problem

Figure 24 Wait Time Autocorrelations - Keebler Problem

original Keebler system did exceed the limits of some data array in SIMAN. If a problem is too large for the linker and can not be reduced or simplified as the Keebler system was, contact Systems Modeling, INC. for additional information for extending the limits of these arrays.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In general, SIMAN was easily applied to the model. When the constructs of SIMAN could not be applied, a Fortran function or subroutine was written. There are a few variables that SIMAN uses that the user does not have direct access to in a Fortran program. Usually, such a problem increased the amount of bookkeeping required by the model. SIMAN did not limit the capabilities of the model. The major drawback encountered was that the user only has one array in which to store variables which are not controlled by SIMAN. As an increasing amount of this project was programmed without the use of SIMAN constructs, this limitation became cumbersome. In the final version of this model, most of the material handling constructs of SIMAN were not used:

- 1) The MOVE function was only used to change the location of the vehicle. The MOVE block can also determine the time it takes the vehicle to change locations. The track sub-model and a data file, DIST.DAT replaced the second function of the MOVE block.
- 2) SIMAN does not allow vehicles of the same type to travel at different speeds. A set of variables was added to store the speed of each vehicle. This allows the speed of the vehicle to vary depending on

whether or not it is loaded.

- 3) SIMAN does not have a facility to handle the movement of idle vehicles. In order to accomplish the movement of empty vehicles, vehicles are not released after a task is finished. This causes the SIMAN status of the vehicle to remain busy. Another set of variables must keep track of the true status of the vehicles. If the vehicle is needed before it reaches its parking zone, the destination of the vehicle must be changed. Once the vehicle reaches its new task, the entity which had been controlling the vehicle must be destroyed so that the new task may seize the vehicle. If the vehicle arrives at the parking zone before a new task enters the system, the vehicle is released and the entity is destroyed.
- 4) Since SIMAN does not know which vehicles are actually busy and which ones are traveling empty, the SIMAN facility to select a vehicle from the set of empty vehicles may no longer be used. A set of selection rules were written to replace the SIMAN rules.
- 5) SIMAN does not determine the utilizations of the vehicles of a vehicle type. Two sets of variables were added so that the idle time of each vehicle could be determined.

There are two times that the status of track segments along the path to a destination must be examined. When a path is selected, it is checked to determine if the path is blocked. When a vehicle approaches an intersection, the status of the next track segment is determined. In order to check the status, the model must be able to look through the sequence the vehicle is following. Unfortunately, the sequence facility in SIMAN does not have this capability. The sequence data had to be stored in two locations to accomplish this look ahead capability in the model, one location for the SIMAN sequence facility and one in the parameters element to allow a Fortran program to access the

data. With large and complex networks, this requirement quickly lead to a large amount of data.

The user controllable array is dimensioned to be 50 in the SIMAN processor. The model requires:

$$\text{Dimension} = 6 * (\text{number of vehicles}) + 2$$

This dimension limited the use of the simulation model to small problems. The dimensions were increased to 150 which should be sufficient for most medium-sized systems. For larger systems, the dimension will have to be increased again. Although not a difficult process, it is time consuming and tedious. Refer to Appendix C for details.

Recommendations

There are some modeling capabilities that due to lack of time were not incorporated into the model. There are many more ideas that have surfaced since this project was defined which would be interesting enhancements. A description of these additions and some ideas about implementing them follow:

- 1) The SIMAN package has an output processor which takes the output from the simulation model and creates tables, histograms, plots, barcharts and other types of compiled output. Limited work has been done with the output processor. Ideally, the output processor should be incorporated into the ASP package so that some of the data analysis is performed automatically. The flexibility to perform additional analysis outside of the ASP package should always be maintained.
- 2) If the package is installed on the MicroVAX, the Tektronix terminal provides an ideal tool for adding graphics to the package. User input would be

enhanced with graphics. Ideally, the simulation would be graphically animated. Most likely, after the simulation is completed, an option to have it played back in graphical form would be used. Systems Modeling, Inc. currently sells such an enhancement for microcomputer applications. This does not include the MicroVAX so the package will have to be developed in-house.

- 3) The model should be tested to determine the significance of the loss of accuracy incurred by approximating the length of track segments around intersections. If the loss of accuracy is enough to warrant a change in the model, a possible solution would be to define a track segment to end at the first diverge or merge at an intersection. Each intersection would be defined in a sub-model by specifying its structure and the lengths of all merge/diverge track segments.
- 4) The model could be extended to model battery charging. This could be accomplished by adding a sub-model. The amount of time the vehicle has worked can be found at a specific time by subtracting the idle time from the current time. When this number reaches a prescribed level, the vehicle is flagged so that after completing its current task it travels to a battery charging area.
- 5) The model has four different scenarios that may be selected for the creation of demand for transport. Another scenario, that could be added, would be for the model to follow a unit load to all the stations the load is required to visit. At each station, the vehicle would be released. When the part completes its sojourn at the station another vehicle must be requested. Additional logic would have to be created to model the processes at each station. This logic would include the number of machines, amount of processing time and the sequencing of waiting parts to the machines. The logic could be added to the station sub-model. If the logic at the machining centers differs, the station sub-model may have to be sub-divided into several station sub-models. The machining center sub-models could be optionally incorporated into any of the already defined methods of creating demand for transport.
- 6) Additional rules for selecting a task when a vehicle becomes available could be added. Some possibilities are to select a task by pre-assigned priorities depending on part type, due date, amount of time the part has been in the shop, time

remaining until due date and many others. If machining centers are modelled, an additional rule might be to select the task that is located at the station with the smallest remaining outgoing buffer capacity. These rules should be added to SUBROUTINE CHOOS-ENT.

- 7) At the initialization of the simulation, vehicles may only be located at stations or parking zones. With some additional logic in the front end programs, the vehicles could also be placed on track segments. This would also require initializing the capacity of each track segment which would be performed by the front end programs.
- 8) A sub-model could be created to model breakdowns of the vehicles. The major problem would be to decide where the vehicle is located after the vehicle has been repaired.
- 9) If breakdowns are modelled, logic should be added to SUBROUTINE CHSEQ to enable a vehicle to look for breakdowns before selecting a path to its destination.
- 10) Priority rules for passing through intersections could be added. Depending on the rules, a Fortran subroutine, similar to CHOOS-ENT and/or the RANKINGS element in the experiment file would contain the logic for these rules.
- 11) The execution time of the front end programs might be reduced if the model file was changed to a direct access file. Any statements that the front end programs write to the model files could be written to a specific record number. Currently, these statements are written to separate files and then appended into one file. This latter step was necessary because the record numbers of the statements changed frequently while the model was being developed. This change should be made after the model is fully developed.

There are two major revisions that are recommended.

First, develop a database management system to handle the data that describes the AGV systems. This capability would allow more rapid data input and less repetition of data that has already been entered. This data base would allow the designer to test different designs more easily and quickly.

Secondly, a different data structure to represent the network is recommended. Currently, an algorithm determines the shortest path from all stations, parking zones and intersections to all others stations, parking zones and intersections. In large problems, this list of sequences quickly becomes a large amount of data. In addition, this list must be stored in two different locations as noted earlier. The network may be better represented as a tree data structure. Such a structure would reduce the amount of storage. It may increase execution time since a path must be determined each time.

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APPENDIX A

User Manual

To use this package enter:

@ASP

This command causes the command file ASP.COM to be executed.

After a pause, the following screen will be presented.

The information entered by the user is underlined in this manual.

```

*****
*
*               ASP
*
*       AGVS Simulation Package
*
*****

```

IF YOU ARE NEW TO THIS PACKAGE:

Please enter Y for a brief introduction
to the conventions used in this package.

Otherwise enter N

Y

If there is an error before this screen is presented, it is likely that a file needed by the package is missing. Check the directory, (enter DIR) and determine if the file AGVMAIN.EXE is in the directory.

If you are new to this package, enter Y and the following information is displayed.

NAME CONVENTIONS:

Stations, intersections and parking zones are referenced by the letters S, I, Z, respectively and a number. All stations, intersections and parking zones must be numbered consecutively from 1. For example.

PROBLEM:

2 stations 3 intersections 1 parking zone

Stations should be referred to as

S1

S2

Intersections should be referred to as

I1

I2

I3

Parking zones should be referred to as

Z1

Please press RET to continue.

UNITS:

It is recommended that MINUTES be used for the unit of time and either METERS or YARDS be used for the unit of distance. This package does not assume a system of units. It does assume that the units of time and distance are used consistently throughout the package.

For example:

If minutes and meters are used for the units of time and distance respectively, then the units for

Velocity are meters/minute

Mean Load Time are minutes

Length of

Track Segment are meters

Please press RET to continue.

One final definition:

TRACK SEGMENT refers to a continuous section of track, uninterrupted by station, intersection or parking zone. Travel is in one direction only. This direction is designated by entering a beginning node and an ending node.

The package now asks for a description of the problem. An example session is shown here. The following is a description of the problem. The layout of the track network is given in Figure 1 of the text, the Maxwell problem. The network topology information is given in Table 2 of the text.

Network Topology:	Vehicle Characteristics:
8 stations	4 vehicles
1 parking zones	80 meters/minute unloaded
5 intersections	60 meters/minute loaded
18 track segments	vehicle 1 in parking zone 1
	vehicle 2 in parking zone 1
	vehicle 3 in station 8
	vehicle 4 in station 7

Unload/load time distribution is exponential.

Station	Mean
1	3
2	4
3	3
4	2
5	3
6	4
7	3
8	4

PICK/DROP Task.

Shift=480 minutes

FROM/TO	Number of loads	Tolerance band width *
S1/S8	20	5
S2/S4	10	8
S3/S6	28	3
S1/S5	10	0
S1/S7	15	5

System Control:

20 meters block distance
 select least utilized vehicle
 select closest task
 select parking zone with the largest remaining capacity
 check up to 3 paths for blockage before selecting one of the paths

Simulation Control:

1 run
 0 starting time
 4800 minutes
 no trace
 100 active requests for transport allowed

* Tolerance band width is the number of time units that the time between loads may vary. (i.e. between S1 and S8 loads occur every $480/20=24$ time units plus or minus 5 time units)

Do you wish to read
 Initial Data
 Vehicle Characteristics
 Simulation Data
 from the TERMINAL or a FILE ?

Enter T for terminal and F for file.

T

Please enter the TITLE of the problem.
 Maximum - 20 ALPHANUMERIC CHARACTERS
 MAXWELL USER MANUAL

Enter the DATE.

MONTH (1-12): 6
 DAY (1-31): 4
 YEAR : 85

Enter your NAME.

Maximum - 20 ALPHANUMERIC CHARACTERS)
 SUSAN NORMAN

Please enter the followings.

Number of STATIONS: 8
 Number of PARKING ZONES: 1
 Number of INTERSECTIONS: 5
 Number of TRACK SEGMENTS: 18

Enter the maximum number ACTIVE REQUESTS for
 TRANSPORT allowed in the system at the same time.

(Suggested input - 100)

300

Please enter the Vehicle Characteristics

Number of AGVs (MAX= 24): 4
 Unloaded Velocity: 80
 Loaded Velocity: 60

Please enter the initial location of each vehicle.

(Must be either a STATION or a PARKING ZONE)

(Enter S for stations and Z for parking zones.)

AGV # 1: Z1
 AGV # 2: Z1 S₁
 AGV # 3: S8
 AGV # 4: S7

Please enter the number of AGVs that may be in a STATION.
 Be sure number is sufficient to contain the
 initial locations of AGVs.

STATION 1: 1
 STATION 2: 1
 STATION 3: 1
 STATION 4: 1
 STATION 5: 1
 STATION 6: 1
 STATION 7: 1
 STATION 8: 1

Please enter the number of AGVs that may be in a PARK ZONE
 Be sure number is sufficient to contain the
 initial locations of AGVs.

PARK ZONE 1: 4

Transport Request Activity may be entered as follows:

1. PICK/DROP Task #1 - FROM/TO loads distributed over
a shift +/-X time units
2. PICK/DROP Task #2 - FROM/TO loads occur every Y
time units +/-X time units
3. PICK/DROP Task #3 - Time between requests for
transport occur according to specified distribution.
FROM-TO load assigned to request by discrete
probability distribution.
4. ASSEMBLY Task - Time between part arrival occur according to
specified distribution. Part type assigned by
discrete probability distribution. Part assigned
sequence of stations to visit depending on part type.

5. MORE INFORMATION

Please enter the appropriate number.

1

Number of time units in a shift: 480

Please enter the FROM/TO pairs and the number of
loads during a shift for each FROM/TO pair.

Please remember that the naming convention is as follows:

S5 - station 5
 S10 - station 10

Enter X when all FROM/TO pairs have been entered.

Pickup Station (X to end): S1

Dropoff Station: S8

Number of loads per shift: 20

Requests for transfer from S 1 TO S 8
 will occur every 24 time units.

Enter the tolerance band width: 5

Pickup Station (X to end): S2

Dropoff Station: S4

Number of loads per shift: 10

Requests for transfer from S 2 TO S 4
will occur every 48 time units.

Enter the tolerance band width: 8

Pickup Station (X to end): S1

Dropoff Station: S5

Number of loads per shift: 10

Requests for transfer from S 1 TO S 5
will occur every 48 time units.

Enter the tolerance band width: 0

Pickup Station (X to end): S3

Dropoff Station: S6

Number of loads per shift: 28

Requests for transfer from S 3 TO S 6
will occur every 17 time units.

Enter the tolerance band width: 3

Pickup Station (X to end): S1

Dropoff Station: S7

Number of loads per shift: 15

Requests for transfer from S 1 TO S 7
will occur every 32 time units.

Enter the tolerance band width: 5

Pickup Station (X to end): X

Please enter load/unload information

Enter the distribution type for load/unload time.

- 1 - Constant
- 2 - Uniform Distribution
- 3 - Triangular Distribution
- 4 - Exponential Distribution
- 5 - Erlang Distribution
- 6 - Normal Distribution
- 7 - Lognormal Distribution
- 8 - Gamma Distribution
- 9 - Beta Distribution
- 10 - Weibull Distribution
- 11 - User Defined Discrete Distribution

Please enter the appropriate number.

4

Please enter the mean of the EXPONENTIAL distribution for load/unload time at each station.

Station 1:

Mean: 3

Station 2:

Mean: 4

Station 3:

Mean: 3

Station 4:

Mean: 2

Station 5:

Mean: 3

Station 6:

Mean: 4

Station 7:

Mean: 3

Station 8:

Mean: 4

Please enter the Simulation Data.

Number of SIMULATION RUNS: 1

START TIME of 1st run: 0

LENGTH of the runs: 4800 sec

Do you want a TRACE? (Y=YES, N=NO)

(A trace is a detailed report of the processing of the simulation)

N Y

Enter VEHICLE select rule.

If when a request for transport occurs, there is
more than 1 vehicle available,

How should the vehicle be selected?

- 1 - Randomly select the vehicle
- 2 - Select the CLOSEST vehicle
- 3 - Select the FARTHEST vehicle
- 4 - Select the LONGEST IDLE vehicle
- 5 - Select the LEAST UTILIZED vehicle

Please enter the appropriate number.

5

Enter the TASK select rule.

If when a vehicle becomes available there is more than
1 request waiting to be assigned to a vehicle,
How should the request be assigned to the vehicle?

- 1 - Select the request RANDOMLY
- 2 - Select the LONGEST WAITING (FCFS) request
- 3 - Select the CLOSEST request
- 4 - Select the FARTHEST request

Track Segment # 6
 BEGINNING POINT: I1
 ENDING POINT: S5
 LENGTH: 60

14 S6
 S4
 120

Track Segment # 7
 BEGINNING POINT: S5
 ENDING POINT: I3
 LENGTH: 120

15 S4
 14

Track Segment # 8
 BEGINNING POINT: I5
 ENDING POINT: S2
 LENGTH: 60

60

Track Segment # 9
 BEGINNING POINT: S2
 ENDING POINT: I1
 LENGTH: 60

16 I5
 21
 120

Track Segment # 10
 BEGINNING POINT: I1
 ENDING POINT: S8
 LENGTH: 60

17 I1
 S1

Track Segment # 11
 BEGINNING POINT: S8
 ENDING POINT: I4
 LENGTH: 120

14
 18 S1

Track Segment # 12
 BEGINNING POINT: I4
 ENDING POINT: I5
 LENGTH: 180

15
 120

Track Segment # 13
 BEGINNING POINT: I2
 ENDING POINT: S6
 LENGTH: 60

Track Segment # 18
 BEGINNING POINT: S1
 ENDING POINT: I5
 LENGTH: 120

If the SHORTEST path for a trip is BLOCKED,
 should another path be checked?

Y

How many paths should be considered?
 Maximum = 10

3

After the problem has been entered, there is a pause. The program is determining all the shortest paths. If a track segment was inadvertently not entered correctly the following will occur.

*** NETWORK INFORMATION IS NOT COMPLETE ***
CHECK TO MAKE SURE THE INFORMATION ABOUT THE
BEGINNING AND ENDING NODES OF EACH TRACK
IS CORRECT AND ENTER THE NETWORK INFORMATION AGAIN.

If the shortest paths have been successfully determined a FORTRAN STOP will be output to the screen. The SIMAN processor then compiles and links the experiment file and the model file and the following messages are displayed.

PLEASE WAIT

INPUT COMPLETE. PLEASE WAIT.
FORTRAN STOP

Processing experiment file...
~~XAPPEND-W-INCOMPAT, QSA1:[SIMAN]AINTENB.MOD;5 (input)~~
FORTRAN STOP

Experiment statement echo file is called AGVSIM1.ELS

Processing model file...
FORTRAN STOP

Model statement echo file is called AGVP.MLS

Linking file...
LINK COMPLETED
FORTRAN STOP

*Experiment file AGVSIM1.ELS
Model file AGVP.MLS
Linking file AGVP.MLS*

Many protections have been included in the front end programs to prevent error. Errors may occur. If an error has occurred in compiling the experiment file, the link will not be successful. The message will look like:

****ELEMENT SEQUENCE ERROR****

****FATAL ERROR - EXECUTION TERMINATED****

To see if the error is in the experiment file, edit the .ELS file. To see if there is an error in the model file, edit the .MLS file. Find the error message for an indication of the problem. Be sure to check all your inputs. If nothing is obvious, run the problem again to be sure there was not an error in entering the information.

After a successful link, the following messages will be displayed to indicate the beginning of the simulation.

**Executing simulation...
Job 249 entered on queue SYS\$BATCH**

The simulation is run as a batch job so that your terminal is not tied up while you wait for the output. The message to indicate completion of the simulation is:

Batch job 249 SIM completed on 1-JUN-1985 20:20

For information about the simulation run, edit SIM.LOG. This file contains all commands executed in batch mode, the amount of CPU time for the simulation to run and error messages if any errors occurred.

To see the results of the simulation, either type or edit the AGVSIM1.OUT file. If a trace of the simulation was requested, the trace will also be printed in this file.

Problems that might be encountered:

1) If the following error is displayed in the AGVSIM1.OUT file:

```

*** SIMAN EXECUTION ERROR ***
DETECTED AT BLOCK SEQUENCE      XX
MAXIMUM NUMBER OF ENTITIES EXCEEDED
INCREASE MENT IN THE DISCRETE ELEMENT

```

Increase the maximum number of active requests for transport when entering the information for the problem.

2) A "DISK QUOTA EXCEEDED" error may occur while the simulation is running. This error is printed in the batch log file, SIM.LOG and indicates that there is no more disk space available for this user. If this error occurs, purge all files and be sure any files that are not needed are deleted. A trace of the simulation requires a lot of disk space. If a trace was requested, try executing the simulation without the trace. If there is still not sufficient space, see the system manager.

3) If at any time a message indicates that certain files are not found, check the directory to determine if the following required files are on disk. If an .OBJ file is not present but the .FOR file is, simply compile the file. If the file is not in the directory at all, the files will have to be read from tape. See the system manager.

Required SIMAN files:

COMPSIMAN.COM	EXP.COM	EXPMT.EXE	INSTSIMAN.COM
LINKER.EXE	LINKSIMAN.COM	LNK.COM	MOD.COM
MODEL.EXE	OUT.COM	OUTPT.EXE	REMSIMAN.COM
RA.OBJ	SETUP.COM	SIM.COM	SIMAN.EXE
SIMAN.OBJ	SMAIN.OBJ		

Required ASP files:

AGVDIST.FOR	AGVDIST.OBJ	AGVINFO.FOR	AGVINFO.OBJ
AGVINP.FOR	AGVINFO.OBJ	AGVKSHRT.FOR	AGVKSHRT.OBJ
AGVMAIN.FOR	AGVMAIN.OBJ	AGVNET.FOR	AGVNET.OBJ
AINITO.MOD	AINIT6.MOD	AINIT9.MOD	AINTE1.MOD
AINTE4A.MOD	AINTE5.MOD	APZ9.MOD	APP.COM
APPCH.COM	ASP.COM	ASTAT2.MOD	ASTAT4.MOD
ASTAT6.MOD	ASTAT9A.MOD	ATRCK1.MOD	ATRCK3.MOD
ATRCK5.MOD	CHSQ0.FOR	CHSQ2.MOD	

There are other files required by the ASP package which are created by the ASP package. Do not delete any files unless you know their use and content.

Description of Files

SIMAN Files:

- AGVSIM1.EXP - SIMAN experiment file created by command file by appending 3 files to the end of the AGVSIM1.EXP file: AGVSIM.EXP, PAR.EXP, AGVSIM2.EXP.
- AGVSIM.EXP - contains the REPLICATE element.
- AGVSIM1.EXP - contains the PROJECT, DISCRETE, INITIALIZE, RESOURCES elements.
- AGVSIM2.EXP - contains the SEQUENCE, DISTANCES, TALLIES, OUTPUT, COUNTERS, DSTAT, and TRANSPORTERS elements.
- PAR.EXP - contains the PARAMETERS element.
- AGVSIM1.E - created by the SIMAN experiment processor from AGV.EXP
- AGVSIM1.ELS - created by the SIMAN experiment processor from AGV.EXP. Contains a listing of AGVSIM1.EXP with errors flagged if there are any errors.
- AGVP.MOD - SIMAN model file created by the command file ASP.COM by appending files created by the front end programs and files already existing. The following files are written by the front end programs:
AINIT5.MOD	AINIT7.MOD	AINTE0.MOD
AINTE4.MOD	AINTE4B.MOD	APZO.MOD
ASTAT0.MOD	ASTAT3.MOD	ASTAT3A.MOD
ASTAT5.MOD	ASTAT8.MOD	ASTAT9.MOD
ATRCK0.MOD	ATRCK1A.MOD	ATRCK2.MOD
ATRCK4.MOD		
- The following is a list of files already existing.
AINIT0.MOD	AINIT6.MOD	AINIT9.MOD
AINTE1.MOD	AINTE4A.MOD	AINTE5.MOD
APZ9.MOD	ASTAT2.MOD	ASTAT4.MOD
ASTAT6.MOD	ASTAT9A.MOD	ATRCK1.MOD
ATRCK3.MOD	ATRCK5.MOD	
- AGVP.M - created by the SIMAN model processor from AGVP.MOD
- AGVP.MLS - created by the SIMAN model processor from AGVP.MOD. Contains a listing of AGV.MOD with errors flagged if there are any errors.
- AGVP.P - created by the SIMAN linker.

AGVSIM1.OUT - Contains the output of the simulation.
Created by the SIMAN processor.

AGVCHSEQ.FOR - Contains the user written subroutines for the model. Created by command file, ASP.COM by appending: CHSQ0.FOR, CHSQ1.FOR, CHSQ1A.FOR, CHSQ2.FOR

Front end files:

AGVINP.FOR - Contains subroutines for entering all data except for the network and demand for transport.

AGVDIST.FOR - Contains subroutines to create distributions.

AGVNET.FOR - Contains subroutines to enter the network and determine the K shortest paths.

AGVLOAD.FOR - Contains subroutines to enter the demands for transport.

Data Files:

DEST.DAT - contains the destination of each path sequence

DIST.DAT - contains the distance between all pairs of nodes, where a node is a station, parking or intersection.

END.DAT - only used when ASSEMBLY task is specified. Contains the last station visited in a part sequence

LOAD2.DAT - only used when FROM/TO Task #3 is specified. Temporary storage for FROM/TO pairs

LOAD2A.DAT - only used when FROM/TO Task #3 is specified. Temporary storage for frequency distribution of FROM/TO pairs

RAW.DAT - contains data for the network as entered by the user. Input for the sorting routine

SORT.DAT - contains data for the network, sorted as required by the shortest path algorithm

SEQ.DAT - contains the sequence number of the first sequence that originates at a node

Description of Fortran Subprograms

SIMAN User Subroutines

- CHOOS-ENT - selects a task to be assigned to a vehicle. May call one of the following: CLOSE-ENT, FARTH-ENT
- CHOOS-ZON - selects the parking zone to which an empty vehicle is sent. May call one of the following: CLOSE-ZON, FARTH-ZON, TOT-CAP, REM-CAP
- CHSEQ - contains decision logic which determines which sequence number a vehicle is to follow to reach its destination.
- CLOSE-REQ - selects the closest task to be assigned to a vehicle
- CLOSE-VEH - selects the closest vehicle to be assigned to a task
- CLOSE-ZON - selects the closest parking zone to be assigned to an empty vehicle
- EVENT - interface between the model file and user subroutines. Determines which subroutine is being called by the SIMAN model. Passes values to the user subroutines from the front end programs.
- FARTH-REQ - selects the farthest task to be assigned to a vehicle
- FARTH-VEH - selects the farthest vehicle to be assigned to a task
- FARTH-ZON - selects the farthest parking zone to be assigned to an empty vehicle
- LEAST-UTIL-VEH - selects the least utilized vehicle to be assigned to a vehicle
- LONG-IDL-VEH - selects the vehicle that has been idle the longest since its last task to assign to a task
- PICK-VEH - determines which vehicle to select for a waiting task. May call one of the following: CLOSE-VEH, FARTH-VEH, LONG-IDLE, LEAST-UTIL
- REM-CAP - selects the parking zone with the largest remaining capacity to assign to an empty vehicle
- SET-A1A2 - redefines the destination of a vehicle that is

traveling empty from a designated parking zone to a station to pickup a load.

TOT-CAP - selects the parking zone with the largest capacity to assign to an empty vehicle

Front End Subroutines

ARRIVE - called by LOAD3 and LOAD4. Queries the user for the parameters for the distribution of time between arrivals.

BOOB00 - called by any routines that query the user for input. Contains error messages.

DSWP - called by KSHRT. Code for the shortest path algorithm, Double Sweep algorithm.

INPUT - called by the main program. Queries the user for information about the problem.

KSHRT - called by NETWRK. Determines the 10 shortest paths distances with cycles and 1-3 shortest path sequences without cycles.

LOAD1 - called by INPUT. Queries the user for input pertaining to FROM/TO Task #1

LOAD2 - called by INPUT. Queries the user for input pertaining to FROM/TO Task #3

LOAD3 - called by INPUT. Queries the user for input pertaining to FROM/TO Task #2

LOAD4 - called by INPUT. Queries the user for input pertaining to ASSEMBLY Task

NETWRK - called by INPUT. Queries the user the network information.

ORDER - called by KSHRT. Sorts the network information, RAW.DAT, by ending node so that the data may be used by the K shortest path algorithm.

PARA - called by INPUT. Queries the user for parameters of load/unload time distribution for each station.

TRACE - called by KSHRT. Determines 1-3 of the path sequences for all nodes to all nodes.

XMULT - called by DSWP. Code for modified matrix multiplication required in shortest path algorithm

Front End Functions

CHDIST - called by INPUT, ARRIVE. Determines the type of distribution the user has requested.

TRANS - called by INPUT, NETWRK. Translates the stations, parking zones, intersections and track segments names to station model numbers used by SIMAN.

SIMAN Attributes of Entities

<u>Attribute</u>	<u>Function</u>
1	Stores initial node for a path sequence. For a dropoff trip, it is set equal to the pickup station. For a trip to the parking zone, it is set equal to the dropoff station.
2	Stores ending node for a path sequence. For a pickup trip, it is set equal to the pickup station. For a dropoff trip, it is set equal to the dropoff station. For a trip to the parking zone, it is set equal to the parking zone.
3	Stores the AGV number that is currently assigned to the entity.
4	Used for various functions as temporary storage
5	Used for various functions as temporary storage
6	Indicates the type of task the vehicles will perform. 0 - indicates FROM/TO task. 1 - indicates ASSEMBLY task
7	Used for Tally 1 to determine the time in the system.
8	Designates the type of trip. 1 - pickup trip, 2 - dropoff trip, 3 - trip to parking zone, 4 - pickup trip that requires that entities be exchanged
9	Used for Tally 2 to determine the waiting time for AGVs
10	Used for Tally 3 to determine the waiting time for track segments
11	Used for Tally 4 to determine the waiting time for stations.
12	Not used
13	Used for Tally 5 to determine the waiting time for intersections.
14	Used only for ASSEMBLY task. 0 - pickup trip, 1 - work trip

- 15 Used only for ASSEMBLY task. Index into routing sequence.
- 16 Used only for ASSEMBLY task. Indicates the next work stop.
- 17 Index into parameter set for work station times.
- 18 Length of last block distances in a track segment remaining to be traveled.
- 19 Index into parameters set for total number of block distances in a track segment
- 20 Number of block distances in a track segment remaining to be traveled.
- 21 Wait signal used to release a vehicle waiting for a block distance on a track segment
- 22 Location number for the entity selected to be assigned to a vehicle.

SIMAN User-assigned System Variables

X_Variable

Dimension = 150

Required = 6*(number of AGVs)+2

This list is in the order that the elements of the array are stored.

Required ElementsFunction

1

Number of vehicles in the AGV system

No. of Vehicles

Previous Location of each vehicle

No. of Vehicles

1 - indicates the vehicle is busy. 0 - indicates the vehicle is idle

No. of Vehicles

Record location of the entity assigned to each vehicle.

No. of Vehicles

Time when vehicle was released.

No. of Vehicles

Total idle time of each vehicle.

No. of Vehicles

Speed of each vehicle

SIMAN Queues

<u>No. of Queues</u>	<u>Functions</u>
1	Wait for vehicle to be assigned and for vehicle to arrive
1	Wait for vehicle to arrive
1	Wait for track segments block distances to become available
1	Dummy queue associated with the ALLOCATE block
No. of Stations	Queue to wait for each station
No. of Parking Zones	Queue to wait for each parking zone
No. of Intersections	Queue to wait for each intersections
No. of Track Segments	Queue to wait for each track segments
No. of AGV	Queue to wait for each AGV after the vehicle has been assigned to the entity.

APPENDIX B

Flow Charts

Subroutine EVENT

```

* * * * *
*
*   Initialize rule
*   selection variables
*   and other variables
*
* * * * *
      ↓
* * * * *
*
*   Determine which
*   subroutine the
*   simulation is
*   calling
*
* * * * *
      ↓
* * * * *
*
*   Call appropriate
*   subroutine
*
* * * * *
      ↓
* * * * *
*
*   Return
*
* * * * *

```

Subroutine CHSEQ

```

* * * * *
*
*   Initialize variables
*   open files: SEQ.DAT
*   DEST.DAT, END.DAT
*
* * * * *

```

```

* * * * *
*
*   Determine initial
*   and final nodes of
*   path to be determined
*
* * * * *

```

```

* * * * *
*
*   Read from SEQ.DAT
*   the beginning ending
*   records in the file
*   to be searched
*
* * * * *

```

```

* * * * *
*
*   Find path with
*   correct destination
*
* * * * *

```

```

*
*   Is path
*   blocked
*
*   ???
*
*   N

```

Y

N

```

      ↓
* * * * *
*
*   If all paths are
*   use first path
*   otherwise select
*   first unblocked path
*
* * * * *
      ↓
* * * * *
*
*   Call SETNS
*   Set SIMAN sequence
*   variable to path
*   number
*
* * * * *
      ↓
* * * * *
*
*   Return
*
* * * * *

```


Subroutine PICK-VEH

Subroutine CH00S-ZONE

```

      Subroutine FARTH-VEH
* * * * *
*
*   Open DIST.DAT which
* contains the distance
*         matrix
*
* * * * *
*
*           ↓
*
* * * * *
*
*   Compare distance of
* each vehicle from
* FROM station and
* select the farthest
*         vehicle
*
* * * * *
*
*           ↓
*
* * * * *
*
*   Return
*
* * * * *

```

Subroutine CLOSE-VEH

```

* * * * *
*
*   Open DIST.DAT which
* contains the distance
*       matrix
*
* * * * *

```

```

* * * * *
*
*   Compare distance each
* vehicle is from FROM
* station and select
* closest vehicle
*
* * * * *

```

```

* * * * *
*
*   Return
*
* * * * *

```

Subroutine LONG-IDL-VEH

```

* * * * *
*
* Determine length of
*   time since each
* vehicle was last busy
*
* * * * *

```

```

* * * * *
*
* Select vehicle that
*   has been idle the
*   longest
*
* * * * *

```

```

* * * * *
*
*   Return
*
* * * * *

```


Subroutine LEAST-UTIL-VEH

```

* * * * *
*           Compare vehicle
*           utilizations
* * * * *
      ↓
* * * * *
*   Select vehicle that
*   has been least
*   utilized
* * * * *
      ↓
* * * * *
*           Return
* * * * *

```

Subroutine CLOSE-REQ

```

* * * * *
*
*   Open DIST.DAT which
*   contains the distance
*   matrix
*
* * * * *
      ↓
* * * * *
*
*   Determine distance
*   of each request in the
*   queue from the vehicle
*
* * * * *
      ↓
* * * * *
*
*   Select the closest
*   request and save its
*   rank in the queue
*
* * * * *
      ↓
* * * * *
*
*   Return
*
* * * * *

```

Subroutine FARTH-REQ

```

* * * * *
*
* Open DIST.DAT which
* contains the distance
*      matrix
*
* * * * *
*
*      ↓
*
* Determine the distance
* each request in the
* queue is from the
* location of the
*      vehicle
*
* * * * *
*
*      ↓
*
* Select the farthest
* request and save its
* rank in the queue
*
* * * * *
*
*      ↓
*
*      Return
*
* * * * *

```

Subroutine CLOSE-ZON

```

* * * * *
*
*   Open DIST.DAT which
*   contains the distance
*   matrix
*
* * * * *
*
*   ↓
*
*   Determine the distance
*   between each zone and
*   the location of the
*   vehicles
*
* * * * *
*
*   ↓
*
*   Select the closest
*   parking zone
*
* * * * *
*
*   ↓
*
*   Return
*
* * * * *

```

Subroutine FARTH-ZON

```

* * * * *
*
*   Open DIST.DAT which
*   contains the distance
*   matrix
*
* * * * *
*
*   ↓
*
*   Determine the distance
*   between each zone and
*   the location of the
*   vehicles
*
* * * * *
*
*   ↓
*
*   Select the farthest
*   parking zone
*
* * * * *
*
*   ↓
*
*   Return
*
* * * * *

```

Subroutine REM-CAP

```

* * * * *
*
*   Determine the unused
*   capacity of each zone
*
* * * * *
      ↓
* * * * *
*
*   Select the zone with
*   the largest unused
*   capacity
*
* * * * *
      ↓
* * * * *
*
*   Return
*
* * * * *

```

Subroutine TOT-CAP

```

* * * * *
*   Determine the   *
*   capacity of each *
*   parking zone    *
* * * * *
      ↓
* * * * *
*   Select zone with *
*   largest capacity *
* * * * *
      ↓
* * * * *
*   Return           *
* * * * *

```

Subroutine PARA

```

* * * * *
*
*   Determine distribution type
*   for load/unload time
*
* * * * *
      ↓
* * * * *
*
*   Read appropriate parameters
*
* * * * *
      ↓
* * * * *
*
*   EXPERIMENT FILE
*   Write parameters to
*   Parameters element
*
* * * * *
      ↓
* * * * *
*
*   Return
*
* * * * *

```


Subroutine INFO

Subroutine TASK1

```
* * * * *
*
* Describe PICK/DROP
* TASK #1 and give
* two examples
*
* * * * *
```

```
* * * * *
*
* Return
*
* * * * *
```

Subroutine TASK2

```
* * * * *
*
*   Describe PICK/DROP
*   TASK #2 and give
*   two examples
*
```

```
* * * * *
*
*   Return
*
```

Subroutine TASK3

```
* * * * *
*
*   Describe PICK/DROP
*   TASK #3 and give
*   example
*
* * * * *
```

```
* * * * *
*
*   Return
*
* * * * *
```

Subroutine ASSEM

```
* * * * *
*
*   Describe ASSEMBLY
* TASK and give example
*
* * * * *
```

```
* * * * *
*
*   Return
*
* * * * *
```

SUBROUTINE INPUT

```

      ↓
* * * * *
*   Read load/unload time   *
*   distribution information  *
* * * * *
      ↓
* * * * *
*   Write the REPLICATE     *
*   element                 *
* * * * *
      ↓
* * * * *
*   Write the TRACE element  *
* * * * *
      ↓
* * * * *
*   Specify operating rules  *
* * * * *
      ↓
* * * * *
*   Specify block distance   *
* * * * *
      ↓
* * * * *
*   CALL NETWRK             *
*   Enter the network and    *
*   determine shortest paths *
* * * * *
      ↓
* * * * *
*   Write Station info, et al *
*   to MODEL file           *
* * * * *
      ↓

```

```

      ↓
* * * * *
*
*   Write the TALLIES element
*
* * * * *
      ↓
* * * * *
*
*   Write the DISCRETE and
*   INITIALIZE elements
*
* * * * *
      ↓
* * * * *
*
*   Write the RESOURCES
*   element
*
* * * * *
      ↓
* * * * *
*
*   Write the TRANSPORTERS
*
* * * * *
      ↓
* * * * *
*
*   RETURN
*
* * * * *

```

Subroutine ORDER

Subroutine XMULT

Subroutine TRACE

```

* * * * *
*
* Initialize array that
* will store paths
*
* * * * *

```

```

* * * * *
*
* Trace path for JJth
* path length.
* Current node is last
* node in the path
*
* * * * *

```

```

* * * * *
*
* Check all nodes
* incident to the
* current node
*
* * * * *

```

```

*
* *
*
* Can path be
* extended to
* initial node of path
*
* ???

```

N

Y

Y

Subroutine LOAD1

Subroutine LOAD2

```

      ↓
* * * * *
*   Call ARRIVE   *
*   Determine time *
*   between arrivals *
* * * * *
      ↓
* * * * *
*   Read discrete *
*   distribution for *
*   assigning FROM/TO *
*   pairs          *
* * * * *
      ↓
* * * * *
*   EXPERIMENT FILE *
*   Store parameters of *
*   FROM/TO pairs dist. *
* * * * *
      ↓
* * * * *
*   MODEL FILE      *
*   Define FROM/TO pair *
*   assignment       *
* * * * *
      ↓
* * * * *
*   Return          *
* * * * *

```

Subroutine LOAD4

Program MAIN

Subroutine INFOR

```

* * * * *
*
*   Describe NAMING
* CONVENTION of package
*
* * * * *
      ↓
* * * * *
*
*   Describe UNIT of the
*           system
*
* * * * *
      ↓
* * * * *
*
*   Define TRACK SEGMENT
*
* * * * *
      ↓
* * * * *
*
*   Return
*
* * * * *

```

Subroutine NETWRK

Function TRANS

```

* * * * *
*
* Translate station,
* intersection and
* parking zone code
* to SIMAN station
* numbers
*
* * * * *

```

AGVP.MOD

MAIN

Station Sub-model

Intersection Sub-Model

Parking Zone Sub-Model

↓
* * * * * * * * * * * *
* * * * * * * * * * * *
* Free vehicle and *
* dispose of entity *
* * * * * * * * * * * *
* * * * * * * * * * * *

Track Segment Sub-Model

APP.COM

```

* * * * *
*
*   Merge Initialization
*   sub-model of MOD file
*
* * * * *

```

```

* * * * *
*
*   Merge Station
*   sub-model of MOD file
*
* * * * *

```

```

* * * * *
*
*   Merge Intersection
*   sub-model of MOD file
*
* * * * *

```

```

* * * * *
*
*   Merge Track Segment
*   sub-model of MOD file
*
* * * * *

```

```

* * * * *
*
*   Merge Parking
*   Zone sub-model
*   of MOD file
*
* * * * *

```

↓

```
* * * * * * * * * * * * * * * *
*
*      Merge EXP file
*
* * * * * * * * * * * * * * * *
*
*      ↓
*
*      Merge Fortran file
*      Call APPCH.COM
*
* * * * * * * * * * * * * * * *
*
*      ↓
*
*      * * * * * * * * * *
*      *
*      *      End      *
*      *
*      * * * * * * * * * *
*      *
```

ASP.COM

```

* * * * *
*
*      Link Fortran files:
*      AGVMAIN,AGVINPUT,AGVNET,
*      AGVKSHRT,AGVLOAD,AGVDIST,
*      AGVINFO
*
* * * * *
*
*      ↓
*
*      Merge simulation file
*      Call APP.COM
*
* * * * *
*
*      ↓
*
*      Compile simulation Fortran
*      file - AGVCHSEQ
*
* * * * *
*
*      ↓
*
*      Process EXP file
*      EXP.COM
*
* * * * *
*
*      ↓
*
*      Process MOD file
*      MOD.COM
*
* * * * *
*
*      ↓
*
*      Link EXP and MOD files
*      LNK.COM
*
* * * * *
*
*      ↓

```

```
* * * * *
*               *
*   Run simulator   *
*   SIM.COM         *
*               *
* * * * *

      ↓
* * * * *
*               *
*   End             *
*               *
* * * * *
```

APPENDIX C

Directions to Increase SIMAN Array Dimensions

Instructions to Change SIMAN Array Dimensions

Load SIMAN Source Files

Since all the SIMAN files are either in executable or object form, the SIMAN tape must be read to load the SIMAN source files. To load the SIMAN tape, follow the Installations Procedure that is listed below. This is a copy from the VAX SIMAN Installation Guide sent with the tape from Systems Modeling Inc.

```
$ ALLOCATE MTAO SIMAN_TAPE
$ MOUNT SIMAN_TAPE SIMAN
$ COPY SIMAN_TAPE:SETUP.COM SYS$SIMAN:SETUP.COM
$ @SETUP
```

The process must be interrupted by entering CTRL Y after compiling has begun. Otherwise the command file deletes the source files after the files have been compiled and linked.

Changing the Dimensions

To execute larger problems, the variables in the common block SIM must be increased in user subroutines. The dimension of X should be $6 * (\text{number of vehicles}) + 2$.

To change Dimensions of X in SIMAN source code:

- 1) Change the dimensions of X in COMMON/SIM/ in the following locations:

<u>FILE</u>	<u>ROUTINE</u>			
EXPMT.FOR	MAIN			
	DEFAULT			
	EXP2			
LINKER.FOR	MAIN			
SIMAN.FOR	MAIN	XXEND	XXBEG	XXRFC
	IINLZ	XDSTAT	ISSET	BBLCK
	BBDUP	RSET	BBCRT	BBASS
	XXPRNT	BBREQ	BBCONV	BBEXIT
	BBBRCH	BBSRCH	BBCOMB	BBGRP
	BBFNDJ	DSTAT	CSTAT	RRVAL
	IXA	SSLRQ	AARSQ	AATRS
	AACNV	IDIST	ISGNT	SSCND
	SSCAN	SUMRY	DAVG	DSTD
	DTPD	CAVG	CSTD	CTPD
	XXERR	CCNT	SSCHL	SIGNAL
	ENTER	INSERT	REMOVE	COPY
	SCHED	TALLY	COUNT	SETA
	SETM	ASSIGN	CREATE	DISPOS
	XXSCH			

2) Change the dimensions of XI and XL to the same as X in COMMON/SIM2 located:

<u>FILE</u>	<u>ROUTINE</u>			
EXPMT.FOR	MAIN			
	DEFAULT			
	EXP2			
SIMAN.FOR	MAIN	XXEND	XXBEG	XXBEG2
	XXRKF	IINLZ	BBLCK	BBDUP
	BBMAT	BBCRT	XXPRNT	BBREQ
	BBCONV	BBEXIT	BBBRCH	BBSRCH
	BBCOMB	BBGRP	BBFNDJ	SSLRQ
	AACNV	SSCND		

3) Change the dimensions of LTMX and ITMS to the same as X in COMMON/SIM3 located:

<u>FILE</u>	<u>ROUTINE</u>			
EXPMT.FOR	MAIN			
	DEFAULT			
	EXP2			
LINKER.FOR	MAIN			
SIMAN.FOR	MAIN	XXEND	XXBEG	XXBEG2
	XXRKF	IINLZ	BBLCK	BBDUP
	BBMAT	BBCRT	BBASS	XXPRNT
	BBREQ	BBCONV	BBEXIT	BBBRCH
	BBSRCH	BBCOMB	BBGRP	BBFNDJ
	RRVAL	IIXA	SSCND	SUMRY
	XXERR	SSCHL	CCPY	A
	ENTER	INSERT	REMOVE	COPY
	SCHED	SETA	SETM	ASSIGN
	M	CREATE	DISPOS	

4) Change the value of MXV and MXV to the dimension of X in EXPMT.FOR, SUBROUTINE DEFAULT

To change the dimensions of S:

1) Change the dimensions of S,D,SL,DL in COMMON/SIM located in:

<u>FILE</u>	<u>ROUTINE</u>			
EXPMT.FOR	MAIN			
	DEFAULT			
	EXP2			
LINKER.FOR	MAIN			
SIMAN.FOR	MAIN	XXEND	XXBEG	XXRFC
	IINLZ	XDSTAT	ISSET	BBLCK
	BBDUP	RSET	BBCRT	BBASS
	XXPRNT	BBREQ	BBCONV	BBEXIT
	BBBRCH	BBSRCH	BBCOMB	BBGRP
	BBFNDJ	DSTAT	CSTAT	RRVAL
	IXA	SSLRQ	AARSQ	AATRS
	AACNV	IDIST	ISGNT	SSCND
	SSCAN	SUMRY	DAVG	DSTD
	DTPD	CAVG	CSTD	CTPD
	XXERR	CCNT	SSCHL	SIGNAL
	ENTER	INSERT	REMOVE	COPY
	SCHED	TALLY	COUNT	SETA
	SETM	ASSIGN	CREATE	DISPOS
	XXSCH			

2) Change the dimension of DI and SI to the same as X in COMMON/SIM2 located in:

<u>FILE</u>	<u>ROUTINE</u>			
EXPMT.FOR	MAIN			
	DEFAULT			
	EXP2			
SIMAN.FOR	MAIN	XXEND	XXBEG	XXBEG2
	XXRKf	IINLZ	BBLCK	BBDUP
	BBMAT	BBCRT	XXPRNT	BBREQ
	BBCONV	BBEXIT	BBBRCH	BBSRCH
	BBCOMB	BBGRP	BBFNDJ	SSLRQ
	AACNV	SSCND		

3) Change the dimensions of A2, A3, A4, A5 in the DIMENSION statement in:

<u>FILE</u>	<u>ROUTINE</u>
SIMAN.FOR	MAIN
	XXEND
	XXBEG
	XXRKf

Re-installing SIMAN

Be sure to save the files as the necessary changes are made. To compile all the files enter:

@COMPSIMAN

To link the files, enter:

@LINKSIMAN

SIMAN must be installed from an account with all system privileges. Please see the systems manager to have the following commands executed:

@REMSIMAN	(Remove the old version of SIMAN)
@INSTSIMAN	(Install the new version of SIMAN)

Be sure to clean up the directory. Delete the following files:

MODEL.OBJ;*	EXPMT.OBJ;*
LINKER.OBJ;*	OUTPT.OBJ;*
ILIB.OBJ;*	LMAIN.OBJ;*

Purge all files with more than one version.

APPENDIX D

SIMAN Installation Guide

version **2.0**

Mainframe Installation Procedure

sm | Systems Modeling Corp.
Calder Sq. P.O. Box 10074
State College, PA 16805
(814) 238-5919

1.0 Introduction

The SIMAN software is distributed in source form on standard nine-track magnetic tape. It should be noted that the software is furnished under a license and may be used or copied only in accordance with the terms of that license. The software is written in ANSI 66 FORTRAN for operation on computers having a word size of 16 bits or larger. Computer operating systems differ substantially among computers and therefore a precise step-by-step procedure for installing SIMAN is not possible. However, as a general guide, the following steps should be accomplished to install the SIMAN program:

- 1: The SIMAN software must be read from the magnetic tape onto the host computer.
- 2: Input/output files employed by SIMAN may require the addition of OPEN statements or other computer-specific file definition statements.
- 3: Program OUTPT is set up for operation in an interactive mode using the non-standard \$ edit descriptor to inhibit the automatic end-of-record. It may be necessary to replace the \$ on some systems.
- 4: The default memory allocation for the SIMAN data array is 5000 integer words (very small). If this memory allocation is to be changed or if the host computer employs unequal integer and real word lengths, the dimensions of the storage arrays ISET and RSET must be modified in programs LMAIN and SMAIN.
- 5: On computers which employ a 16-bit integer word length, variables which are associated with the random number generator must be declared as INTEGER*4 variables.
- 6: The input library routines and the SIMAN programs (MODEL, EXPMT, LINKER, SIMAN, OUTPT, RA, LMAIN, and SMAIN) must be compiled using the FORTRAN compiler.
- 7: The binary code for programs MODEL, EXPMT, and OUTPT must be linked with the subprograms contained in the input library, program SIMAN must be linked with both its calling program (SMAIN) and the random number generator (RA), and program LINKER must be linked with its calling program (LMAIN).
- 8: An example problem included on the tape should be executed to verify the operation of the SIMAN software.

In this manual we describe the procedure for executing these eight steps for installing the SIMAN software.

Special installation procedures have been developed for the VAX/VMS System (Attachment A) and the UNIX System (Attachment B). ~~If you are installing SIMAN~~ on either of these systems you should proceed directly to the special instructions included in the attachments.

2.0 Reading the SIMAN Tape

The SIMAN software is distributed in source form on 600-foot nine-track magnetic tape. The first step in the installation procedure is to read this tape into files on the host system. The data is written on the tape in the following format (VAX/VMS users see special instructions in Note 1).

- 1: ASCII (non-IBM systems) or EBCDIC (IBM systems) or VAX/VMS format.
- 2: 9 track
- 3: 1600 bpi
- 4: 80 characters per record
- 5: 24 records per block - 120
- 6: even parity
- 7: unlabeled

The tape contains 33 separate files. The programs contained in these files are summarized below:

- File 1: The input library routines
- File 2: Program MODEL
- File 3: Program EXPMT
- File 4: Program LINKER
- File 5: Program SIMAN
- File 6: Program OUTPT
- File 7: Program SMAIN
- File 8: Program LMAIN
- File 9: Subroutine RA
- File 10: Example 2A input statements
- File 11: Example 2A experiment input statements
- File 12: Example 2B model input statements
- File 13: Example 2B experiment input statements
- File 14: Example 2C model input statements
- File 15: Example 2C experiment input statements
- File 16: Example 3A model input statements
- File 17: Example 3A experiment input statements
- File 18: Example 3B model input statements
- File 19: Example 3B experiment input statements
- File 20: Example 3C model input statements
- File 21: Example 3C experiment input statements
- File 22: Example 4A model input statements
- File 23: Example 4A experiment input statements
- File 24: Example 4B model input statements
- File 25: Example 4B experiment input statements
- File 26: Example 4C model input statements
- File 27: Example 4C experiment input statements
- File 28: Example 5A model input statements
- File 29: Example 5A experiment input statements
- File 30: Example 5B model input statements
- File 31: Example 5B experiment input statements
- File 32: Example 5C model input statements
- File 33: Example 5C experiment input statements

The first nine files contain FORTRAN source code and the last twenty-four files contain the model and experiment input statements for the examples in the SIMAN User's Manual.

3.0 Defining Input/Output Files

Each of the five SIMAN processors employs input/output files for reading and writing data. These files may require special declarations in the form of a PROGRAM card, OPEN statements, or special job control language, depending upon the particular host. The files employed in each of the five programs are summarized in Table 1. The file numbers in Table 1 correspond to the following devices/file types:

File 5: input from the user's terminal or cardreader
 File 6: output to the user's terminal or line printer
 File 8: the model object file
 File 9: the experiment object file
 File 10: the program object file
 User Specified Files; auxiliary data files

These file arrangements may be changed as described by the header comments at the beginning of each program.

Table 1: Summary of Program Files

Program	File Number	Read/Write	Type
MODEL	5	read	formatted
	6	write	formatted
	8	write	formatted
EXPMT	5	read	formatted
	6	write	formatted
	9	write	formatted
LINKER	6	write	formatted
	8	read	formatted
	9	read	formatted
	10	write	unformatted
SIMAN	6	write	formatted
	10	read	unformatted
	user specified	write	unformatted
OUTPT	6	write	formatted
	user specified	read/write	unform./form.

In the case of programs SIMAN and OUTPT, the data set numbers of the auxiliary data files are user-specified at run time as input to the programs. The appropriate locations for opening these files are indicated by comment cards within the program (see the program header comments). In addition, ANSI 1977 OPEN statements have been included at the appropriate places throughout the programs as comment lines with the characters C*OPN in the first five spaces of the line.

If you are installing SIMAN on a CDC computer under the 1966 FORTRAN compiler, all input/output files must be listed in the PROGRAM statement. Please refer to note 2 for special instructions.

4.0 Modifying OUTPT for Interactive Operation

Program OUTPT may be operated in either an interactive or batch mode. By default, the program is set up to operate in an interactive mode and employs a WRITE and FORMAT statement to display a prompt character to the screen. The exact form of these statements is system-dependent since they require the use of a non-standard edit descriptor to inhibit the normal automatic end of record generated by FORTRAN when writing to the terminal.

The statements included in the program are shown below:

```
          WRITE(NPT,15)
15      FORMAT(1X,1H),$)
```

Note that the \$ character is a non-standard edit descriptor to inhibit the automatic end of record. This allows the user's input line to be entered on the same line as the prompt. If your system does not support the \$ edit descriptor, you should replace it with the appropriate coding. To operate the program in a batch mode you should delete the above two statements.

5.0 Declaring INTEGER*4 Variables on 16 Bit Machines

On systems which by default represent integer words using 16 bits, it is necessary to explicitly declare certain integer variables in programs LINKER, SIMAN, and RA as INTEGER*4 variables. The necessary declaration statements are included as comment lines in each of these programs with the characters C*16B in the first five spaces of the line. These statements may be activated by globally replacing C*16B with five blanks in each of these three files.

6.0 Reallocation of SIMAN Memory

In programs SIMAN and LINKER, information related to the simulation is stored in arrays ISET (integer) and RSET (real). The dimension of these arrays limits the maximum size of the model which can be executed by SIMAN. The default dimension for these arrays is 5000 each, which is adequate for small models. For large models these dimensions must be increased. These dimensions must also be changed for computers which have unequal integer and real word sizes (VAX/VMS users see note 3).

The dimensions for the ISET and RSET arrays for programs SIMAN and LINKER are specified in the small main programs SMAIN and LMAIN, respectively. These main programs (with default dimensions) are shown below:

```

PROGRAM SMAIN
  DIMENSION ISET (5000)
  COMMON/SIM10/LEND,NIR
  COMMON RSET (5000)
  EQUIVALENCE(ISET(1),RSET(1))

```

C

```

  LEND=5000
  NIR=1
  CALL SIMAN
  STOP
  END

```

```

PROGRAM LMAIN
  DIMENSION ISET(5000)
  COMMON/SIM10/LEND,NIR
  COMMON RSET (5000)
  EQUIVALENCE(ISET(1),RSET(1))

```

C

```

  LEND=5000
  NIR=1
  CALL LINKER
  STOP
  END

```

In both main programs the local array ISET is dimensioned to 5000 and the COMMON array RSET is dimensioned to 5000. The EQUIVALENCE statement causes the two arrays to be superimposed in memory, i.e., the starting address of each array is the same. The variable LEND is set to the dimension of ISET (which in the default case is the same as the dimension of RSET), and the variable NIR, denoting the number of integer words per real word, is set to 1. The default main programs assume that the size of an integer and real word is the same. In the main program for program SIMAN, a call is then made to subroutine SIMAN which executes the SIMAN processor. In the main program for program

LINKER, a call is made to subroutine LINKER which executes the LINKER processor.

The reason for including the dimension statements in short main programs rather than directly in subroutines SIMAN and LINKER is to avoid the need to reconcile these routines in order to allocate more memory to the programs. Only the two short main programs need to be compiled to allocate memory to the program.

If the host computer employs different word sizes within FORTRAN to store integer and real words, the default main programs must be modified accordingly. In general, the number of bytes of memory allocated to ISET and RSET must be exactly the same. Hence once the dimension of ISET is established, the dimension of RSET must be selected so that the total number of bytes of memory assigned to each is the same. In the case of equal integer and real word sizes, this means that the dimension of ISET and RSET must be identical. In the case of two byte integers and four byte reals, the dimension of ISET must be twice the dimension of RSET. In the latter case the variable NIR would be specified as 2.

In summary, to modify the memory allocated to the program, perform the following steps:

- 1: Change the dimensions of ISET and RSET in the short main programs SMAIN and LMAIN to the desired values. The number of bytes assigned to ISET and RSET must be the same.
- 2: Reset LEND to the dimension of ISET in both main programs.
- 3: Reset NIR to the number of integer words per real word (typically 1 or 2) in both main programs.

It should be emphasized that the dimensions assigned to SMAIN and LMAIN must be the same.

In addition to changing the dimensions of ISET and RSET, the need may arise to increase the number of continuous variables or X variables beyond their current limit of 50. The necessary program modifications are summarized in the header comments on program SIMAN.

7.0 Program Compilation

The next step in the installation process is to compile each of the nine program files. The programs should compile without error under any FORTRAN compiler consistent with the 1966 ANSI FORTRAN standard. If an optimization option is available, the programs should be compiled under the highest level of optimization.

8.0 Program Linking

Once the program modules have been compiled, the next step is to resolve the external references for each of the programs using the FORTRAN linker. Programs MODEL (file 2), EXPMT (file 3), and OUTPT (file 6) make calls to subprograms contained in the input library, and therefore the input library (file 1) should be linked to these programs. The main program LMAIN (file 8) should be linked with program LINKER (file 4) to produce an executable module named LINKER. The main program SMAIN (file 7) and subroutine RA (file 9) should be linked with program SIMAN (file 5) to produce an executable module named SIMAN.

Executable binary files should be saved for all five programs (MODEL, EXPMT, LINKER, SIMAN, and OUTPT). In addition, binary versions of SMAIN, SIMAN, and RA should be kept in library form which the user may access for linking user-tailored executable binary files for program SIMAN by replacing one or more of the following subprograms with user-written versions:

- Subroutine PRIME
- Subroutine WRAPUP
- Subroutine EVENT
- Subroutine STATE
- Function UR
- Function UF

Default versions of these subprograms are included in the SIMAN program (file 5).

9.0 Executing the Test Problem

The last step in the installation process is to execute the test problem included in files 10 and 11. This is problem 2A described in Section 2-6 of the SIMAN User's Manual. The procedures for inputting, linking, and running a model are summarized in Section 2-5 of the manual. The answers generated by SIMAN will likely differ slightly from the results shown in the manual due to differences in the random number generators.

10.0 For Help

Questions or problems related to the installation or operation of SIMAN should be directed to:

Systems Modeling Corporation
Calder Square P.O. Box 10074
State College, PA 16805-0074
(814) 238-5919

Notes:

- ① A standard VAX tape with an automatic installation routine is supplied in place of the ASCII formatted tape for VAX/VMS systems. See Attachment A.
- 2: The user-specified auxiliary data file numbers present a problem for CDC computers using ANSI 1966 FORTRAN since all files must be listed in the PROGRAM statement at compilation time. One solution is to reserve a standard set of data set numbers for user-specified files. For example, data set numbers 11 through 16 might be reserved for this purpose. Default versions of the PROGRAM statements required by CDC computers have been included in each program as comment lines with the characters C*CDC in the first five spaces of the line.
- ③ When installing SIMAN on a VAX/VMS system, the dimensions assigned to ISET and RSET should be large (e.g., 50,000). The VMS operating system will automatically omit the unused portion of the array from memory. As a result, the size of the executable module will automatically adjust to the size of the problem.

ATTACHMENT A: VAX/VMS INSTALLATION NOTES

The installation of SIMAN can be done by anyone with write access to system files but it is recommended that the system manager or a system user with the same privileges perform the installation. The following resources must be available when the installation begins:

1. 4500 blocks of working disk space
2. 1100 blocks of permanent disk space
3. An additional 2400 blocks of permanent space if you wish to keep source on disk.
4. An additional 600 blocks of permanent space if you wish to keep all object files on disk. The object files needed to link routines to SIMAN are saved for you automatically.
5. 10 Global Sections and 322 Global Pages if you are going to install SIMAN. See below for more details.

The examples supplied and the command procedures used to run them use the logical name SYS\$SIMAN. You should make this system-wide logical name assignment for the directory containing the new files.

To find out how many global section are free on your system, do the following before the installation:

```
$ MCR INSTALL
INSTALL> /GLOBAL
```

If either of these parameters must be increased, you will have to modify them with SYSGEN and reboot the system before installing SIMAN. You may also use the command files INSTSIMAN.COM and REMSIMAN.COM in SYS\$SIMAN to install and remove the installed images.

Starting the Installation

Begin by logging into the system manager's account or an account with the same privileges and create a directory for the new version. Use the following as an example:

```
<cr>
Username: SYSTEM<cr>
Password: .....<cr>
$ SET UIC [1,4]
$ CREAT disk:[directory] Q341:[Siman]
$ ASSIGN/SYSTEM disk:[directory] SYSSSIMAN
$ SET DEFAULT SYSSSIMAN:~
```

Now allocate a tape drive and mount the distribution tape on it. Copy the installation procedure from tape and execute it:

```
$ ALLOCATE MTA0 SIMAN_TAPE
$ MOUNT SIMAN_TAPE SIMAN
$ COPY SIMAN_TAPE:SETUP.COM SYSSSIMAN:SETUP.COM
$ @SETUP
```

While the Procedure is Running

While the procedure is running, status reports are given at various points and several questions require the installer to provide information. If the logical names SYSSSIMAN and/or SIMANTAPE are not found, you will be prompted for them.

Once the files have been copied to disk, SIMAN is compiled and linked. Compilation of the source takes about seven minutes of CPU time. The command procedures, COMPSIMAN.COM and LINKSIMAN.COM can be used to compile and link future updates to SIMAN.

All SIMAN programs are linked as shareable images. If you wish, you may choose to have them installed. As noted above, this will use 10 global sections and 322 global pages.

A standard VAX/VMS help file is provided. It is recommended that you install this since example command procedures are documented here. The file provided is SIMAN.HLP. Due to VMS limitations, the system help file may not be accessible because another user is waiting at a prompt in VMSHELP. If this happens, you will be notified of the error and will be asked to install it at a later time. If you need to install the help file at a later time or have modified the file provided, do the following:

```
$ @SYSSSIMAN:HELP
```

Since this is the same procedure used by SETUP, the same information described above will be provided when the procedure succeeds or fails.

You will now be asked if a cleanup should be done. If you wish to leave all files on disk, type NO to the question. Since user-written routines must be linked to the SIMAN run processor, object files for this module will be left on disk no matter which way you answer the question. Answering YES will delete the SIMAN source files and all unused object files.

After Installation

The installation is now complete and you should add the line(s) printed on your terminal to the SYSTARTUP.COM file in SYSSMANAGER. SIMAN will not be accessible to users if this is not done..

APPENDIX E

Program Listings

```

      AGUCHSEQ.FOR
C*****
C      SUBROUTINE EVENT(LREQ,1)
C
C      THIS SUBROUTINE PROVIDES THE INTERFACE BETWEEN SIMAN
C      AND THE USER WRITTEN SUBROUTINES. PLEASE SEE INTRODUCTION
C      TO SIMAN BY C. DENNIS PEGDEN FOR FURTHER INFORMATION.
C
C      VARIABLES:
C      LREQ  -- REQUEST SELECTION RULE USED FOR THE RUN
C      LPOH  -- VEHICLE SELECTION RULE USED FOR THE RUN
C      NODE  -- NUMBER OF NODES IN THE SYSTEM (STATIONS, PARKING ZONES,
C      INTERSECTIONS
C      NPST  -- NUMBER OF STATIONS IN THE SYSTEM
C      NPZ  -- NUMBER OF PARKING ZONES
C      NPS  -- INDEX INTO THE PARAMETER ELEMENT
C*****
      LPOH=5
      LPRO=3
      NPST= 8
      NODE= 14
      NPZ= 1
      NPS= 40
      IF (1, EQ, 1) THEN
        CALL CHSEQ(LREQ,NODE,NPST)
      ELSE IF (1, EQ, 2) THEN
        CALL PICK_VEH(LREQ,NODE,LPOH,NPS)
      ELSE IF (1, EQ, 4) THEN
        CALL SET_AIA2(LREQ)
      ELSE IF (1, EQ, 5) THEN
        CALL CROSS_ENT(LREQ,NODE,LPRO)
      ELSE IF (1, EQ, 6) THEN
        CALL CROSS_ZON(LREQ,NPZ,NPST,NODE,1CHPZ)
      ENDIF
      RETURN
      END
C*****
C      SUBROUTINE CHSEQ(LREQ,NODE,NPST)
C
C      THIS SUBROUTINE DETERMINES THE SEQUENCE NUMBER FOR A VEHICLE TO GO
C      FROM ONE POINT TO ANOTHER.
C
C      VARIABLES
C      ATTRIB3 - ATTRIBUTE 3, STORES THE VEHICLE NUMBER ASSIGNED TO THE ENTITY
C      ATTRIB6 - ATTRIBUTE 6, STORES THE PART TYPE NUMBER FOR AN ASSEMBLY TASK
C      ATTRIB8 - ATTRIBUTE 8, DETERMINES WHAT TYPE OF TRIP THE VEHICLE IS
C      MAKING, 1 - PICKUP, 2 - DROPOFF, 4 - EXCHANGE
C      ATTRIB14 - ATTRIBUTE 14, DESIGNATES THAT VEHICLES ARE PERFORMING AN
C      ASSEMBLY TASK
C      ATTRIB16 - ATTRIBUTE 16, INTERMEDIATE DESTINATION IN AN ASSEMBLY TASK
C      RSEARCH - FILE RECORD NUMBER TO BEGIN SEARCHING FOR THE DESIRED PATH
C      DEST - FINAL STATION IN A SEQUENCE
C      ENSERCH - FILE RECORD NUMBER TO STOP SEARCHING FOR THE DESIRED PATH
C      NF - CURRENT DESTINATION OF THE VEHICLE
C      NI - CURRENT LOCATION OF THE VEHICLE
C
C      COMMON/SIM/D(150),UL(150),S(150),SI(150),X(150),OTIMU=INOW,
C      *TFIN,J,NRUN
C      INTEGER RSEARCH,ENSEARCH,DEST,FO,ATTRIB3,ATTRIB6,ATTRIB8,ATTRIB14
C      INTEGER ATTRIB16
C      LOGICAL AVAIL,NOTKN
C*****
C      INITIALIZE VARIABLES AND OPEN FILES SEQ.DAT, DEST.DAT, END.DAT
C

```

```

C*****
      ATTRIB8=A(LREQ,8)
      ATTRIB16=A(LREQ,16)
      ATTRIB14=A(LREQ,14)
      ATTRIB6=A(LREQ,6)
      ATTRIB3=A(LREQ,3)
      OPEN(UNIT=13,ACCESS='DIRECT',STATUS='OLD',FILE='SEQ.DAT')
      OPEN(UNIT=14,ACCESS='DIRECT',STATUS='OLD',FILE='DEST.DAT')
      OPEN(UNIT=15,ACCESS='DIRECT',STATUS='OLD',FILE='END.DAT')
C*****
C      IF AN ASSEMBLY TASK IS BEING PERFORMED, READ THE FINAL DESTINATION AND
C      DETERMINE IF THE NEXT STATION IS THE FINAL STATION. IF SO, SET
C      ATTRIBUTE 16 TO 0
C*****
      IF (ATTRIB14 .EQ. 1) THEN
        READ(15,REC=ATTRIB6) TO
        NI=A(LREQ,1)
        NF=ATTRIB16
        IF (ATTRIB16 .EQ. 10) THEN
          CALL SETA(LREQ,2,FLOATJ(ATTRIB16))
          CALL SETA(LREQ,16,0)
        ENDIF
C*****
C      ASSIGN THE INITIAL AND FINAL STATIONS OF THE PATH SEQUENCE THAT IS
C      NEEDED
C*****
      ELSE IF (ATTRIB8 .EQ. 1) THEN
        NI=X(ATTRIB312)
        NF=A(LREQ,1)
      ELSEIF (ATTRIB8 .EQ. 2) THEN
        NI=A(LREQ,1)
        NF=A(LREQ,2)
      ELSEIF (ATTRIB8 .EQ. 4) THEN
        NI=A(LREQ,1)
        NF=A(LREQ,2)
      ENDIF
C*****
C      READ FROM SEQ.DAT THE THE BEGINNING AND ENDING RECORD NUMBERS TO SEARCH
C      FOR THE CORRECT DESTINATION IN DEST.DAT
C*****
      READ(13,REC=NI) BSEARCH
      READ(13,REC=NI+1) ENSEARCH
      I=BSEARCH
      READ(14,REC=I) DEST
C*****
C      FIND THE CORRECT DESTINATION
C*****
      DO WHILE (DEST .NE. NF .AND. 1 .LT. ENSEARCH)
        I=I+1
        READ(14,REC=I) DEST,IP,NUM
      ENDDO
      NOTFN=.TRUE.
      ICUR=I
C*****
C      CHECK THE PATH TO SEE IF ITS BLOCKED. A PATH IS BLOCK IF
C      ANY STATION ALONG THE ROUTE IS AT FULL CAPACITY
C*****
      DO WHILE (DEST .EQ. NF .AND. 1 .LT. ENSEARCH .AND. NOTFN)

```



```

J=2
AVAIL=.TRUE.
DO WHILE (AVAIL .AND. J .LE. NUM-1)
  ITEMP=P(CIP,J)
  IF (ITEMP .LE. NPST) THEN
    ISTAT=P(ITEMP,1)
    IF (NR(ITEMP) .GE. 11ST .AND. (ITEMP .NE. NF) THEN
      AVAIL=.FALSE.
    ENDIF
  ELSE IF (ITEMP .LE. NODE .AND. ITEMP .GT. NPST) THEN
    IF (NR(ITEMP) .GE. 1) THEN
      AVAIL=.FALSE.
    ENDIF
  ENDIF
  MIGHT WANT TO CHECK TO SEE IF THERE ARE ANY BREAKDOWNS
  ON THE TRACK SEGMENT, OTHERWISE ASSUME TRACK IS REASONABLY
  CLEAR
  ENDDO
  J=J+1
ENDDO
IF (AVAIL) THEN
  NOTKN=.FALSE.
ELSE
  I=I+1
ENDIF
READ(14,REC=1)DEST,IP,NUM
ENDDO
C*****
C
C   IF ALL PATHS ARE BLOCKED, SELECT THE FIRST PATH WITH THE CORRECT
C   DESTINATION
C*****
C   IF (NOTKN) THEN
C     I=ICUR
C   ENDIF
C*****
C   CALL SIMAN SUBROUTINE SETNS TO SET THE SEQUENCE NUMBER THAT THE VEHICLE
C   IS TO FOLLOW
C*****
C   CALL SETNS(LREQ,I)
C   CLOSE(13)
C   CLOSE(14)
C   CLOSE(15)
C   RETURN
C   END
C*****
C*****
C
C   SUBROUTINE PICK_VEH(LREQ,NODE,LEPH,NPS)
C
C   THIS SUBROUTINE SELECTS A VEHICLE FOR A WAITING TASK GIVEN THAT
C   MORE THAN 1 VEHICLE IS AVAILABLE
C
C   VARIABLES
C   CAND(150) -- STORES THE VEHICLE NUMBERS OF AVAILABLE VEHICLES
C   ICH       -- IS ONE SELECTED VEHICLE NUMBER
C   IIS       -- INDEX INTO THE SEQUENCE THAT THE VEHICLE IS CURRENTLY
C               FOLLOWING
C   ISQ       -- THE SEQUENCE NUMBER THAT THE VEHICLE IS CURRENTLY FOLLOWING
C   ISTAT     -- THE SIMAN STATUS OF THE VEHICLE SELECTED
C   IV        -- RANDOM NUMBER BETWEEN 1 AND THE NUMBER OF AVAILABLE VEHICLES
C   K         -- COUNTS THE NUMBER OF AVAILABLE VEHICLES
C   LENT      -- THE RECORD LOCATION OF THE ENTITY CURRENTLY CONTROLLING THE
C               VEHICLE
C   LREQ      -- IS THE RECORD LOCATION OF THE REQUESTING ENTITY
C   MLENT     -- THE SIMAN STATION NUMBER OF THE LOCATION OF THE VEHICLE

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C      MLREQ - THE SIMAN STATION NUMBER OF THE LOCATION OF THE REQUEST
C
C*****
C      COMMON/SIM/D(150),DL(150),S(150),SL(150),X(150),DTNOW,TNOW,
      *TFIN,J,NRUN
      INTEGER CAND(150)
      K=0
C*****
C      DETERMINE HOW MANY VEHICLES ARE AVAILABLE.  STORE THE VEHICLE NUMBERS
C      OF AVAILABLE VEHICLE IN CAND
C*****
C      DO 10 I=1,X(1)
C      IJ=X(1)+I+2
C      IF (X(IJ).EQ. 0) THEN
C      K=K+1
C      CAND(K)=I
C      ENDDIF
10  CONTINUE
C*****
C      IF NO VEHICLES ARE AVAILABLE SET K TO 0
C*****
C      IF (K .EQ. 0) THEN
C      CALL SETN(MLREQ,0)
C*****
C      IF ONE VEHICLE IS AVAILABLE SELECT THAT VEHICLE
C*****
C      ELSE IF (K .EQ. 1) THEN
C      ICH=CAND(1)
C*****
C      IF MORE THAN ONE VEHICLE IS AVAILABLE, SELECT THE VEHICLE
C      ACCORDING TO THE RULE SPECIFIED BY THE USER
C*****
C      ELSEIF (LPUH .EQ. 1) THEN
C*****
C      PICK VEHICLE RANDOMLY
C      IV=IRK3RAC(10)
C      ICH=CAND(IV)
C      ELSEIF (LPUH .EQ. 2) THEN
C*****
C      PICK CLOSEST VEHICLE
C      CALL CLOSE_VEHICLE(REQ,K,CAND,NODE,NPS,LENT,ICH)
C      ELSEIF (LPUH .EQ. 3) THEN
C*****
C      PICK FARTHEST VEHICLE
C      CALL FARTH_VEHICLE(REQ,K,CAND,NODE,NPS,LENT,ICH)
C      ELSEIF (LPUH .EQ. 4) THEN
C*****
C      PICK VEHICLE THAT HAS BEEN IDLE THE LONGEST
C      CALL LONG_IDLE_VEH(K,CAND,ICH)
C      ELSEIF (LPUH .EQ. 5) THEN
C*****
C      PICK THE LEAST UTILIZED VEHICLE
C      CALL LEAST_UTIL_VEH(K,CAND,ICH)
C      ENDDIF
C*****
C

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```

C      IF A VEHICLE HAS BEEN SELECTED, DETERMINE ITS LOCATION AND
C      CURRENT ACTIVITY
C
C*****
C      IF (K.NE.0) THEN
C          ISAT=IT(1,ICH)
C*****
C      IF THE VEHICLE IS CURRENTLY TRAVELING TO A PARKING ZONE, INTERCEPT
C      THE VEHICLE AND SEND IT TO ITS NEW TASK
C
C*****
C      IF (ISAT.EQ.1) THEN
C          LENT=X(2*X(1)+2+ICH)
C          MLENT=M(LENT)
C          MLREQ=M(LREQ)
C          IF (MLREQ.EQ.100) THEN
C              CALL DISPOS(LENT)
C              IFLAG=-1
C              RICH=ICH
C              CALL SETA(LREQ,4,RICH)
C              CALL SETM(LREQ,-1)
C          ELSE
C              ISQ=NS(LENT)
C              ITS=IS(LENT)
C              IF (LOC(IST,MODE).EQ.1) THEN
C                  DES=P(ISO+MPS,ITS)
C                  IF (DES.EQ.100) THEN
C                      IIS=115+1
C                      DES=P(ISO+MPS,IIS)
C                  ENDIF
C                  CALL SETA(LENT,2,DES)
C                  J=X(1)+ICH+2
C                  X(J)=1
C                  IF (MLENT.NE.100.AND.MLENT.EQ.MLREQ) THEN
C                      CALL SETA(LENT,8,4,0)
C                  ELSE
C                      CALL SETA(LENT,8,3,0)
C                  ENDIF
C              ELSE
C                  ENTM=MLENT
C                  CALL SETA(LENT,1,ENTM)
C                  ALLREQ=A(LREQ,1)
C                  CALL SETA(LENT,2,ALLREQ)
C                  A3=A(LENT,3)
C                  J=X(1)+A3+2
C                  X(J)=1
C                  CALL SETA(LENT,8,3,0)
C              ENDIF
C          ENDIF
C          X(2*X(1)+2+ICH)=LREQ
C          IF (IFLAG.NE.-1) THEN
C              CALL SETM(LREQ,ICH)
C          ENDIF
C          RICH=ICH
C*****
C      STORE THE VEHICLE NUMBER IN ATTRIBUTE 3
C
C*****
C      CALL SETA(LREQ,3,RICH)
C      ENDTF
C      CLOSE(30)
C      IFLAG=0
C      RETURN
C      END

```

```

C *****
C
C      SUBROUTINE SET_LA1A2(LREQ)
C
C      THIS SUBROUTINE CHANGES THE CURRENT DESTINATION OF A VEHICLE
C      TO THE LOCATION OF A NEW REQUEST WHICH THE VEHICLE HAS JUST BEEN
C      ASSIGNED
C
C      VARIABLES
C      A2      - ATTRIBUTE 2, THE DESTINATION OF THE VEHICLE
C      A3      - ATTRIBUTE 3, THE VEHICLE NUMBER
C      LENT    - THE RECORD LOCATION OF THE REQUESTING ENTITY
C *****
C      COMMON/SIM/D(150),DL(150),S(150),SL(150),X(150),DTNOW,TNOW,
C      *TFIN,J,NRUN
C      A3=A(LREQ,3)
C      IJ=3*X(1)+A3+2
C      LENT=X(IJ)
C      A2=A(LENT,1)
C      CALL SETA(LREQ,2,A2)
C      RETURN
C      END
C *****
C
C      SUBROUTINE CHOOSE_ENT(LENT,NRQ,LREQ)
C
C      THIS SUBROUTINE SELECTS A REQUEST FROM AMONG SEVERAL WAITING REQUEST
C      TO ASSIGN AN AVAILABLE VEHICLE
C
C      VARIABLES
C      A3      - THE NUMBER OF THE VEHICLE THAT IS AVAILABLE
C      ICHR    - THE RANK IN THE QUEUE OF THE SELECTED REQUEST
C      IENT    - THE RECORD LOCATION OF THE SELECTED ENTITY
C      ITER    - THE NUMBER OF REQUESTS WAITING FOR A VEHICLE
C      LENT    - THE ENTITY THE CURRENTLY CONTROLS THE VEHICLE
C      MLENT   - LOCATION OF THE VEHICLE
C *****
C      COMMON/SIM/D(150),DL(150),S(150),SL(150),X(150),DTNOW,TNOW,
C      *TFIN,J,NRUN
C      OPEN(38,STATUS='OLD',FILE='DIS1.DAT',ACCESS='DIRECT')
C      IJ=3*X(1)+2
C      IN=(IJ)*X(1)
C *****
C
C      INITIALIZE VARIABLES
C *****
C      ISHDIST=799999
C      MENT=M(LENT)
C      A3=A(LENT,3)
C      IAS=A3
C      ITER=NO(1)
C      LREQ=LREQ(1)
C *****
C
C      IF THERE IS ONLY ONE REQUEST WAITING FOR A VEHICLE, SELECT THAT
C      REQUEST
C *****
C      IF (NR(1),EQ, 1) THEN
C          ICHR=1
C          IENT=LREQ
C *****
C

```

```

C      OTHERWISE SELECT THAT REQUEST BY THE USER SPECIFIED RULE
C
C*****
C*****
C      SELECT THE REQUEST RANDOMLY
C      ELSEIF (LPRQ .EQ. 1) THEN
C        ICHR=LEITER*RA(10)
C        IF (ICHR .EQ. 1) THEN
C          IENT=LREQ
C        ELSE
C          DO 10 I=1,ICHR-1
C            LREQ=LSUCC(LREQ)
C10      CONTINUE
C          IENT=LREQ
C        ENDIF
C*****
C      SELECT THE REQUESTS ON A FIRST COME FIRST SERVE BASIS
C      ELSEIF (LPRQ .EQ. 2) THEN
C        ICHR=1
C        IENT=LREQ
C*****
C      SELECT THE CLOSEST REQUEST
C      ELSEIF (LPRQ .EQ. 3) THEN
C        CALL CLOSE_REQ(MENT,LREQ,ITER,ICHR,IENT)
C*****
C      SELECT THE FARTHEST REQUEST
C      ELSEIF (LPRQ .EQ. 4) THEN
C        CALL FARTH_REQ(MENT,LREQ,ITER,ICHR,IENT)
C      ENDIF
C      RICHR=ICHR
C      X(2*X(1)+3+2)=IENT
C*****
C
C      STORE THE RANK OF THE SELECTED REQUEST IN ATTRIBUTE 22
C
C*****
C      CALL SETA(IENT,22,RICHR)
C      CALL SETA(IENT,3,A3)
C      CALL SETM(IENT,A3)
C      CLOSE(38)
C      RETURN
C      END
C*****
C*****
C      SUBROUTINE CHOOSE_ZONE(LENT,NPZ,NPDST,NODE,I(HPZ))
C
C      THIS SUBROUTINE SELECTS WHICH PARKING ZONE TO SEND AN EMPTY VEHICLE
C
C      VARIABLES
C      CAND(150) - STORES THE PARKING ZONE NUMBERS OF AVAILABLE PARKING ZONES
C      ICH      - PARKING ZONE SELECTED
C      K        - COUNTS THE NUMBER OF PARKING ZONES WITH SUFFICIENT CAPACITY
C      LENT     - RECORD LOCATION OF THE ENTITY CONTROLLING THE VEHICLE
C      MENT     - CURRENT LOCATION OF THE VEHICLE
C      NPZ      - NUMBER OF PARKING ZONES
C*****
C      COMMON/SIN/D(150),DL(150),S(150),SL(150),X(150),BTNUM,INOW,
C      *TFIN,J,NRUN
C      INTEGER CAND(150)
C      MENT=M(LENT)
C*****
C
C      IF THERE ARE NO PARKING ZONES IN THE SYSTEM SET ICH TO 0
C
C*****
C      IF (NPZ .EQ. 0) THEN

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      ICH=0
C*****
C
C      IF THERE IS ONE PARKING ZONE IN THE SYSTEM THEN SELECT IT
C
C*****
      ELSEIF (NPZ .EQ. 1) THEN
          ICH=NPDIST+1
          ELSE
              K=0
C*****
C
C      DETERMINE WHICH PARKING ZONES ARE NOT FULL
C
C*****
      DO 10 I=NPDIST+1,NPZ
          IF (MR(I)-NR(I) .GT. 0) THEN
              K=K+1
              CAND(K)=I
          ENDIF
10      CONTINUE
          IF (K .EQ. 0) THEN
              ICH=0
C*****
C
C      IF ONE PARKING ZONE IS AVAILABLE, SELECT IT
C
C*****
          ELSEIF (K .EQ. 1) THEN
              ICH=CAND(1)
C*****
C      SELECT THE PARKING ZONE RANDOMLY
C
          ELSEIF (ICHPZ .EQ. 1) THEN
              IV=1+K*RA(10)
              ICH=CAND(IV)
C*****
C      SELECT THE CLOSEST ZONE
C
          ELSEIF (ICHPZ .EQ. 2) THEN
              CALL CLOSE_ZON(MENT,K,NODE,ICH,CAND)
C*****
C      SELECT THE FARTHEST ZONE
C
          ELSEIF (ICHPZ .EQ. 3) THEN
              CALL FARTH_ZON(MENT,K,NODE,ICH,CAND)
C*****
C      SELECT THE ZONE WITH THE LARGEST REMAINING CAPACITY
C
          ELSEIF (ICHPZ .EQ. 4) THEN
              CALL REM_CAP(K,CAND)
C*****
C      SELECT THE ZONE WITH THE LARGEST CAPACITY
C
          ELSEIF (ICHPZ .EQ. 5) THEN
              CALL TOT_CAP(K,CAND)
          ENDIF
      ENDIF
      RICH=ICH
C*****
C
C      SET ATTRIBUTE 2 TO THE SELECTED PARKING ZONE NUMBER
C
C*****
      CALL SETA(LENT,2,RICH)
      RETURN
      END

```

```

C*****
C
      SUBROUTINE CLOSE.VEH(REQ,K,CAND,NODE,NPS,LENT,ICH)
C
C      THIS SUBROUTINE DETERMINES THE CLOSEST AVAILABLE VEHICLE TO A REQUEST
C
C      VARIABLES
C      IIS      - INDEX INTO THE SEQUENCE THAT THE VEHICLE IS FOLLOWING
C      IRCL     - RECORD NUMBER INTO FILE DIST.DAT THAT CORRESPONDS TO THE
C                DISTANCE MATRIX BETWEEN THE LOCATION OF THE VEHICLE AND
C                THE REQUESTING ENTITY
C      ISQ      - SEQUENCE NUMBER THAT THE VEHICLE IS FOLLOWING
C      LENT     - RECORD LOCATION OF THE ENTITY CONTROLLING A VEHICLE
C      LOC      - LOCATION OF THE VEHICLE
C*****
C      COMMON/SIN/D(150),DL(150),S(150),SL(150),X(150),ATNOW,ENOW,
C      *TFIN,J,NRUN
C      INTEGER CAND(150)
C      OPEN(38,ACCESS='DIRECT',STATUS='OLD',FILE='DIST.DAT')
C      ISHDIST=999999
C      A1=A(REQ,1)
C*****
C      LOOK AT EACH AVAILABLE VEHICLE TO DETERMINE IF IT IS THE CLOSEST
C      DO 20 I=1,K
C        ITMP=CAND(I)
C        LOC=LT(I,ITMP)
C*****
C        IF THE VEHICLE IS NOT CURRENTLY LOCATED AT A NODE THEN INDEX I INTO
C        ITS SEQUENCE AND USE THAT DISTANCE
C*****
C        IF (LOC.GT. NODE) THEN
C          LENT=X(2*X(1)+2+ITMP)
C          ISQ=NS(LENT)
C          IIS=IS(LENT)
C          LOC=P(ISQ,NPS,IIS)
C          IF (LOC.GT. NODE) THEN
C            LOC=P(ISQ,NPS,IIS+1)
C          ENDTF
C        ENDTF
C*****
C        READ FROM DIST.DAT, THE DISTANCE MATRIX, THE DISTANCE BETWEEN THE
C        VEHICLE UNDER EXAMINATION AND THE REQUESTING ENTITY
C*****
C        IRCL=(LOC-1)*NODE+A1
C        READ(38,REC=IRCL)IDIST
C*****
C        COMPARE THE DISTANCE WITH THE SHORTEST DISTANCE EXAMINED SO FAR
C*****
C        IF (IDIST.LT. ISHDIST) THEN
C          ISHDIST=IDIST
C          ICH=CAND(I)
C        ENDTF
C      20 CONTINUE
C      RETURN
C      END
C*****
C
      SUBROUTINE FARTH.VEH(REQ,K,CAND,NODE,NPS,LENT,ICH)
C
C      THIS SUBROUTINE DETERMINES THE FARTHEST AVAILABLE VEHICLE TO A REQUEST
C
C      VARIABLES
C      IIS      - INDEX INTO THE SEQUENCE THAT THE VEHICLE IS FOLLOWING
C      IRCL     - RECORD NUMBER INTO FILE DIST.DAT THAT CORRESPONDS TO THE
C                DISTANCE MATRIX BETWEEN THE LOCATION OF THE VEHICLE AND

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C          THE REQUESTING ENTITY
C          ISO - SEQUENCE NUMBER THAT THE VEHICLE IS FOLLOWING
C          LENT - RECORD LOCATION OF THE ENTITY CONTROLLING A VEHICLE
C          LOC - LOCATION OF THE VEHICLE
C*****
C      COMMON/SIN/D(150),DL(150),S(150),SL(150),X(150),DTNOW,TNOW,
C      *TFIN,J,NRUN
C      INTEGER CAND(150)
C      OPEN(38,ACCESS='DIRECT',STATUS='OLD',FILE='DIST.DAT')
C      IDISTLNG=-999999
C      A1=A(LREQ,1)
C*****
C      DETERMINE THE LOCATION OF EACH AVAILABLE VEHICLE
C*****
C      DO 30 I=1,K
C          ITMP=CAND(I)
C          LOC=LT(1,ITMP)
C*****
C      IF THE VEHICLE IS NOT CURRENTLY LOCATED AT A NODE THEN
C      INDEX ONE INTO THE SEQUENCE IT IS FOLLOWING AND USE THIS FOR
C      A DISTANCE
C*****
C          IF (LOC.GT. NODE) THEN
C              LENT=X(2*X(1)+2:ITMP)
C              ISO=NS(LENT)
C              ITS=IS(LENT)
C              LOC=P(ISO+NS,115)
C              IF (LOC.GT. NODE) THEN
C                  LOC=P(ISO+NS,115+1)
C              ENDIF
C          ENDIF
C*****
C      READ FROM DIST.DAT, THE DISTANCE MATRIX, THE DISTANCE BETWEEN THE
C      VEHICLE AND THE REQUESTING ENTITY
C*****
C          IRCL=(LOC-1)*NODE+A1
C          READ(38,REC=IRCL)IDIST
C*****
C      COMPARE THE LONGEST DISTANCE SO FAR WITH THE DISTANCE OF THIS VEHICLE
C*****
C          IF (IDIST.GT. IDISTLNG) THEN
C              IDISTLNG=IDIST
C              ICH=CAND(I)
C          ENDIF
30      CONTINUE
      RETURN
      END

C*****
C      SUBROUTINE LONG.IDL_VEH(K,CAND,ICH)
C
C      THIS SUBROUTINE DETERMINES WHICH OF THE AVAILABLE VEHICLES HAS BEEN
C      IDLE THE LONGEST SINCE ITS LAST TASK
C*****
C      COMMON/SIN/D(150),DL(150),S(150),SL(150),X(150),DTNOW,TNOW,
C      *TFIN,J,NRUN
C      INTEGER CAND(150)
C      TIMLNG=-99999.99
C      DO 40 I=1,K
C          IJ=2*X(1)+CAND(I)+2
C          ITMP=TNOW-X(IJ)
C          IF (ITMP.GT. TIMLNG) THEN
C              TIMLNG=ITMP
C              ICH=CAND(I)
C          ENDIF
C      40 CONTINUE

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40      CONTINUE
      RETURN
      END

C*****
C
C      SUBROUTINE LEAST_UTIL_VEH(K,CAND,ICH)
C
C      THIS SUBROUTINE DETERMINES WHICH VEHICLE AMONG AVAILABLE VEHICLES
C      IS LEAST UTILIZED
C*****
COMMON/SIM/D(150),DL(150),S(150),SL(150),X(150),DTNOW,TNOW,
      *TFIN,J,NRUN
      INTEGER CAND(150)
      TIMING=999999.99
      DO 50 I=1,K
          IJ=4*X(I)+CAND(I)+2
          IF (X(IJ).GT. TIMING) THEN
              TIMING=X(IJ)
              ICH=CAND(I)
          ENDIF
50      CONTINUE
      RETURN
      END

C*****
C
C      SUBROUTINE CLOSE_REQ(MENT,LREQ,IER,ICHR,IENT)
C
C      THIS SUBROUTINE DETERMINES WHICH REQUEST AMONG ALL WAITING REQUESTS
C      IS CLOSEST TO THE AVAILABLE VEHICLE
C
C      VARIABLES
C      ICHR -- RANK IN THE QUEUE OF THE SELECTED ENTITY
C      IENT -- SELECTED REQUEST
C      IRCL -- RECORD NUMBER INTO DISTANCE MATRIX
C*****
COMMON/SIM/D(150),DL(150),S(150),SL(150),X(150),DTNOW,TNOW,
      *TFIN,J,NRUN
      INTEGER CAND(150)
C*****
C      EXAMINE THE FIRST ENTITY IN THE QUEUE AND DETERMINE THE DISTANCE
C      FROM THE VEHICLE
C*****
      LAIREQ=A(LREQ,1)
      IROW=(MENT-1)*NODE
      IRCL=IROW+LAIREQ
      READ(38,REC=IRCL) IDIST
      ISHDIST=IDIST
      ICHR=1
      IENT=LREQ
C*****
C      EXAMINE ALL SUCCEEDING ENTITIES IN THE QUEUE AND COMPARE THE DISTANCES
C      TO DETERMINE THE SHORTEST DISTANCE
C*****
      DO 10 I=1,ITER-1
          LREQ=LSUCC(LREQ)
          LAIREQ=A(LREQ,1)
          IRCL=IROW+LAIREQ
          READ(38,REC=IRCL) IDIST
          IF (IDIST.LE. ISHDIST) THEN
              ISHDIST=IDIST
              ICHR=I+1
              IENT=LREQ
          ENDIF
10      CONTINUE

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      RETURN
      END

C*****
C      SUBROUTINE FARTHERQ(MENT,LREQ,ITER,ICHR,IENT)
C
C      THIS SUBROUTINE DETERMINES THE FARTHEST REQUEST FROM AN AVAILABLE
C      VEHICLE
C
C      VARIABLES
C      ICHR  -- RANK IN THE QUEUE OF THE SELECTED ENTITY
C      IENT  -- SELECTED REQUEST
C      IRCL  -- RECORD NUMBER INTO DISTANCE MATRIX
C*****
C      COMMON/SIM/D(150),DL(150),S(150),SL(150),X(150),DTNOW,INOW,
C      *TFIN,J,NRUN
C      INTEGER CAND(150)
C      LAIREQ=A(LREQ,1)
C*****
C      EXAMINE THE FIRST ENTITY IN THE QUEUE AND DETERMINE THE DISTANCE
C      FROM THE VEHICLE
C*****
C      IROW=(MENT-1)*NODE
C      IRCL=IROW+LAIREQ
C      READ(38,REC=IRCL) IDIST
C      ILNGDIST=IDIST
C      ICHR=1
C      IENT=LREQ
C*****
C      EXAMINE ALL SUCCEEDING ENTITIES IN THE QUEUE AND COMPARE THE DISTANCES
C      TO DETERMINE THE FARTHEST DISTANCE
C*****
C      DO 10 I=1,ITER-1
C         LREQ=LSUCC(LREQ)
C         LAIREQ=A(LREQ,1)
C         IRCL=IROW+LAIREQ
C         READ(38,REC=IRCL) IDIST
C         IF (IDIST.GT.ILNGDIST) THEN
C            ILNGDIST=IDIST
C            ICHR=I+1
C            IENT=LREQ
C         ENDIF
C      10  CONTINUE
C      RETURN
C      END

C*****
C      SUBROUTINE CLOSE_ZON(MENT,K,NODE,ICH,CAND)
C
C      THIS SUBROUTINE DETERMINES THE CLOSEST PARKING ZONE TO AN EMPTY
C      VEHICLE
C
C      VARIABLES
C      ICH  -- THE NUMBER OF THE SELECTED PARKING ZONE
C      IDIST -- DISTANCE BETWEEN A PARKING ZONE AND THE EMPTY VEHICLE
C      IRCL  -- RECORD NUMBER OF DISTANCE FROM DISTANCE MATRIX
C*****
C      INTEGER CAND(150)
C      OPEN(38,ACCESS='DIRECT',STATUS='OLD',FILE='DIST.DAT')
C      ISHDIST=999999
C      DO 10 I=1,K
C         IIMP=CAND(I)
C         IRCL=(MENT-1)*NODE+IIMP
C         READ(38,REC=IRCL) IDIST

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        IF (IDIST .LT. JSHDIST) THEN
            JSHDIST=IDIST
            ICH=CAND(I)
        ENDIF
10    CONTINUE
    RETURN
END

SUBROUTINE FARTH.ZON(MENT,K,NODE,ICH,CAND)
C*****
C    THIS SUBROUTINE DETERMINES THE FARTHEST PARKING ZONE FROM AN EMPTY
C    VEHICLE
C    VARIABLES
C    ICH - THE NUMBER OF THE SELECTED PARKING ZONE
C    IDIST - DISTANCE BETWEEN A PARKING ZONE AND THE EMPTY VEHICLE
C    IRCL - RECORD NUMBER OF DISTANCE FROM DISTANCE MATRIX
C*****
    INTEGER CAND(150)
    OPEN(38,ACCESS='DIRECT',STATUS='OLD',FILE='DIST.DAT')
    LNGDIST=-999999
    DO 10 I=1,K
        ITMP=CAND(I)
        IRCL=(MENT-1)*NODE+ITMP
        READ(38,REC=IRCL)IDIST
        IF (IDIST .GT. LNGDIST) THEN
            LNGDIST=IDIST
            ICH=CAND(I)
        ENDIF
10    CONTINUE
    RETURN
END

C*****
C    SUBROUTINE REM.CAP(K,CAND)
C    THIS SUBROUTINE DETERMINES THE PARKING ZONE WITH THE LARGEST
C    AVAILABLE CAPACITY
C    VARIABLES
C    ICH - THE NUMBER OF THE PARKING ZONE SELECTED
C    IMOST - THE MAXIMUM CAPACITY OF ALL PARKING ZONES EXAMINED SO FAR
C    IREM - THE REMAINING CAPACITY OF A PARKING ZONE
C*****
    INTEGER CAND
    IMOST=-999999
    DO 10 I=1,K
        ITMP=CAND(I)
        IREM=NR(ITMP)-NR(ITMP)
        IF (IREM .GT. IMOST) THEN
            IMOST=IREM
            ICH=CAND(I)
        ENDIF
10    CONTINUE
    END

C*****
C    SUBROUTINE TOT.CAP(K,CAND)
C    THIS SUBROUTINE DETERMINES THE PARKING ZONE WITH THE LARGEST
C    CAPACITY, FILLED OR UNFILLED
C    VARIABLES

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C      ICH -- THE SELECT PARKING ZONE NUMBER
C      IMOST-- THE MAXIMUM TOTAL CAPACITY OF ALL PARKING ZONES EXAMINED
C      SO FAR
C      ITOT -- THE TOTAL CAPACITY OF A PARKING ZONE
C*****
C      INTEGER CAND(150)
C      IMOST=-999999
C      DO 10 I=1,K
C         ITMP=CAND(I)
C         ITOT=MR(ITMP)
C         IF (ITOT .GT. IMOST) THEN
C            IMOST=ITOT
C            ICH=CAND(I)
C         ENDIF
10    CONTINUE
      RETURN
      END

```

```

      AGZDIS1, FOR
C*****
C      FUNCTION CHRDIS1()
C
C      THIS FUNCTION ASKS THE USER TO SELECT A DISTRIBUTION AND
C      DEFINES A VARIABLE WHICH CONTAINS THE SIMAN DISTRIBUTION
C      TYPE.
C
C      VARIABLES
C      CHDIST - SIMAN SPECIFICATION OF DISTRIBUTION SELECTED,
C              CHARACTER VARIABLE
C      NI      - NUMBER OF DISTRIBUTION SELECTED
C*****
C      CHARACTER CHDIST*2
C*****
C      ASK THE USER TO SELECT A DISTRIBUTION
C*****
      COMMON/BLKG/LU,LUM,IF
      WRITE(LUM,*) ' 1 - Constant'
      WRITE(LUM,*) ' 2 - Uniform Distribution'
      WRITE(LUM,*) ' 3 - Triangular Distribution'
      WRITE(LUM,*) ' 4 - Exponential Distribution'
      WRITE(LUM,*) ' 5 - Erlang Distribution'
      WRITE(LUM,*) ' 6 - Normal Distribution'
      WRITE(LUM,*) ' 7 - Lognormal Distribution'
      WRITE(LUM,*) ' 8 - Gamma Distribution'
      WRITE(LUM,*) ' 9 - Beta Distribution'
      WRITE(LUM,*) '10 - Weibull Distribution'
      WRITE(LUM,*) '11 - User Defined Discrete Distribution'
      WRITE(LUM,*)
28      WRITE(LUM,*) 'Please enter the appropriate number.'
      READ(LU,*,IOSTAT=IOERR) NI
      IF (IOERR .NE. 0) CALL BOOBOO(IOERR,*00)
C*****
C      TRANSLATE THE DISTRIBUTION TYPE TO THE SIMAN SPECIFICATION
C*****
      IF (NI .EQ. 1) THEN
        CHDIST='CO'
      ELSE IF (NI .EQ. 2) THEN
        CHDIST='UN'
      ELSE IF (NI .EQ. 3) THEN
        CHDIST='TR'
      ELSE IF (NI .EQ. 4) THEN
        CHDIST='EX'
      ELSE IF (NI .EQ. 5) THEN
        CHDIST='ER'
      ELSE IF (NI .EQ. 6) THEN
        CHDIST='RN'
      ELSE IF (NI .EQ. 7) THEN
        CHDIST='RL'
      ELSE IF (NI .EQ. 8) THEN
        CHDIST='GA'
      ELSE IF (NI .EQ. 9) THEN
        CHDIST='BE'
      ELSE IF (NI .EQ. 10) THEN
        CHDIST='WE'
      ELSE IF (NI .EQ. 11) THEN
        CHDIST='DP'
      ELSE
        WRITE(LU,*) 'YOUR SELECTION MUST BE
        * BETWEEN 1 AND 11. PLEASE ENTER AGAIN.'
        GO TO 28
      ENDIF

```

```

      RETURN
      END
C*****
C
      SUBROUTINE PARA(DISTYP,NPDST)
C
C      THIS SUBROUTINE ASKS THE USER TO ENTER THE APPROPRIATE
C      PARAMETERS FOR THE DISTRIBUTION SPECIFIED IN FUNCTION CHDIST
C
C      VARIABLES
C      DISTYP - SINAN SPECIFICATION OF DISTRIBUTION TYPE,
C              CHARACTER VARIABLE
C      I      - COUNTER FOR EACH STATION NUMBER
C      IP     - INDEX INTO PARAMETER ELEMENT
C      P1     - FIRST PARAMETER OF THE DISTRIBUTION
C      P2     - SECOND PARAMETER OF THE DISTRIBUTION
C      P3     - THIRD PARAMETER OF THE DISTRIBUTION
C*****
      COMMON/BLK8/LU,LUM,IP
      CHARACTER DISTYP*2
      LOGICAL EQUAL1
C*****
C      CLEAR THE SCREEN
C*****
      IESC=27
      WRITE(LUM,4000) IESC,IESC
4000  FORMAT(IX,A,'1030H',A,'12J')
      IF (DISTYP.EQ. 'CO') THEN
         WRITE(LUM,*) 'Please enter the constant load/unload times for'
         WRITE(LUM,*) 'each station.'
         WRITE(LUM,*)
C*****
C      ENTER THE CONSTANT TIME BETWEEN ARRIVALS FOR EACH STATION
C*****
         DO 100 I=1,NPDST
            WRITE(LUM,1000) I
1000   FORMAT('I', 'Station', I5, ':')
            READ(LU,*,IOSTAT=IOERR) P1
            IF (IOERR.NE. 0) CALL R00B00(IOERR,29)
            WRITE(3,2000) IP,P1
1000   FORMAT(I6,' ',F10.3,' ')
            IP=IP+1
100    CONTINUE
         ELSE IF (DISTYP.EQ. 'UN') THEN
C*****
C      ENTER THE MINIMUM AND MAXIMUM OF THE UNIFORM DISTRIBUTION
C      FOR EACH STATION
C*****
            WRITE(LUM,*) 'Please enter the parameters of the UNIFORM'
            WRITE(LUM,*) 'distribution for load/unload time at each'
            * station.
            DO 110 I=1,NPDST
               WRITE(LUM,*)
               WRITE(LUM,1000) I
30      WRITE(LUM,2010)
2010   FORMAT('I', ' Minimum: ')
               READ(LU,*,IOSTAT=IOERR) P1
               IF (IOERR.NE. 0) CALL R00B00(IOERR,30)
31      WRITE(LUM,2015)
2015   FORMAT('I', ' Maximum: ')
               READ(LU,*,IOSTAT=IOERR) P2
               IF (IOERR.NE. 0) CALL R00B00(IOERR,31)
               WRITE(3,2020) IP,P1,P2
2020   FORMAT(I6,2(' ',F10.3),' ')
               IP=IP+1
110    CONTINUE
            ELSE IF (DISTYP.EQ. 'EX') THEN

```

```

        WRITE(LUN,*) 'Please enter the mean of the EXPONENTIAL'
        WRITE(LUN,*) 'distribution for load/unload time at each
          * station.'
C*****
C      ENTER THE MEAN OF THE EXPONENTIAL DISTRIBUTION FOR EACH STATION
C*****
      DO 120 I=1,NPDST
32        WRITE(LUN,1000)I
          WRITE(LUN,1020)
1020        FORMAT(' ', 'Mean: ')
          READ(LU,*,IOSTAT=IOERR)P1
          IF (IOERR.NE. 0) CALL B00B00(IOERR,32)
          WRITE(3,9000)IP,P1
          IP=IP+1
120        CONTINUE
          ELSE IF (DISTYP.EQ. 'RN') THEN
            WRITE(LUN,*) 'Please enter the mean and std. dev. for'
            WRITE(LUN,*) 'the NORMAL distribution for the load/unload'
            WRITE(LUN,*) 'at each station.'
C*****
C      ENTER THE MEAN AND STANDARD DEVIATION OF THE NORMAL DISTRIBUTION
C      FOR EACH STATION
C*****
      DO 130 I=1,NPDST
33        WRITE(LUN,1000)I
          WRITE(LUN,9030)
9030        FORMAT(' ', 'Mean: ')
          READ(LU,*,IOSTAT=IOERR)P1
          IF (IOERR.NE. 0) CALL B00B00(IOERR,33)
34        WRITE(LUN,9035)
          FORMAT(' ', 'Std. Dev.: ')
9035        READ(LU,*,IOSTAT=IOERR)P2
          IF (IOERR.NE. 0) CALL B00B00(IOERR,34)
          WRITE(3,9020) IP,P1,P2
          IP=IP+1
130        CONTINUE
          ELSE IF (DISTYP.EQ. 'DP') THEN
            I=1
C*****
C      ENTER THE PARAMETERS FOR THE DISCRETE DISTRIBUTION FOR EACH
C      STATION
C*****
      DO 140 WHILE (I.LE. NPDST)
        WRITE(LUN,*) 'Please enter the DISCRETE distribution
          *for station',I6
        WRITE(3,2001) IP
        FORMAT(I6,' ')
2001        SUM1=0
        DO WHILE (SUM1.LT. 1.0)
35          WRITE(LUN,1030)
1030          FORMAT('Enter a possible value: ')
          READ(LU,*,IOSTAT=IOERR) P2
          IF (IOERR.NE. 0) CALL B00B00(IOERR,*35)
36          WRITE(LUN,2005) P2
2005          FORMAT(' ', 'What is the PROB(1/5,1-1)? ')
          READ(LU,*,IOSTAT=IOERR) P1
          IF (IOERR.NE. 0) CALL B00B00(IOERR,*36)
          SUM1=SUM1+P1
          IF (SUM1.LE. 1.0) THEN
            IF (SUM1.LT. 1) THEN
2010              WRITE(3,2010) SUM1,P2
                FORMAT(7X,F4.3,' ',F10.2,' ')
            ELSE
2015              WRITE(3,2015) SUM1,P2
                FORMAT(7X,F5.3,' ',F10.2,' ')
            ENDIF
          ENDIF
        ENDIF
      ENDDO

```

```

IF (SUM1 .GT. 1) THEN
  WRITE(6,*) 'PROBABILITIES SUM TO GREATER THAN 1.0'
  WRITE(6,*) 'PLEASE ENTER FOR STATION', I, ' AGAIN'
ELSE
  I=I+1
  IP=IP+1
ENDIF
CONTINUE
ELSEIF (DISTYP .EQ. 'IR') THEN
  WRITE(LUW,*) 'Please enter the parameters for the
    * TRIANGULAR distribution.'
C*****
C      ENTER THE MINIMUM, MODE AND MAXIMUM OF THE TRIANGULAR
C      DISTRIBUTION FOR EACH STATION
C*****
DO 150 I=1,NPDST
  WRITE(LUW,1000) I
  WRITE(LUW,9010)
  READ(LU,*,IOSTAT=IOERR) P1
  IF (IOERR .NE. 0) CALL BOOEROO(IOERR,*37)
  WRITE(LUW,9012)
  FORMAT(' ', ' Mode: ')
  READ(LU,*,IOSTAT=IOERR) P2
  IF (IOERR .NE. 0) CALL BOOEROO(IOERR,*40)
  WRITE(LUW,9015)
  READ(LU,*,IOSTAT=IOERR) P3
  IF (IOERR .NE. 0) CALL BOOEROO(IOERR,*39)
  WRITE(3,9040) IP,P1,P2,P3
  FORMAT(16,3(' ',F10.3),':')
  IP=IP+1
150 CONTINUE
ELSEIF (DISTYP .EQ. 'ER') THEN
  WRITE(LUW,*) 'Please enter the parameters for the
    * ERLANG DISTRIBUTION'
C*****
C      ENTER THE MEAN AND K OF THE ERLANG DISTRIBUTION FOR EACH
C      STATION
C*****
DO 160 I=1,NPDST
  WRITE(LUW,1000) I
  WRITE(LUW,9030)
  READ(LU,*,IOSTAT=IOERR) P1
  IF (IOERR .NE. 0) CALL BOOEROO(IOERR,*40)
  WRITE(LUW,9045)
  FORMAT(' ', ' K: ')
  READ(LU,*,IOSTAT=IOERR) P2
  IF (IOERR .NE. 0) CALL BOOEROO(IOERR,*41)
  WRITE(3,9020) IP,P1,P2
  IP=IP+1
160 CONTINUE
ELSEIF (DISTYP .EQ. 'NL') THEN
  WRITE(LUW,*) 'Please enter the parameters for the
    * LOGNORMAL distribution'
C*****
C      ENTER THE MEAN AND STANDARD DEVIATION OF THE LOGNORMAL DISTRIBUTION FOR
C      EACH STATION
C*****
DO 170 I=1,NPDST
  WRITE(LUW,1000) I
  WRITE(LUW,9030)
  READ(LU,*,IOSTAT=IOERR) P1
  IF (IOERR .NE. 0) CALL BOOEROO(IOERR,*42)
  WRITE(9035)
  READ(LU,*,IOSTAT=IOERR) P2
  IF (IOERR .NE. 0) CALL BOOEROO(IOERR,*43)
  WRITE(3,9020) IP,P1,P2
  IP=IP+1
170 CONTINUE

```



```

      ELSEIF (DISTYP .EQ. 'GA') THEN
        WRITE(LUN,*) 'Please enter the parameters
          * for the GAMMA distribution'
C*****
C      ENTER ALPHA AND BETA OF THE GAMMA DISTRIBUTION FOR EACH STATION
C*****
      DO 180 I=1,NPDST
        WRITE(LUN,1000)I
        WRITE(LUN,9055)
        FORMAT(' ',/ Alpha: ')
        READ(LU,*,IOSTAT=IOERR)P1
        IF (IOERR .NE. 0) CALL BOOR00(IOERR,*44)
        WRITE(LUN,9060)
        FORMAT(' ',/ Beta: ')
        READ(LU,*,IOSTAT=IOERR)P2
        IF (IOERR .NE. 0) CALL BOOR00(IOERR,*45)
        WRITE(3,9020)I,P1,P2
        IP=IP+1
180      CONTINUE
      ELSEIF (DISTYP .EQ. 'BE') THEN
        WRITE(LUN,*) 'Please enter the parameters
          * for the BETA Distribution'
C*****
C      ENTER THETA AND PHI OF THE BETA DISTRIBUTION FOR EACH STATION
C*****
      DO 190 I=1,NPDST
        WRITE(LUN,1000)I
        WRITE(LUN,9065)
        FORMAT(' ',/ Theta: ')
        READ(LU,*,IOSTAT=IOERR)P1
        IF (IOERR .NE. 0) CALL BOOR00(IOERR,*46)
        WRITE(LUN,9070)
        FORMAT(' ',/ Phi: ')
        READ(LU,*,IOSTAT=IOERR)P2
        IF (IOERR .NE. 0) CALL BOOR00(IOERR,*47)
        WRITE(3,9020)I,P1,P2
        IP=IP+1
190      CONTINUE
      ELSEIF (DISTYP .EQ. 'WE') THEN
        WRITE(LUN,*) 'Please enter the parameters
          * for the WEIBULL distribution.'
C*****
C      ENTER ALPHA AND BETA OF THE WEIBULL DISTRIBUTION FOR EACH STATION
C*****
      DO 195 I=1,NPDST
        WRITE(LUN,1000)I
        WRITE(LUN,9055)
        READ(LU,*,IOSTAT=IOERR)P1
        IF (IOERR .NE. 0) CALL BOOR00(IOERR,*48)
        WRITE(LUN,9060)
        READ(LU,*,IOSTAT=IOERR)P2
        IF (IOERR .NE. 0) CALL BOOR00(IOERR,*49)
        WRITE(3,9020)I,P1,P2
        IP=IP+1
195      CONTINUE
    ENDOF
    RETURN
  END
C
C*****
C
C      SUBROUTINE BOOR00(IOERR,*)
C
C      THIS SUBROUTINE IS CALLED WHEN THERE IS A FORTRAN I/O ERROR.
C      SOME SPECIFIC ERRORS ARE EXPLAINED, OTHERS MUST BE LOOKED UP.
C      THE SUBROUTINE RETURNS TO THE ROUTINE SO THAT THE USER MAY ENTER
C      THE INCORRECT INFORMATION AGAIN

```

```

C
C*****
COMMON/BUK3/LU,LW,IF
WRITE(6,*) '*** YOUR RESPONSE WAS NOT UNDERSTOOD. PLEASE ENTER
* AGAIN, ***'
IF (IOERR .EQ. 59) THEN
  WRITE(6,*) 'A NUMBER WAS EXPECTED BUT A CHARACTER WAS READ'
ELSEIF (IOERR .EQ. 29) THEN
  WRITE(6,*) '***FILE NOT FOUND. PLEASE ENTER FILENAME AGAIN***'
ELSE
  WRITE(6,*) 'ERROR NUMBER',IOERR,'. PLEASE REFER TO FORTRAN
* USERS GUIDE P. 7-2'
  LU=6
  LW=6
ENDIF
RETURN 1
END

```

```

      AGVINFO.FOR
C*****
C
      SUBROUTINE INFO
C
      THIS SUBROUTINE PROVIDES INFORMATION ABOUT EACH TYPE OF TASK
      THAT VEHICLES CAN PERFORM. THE USER HAS THE CHOICE OF 1 DURING
      ANY GIVEN SIMULATION. THE USER MAY READ ABOUT ONE OR MORE OF THE
      DIFFERENT TYPES OF TASKS
C*****
      LOGICAL AGAIN
      CHARACTER*1 RESP
      AGAIN=.TRUE.
      IESC=27
      DO WHILE (AGAIN)
C*****
C      CLEAR THE SCREEN
C*****
      WRITE(6,1000) IESC, IESC
1000  FORMAT(1X,A,'LOGON',A,'E2J')
      WRITE(6,*) 'For which topic would you like more information?'
      WRITE(6,*) '1. PICK/DROP Task #1 - FROM/TO loads distributed
      * over
      WRITE(6,*) '    a shift 1/-X time
      * units'
      WRITE(6,*) '2. PICK/DROP Task #2 - FROM/TO loads occur every 1/
      WRITE(6,*) '    time units 1/-X
      * time units'
      WRITE(6,*) '3. PICK/DROP Task #3 - Time between requests for
      WRITE(6,*) '    transport occur according to specified
      * distribution.'
      WRITE(6,*) '    FROM-TO load assigned to request by discrete
      WRITE(6,*) '    probability distribution.'
      WRITE(6,*) '4. ASSEMBLY Task - Time between part arrival occur
      * according to
      WRITE(6,*) '    specified distribution. Part type assigned by
      WRITE(6,*) '    discrete probability distribution. Part
      * assigned'
      WRITE(6,*) '    sequence of stations to visit depending on part
      * type.'
      WRITE(6,*) 'Enter a number for more information.'
1      READ(6,*,Iostat=iocerr) ISEL
      IF (IOCERR .ne. 0) CALL EOOB00(IOCERR,*1)
      read(6,*) isel
      IF (ISEL .gt. 4) THEN
        WRITE(6,*) '*** YOUR SELECTION MUST BE BETWEEN 1 AND 4.
      * PLEASE ENTER AGAIN'
        GO TO 1
      ENDIF
C*****
C      CALL THE SUBROUTINE WHICH CONTAINS INFORMATION ON THE TYPE
C      OF TASK SPECIFIED BY THE USER
C*****
      IF (ISEL .EQ. 1) THEN
        CALL TASK1
      ELSEIF (ISEL .EQ. 2) THEN
        CALL TASK2
      ELSEIF (ISEL .EQ. 3) THEN
        CALL TASK3
      ELSEIF (ISEL .EQ. 4) THEN
        CALL ASSEM
      ENDIF

```

```

C*****
C READ ANOTHER TYPE OF TASK OR RETURN TO THE QUERY PART OF THE PACKAGE
C*****
      WRITE(6,*)
2      WRITE(6,*) 'Enter Y for another selection or N to stop.'
      READ(6,1001)RESP
1001   FORMAT(A)
      IF (RESP.EQ. 'Y') THEN
         AGAIN=.TRUE.
      ELSE IF (RESP.EQ. 'N') THEN
         AGAIN=.FALSE.
      ELSE
         WRITE(6,*) '*** PLEASE ENTER Y OR N ***'
         GOTO 2
      ENDDIF
      ENDDO
      RETURN
      END

C*****
C
C SUBROUTINE TASK1
C THIS SUBROUTINE PROVIDES INFORMATION ABOUT PICK/DROP TASK #1
C
C*****
      IESC=27
1000   WRITE(6,1000)IESC,IESC
      FORMAT(IX,A,'C0:0H',A,'E2J')
      WRITE(6,*) 'PICK/DROP TASK#1'
      WRITE(6,*)
      WRITE(6,*) ' This is a PICK/DROP task with the number of '
      WRITE(6,*) ' specified. The number of loads per shift between '
      WRITE(6,*) ' each FROM/TO pair is defined by the user. The model '
      WRITE(6,*) ' spreads the loads over a user-defined shift. A '
      WRITE(6,*) ' tolerance band width, X, may be specified. If a '
      WRITE(6,*) ' tolerance band width is specified, the model '
      WRITE(6,*) ' spreads the loads over a user-defined shift plus or '
      WRITE(6,*) ' minus X, the given number of time units. The model '
      WRITE(6,*) ' performs this by sampling from a triangular '
      WRITE(6,*) ' distribution defined by: '
      WRITE(6,*) ' MODE = (number of loads)/(time units per shift) '
      WRITE(6,*) ' MINIMUM = MODE - X '
      WRITE(6,*) ' MAXIMUM = MODE + X '
      WRITE(6,*)
      WRITE(6,*) 'Please note: '
      WRITE(6,*) ' The TOLERANCE BAND WIDTH must be less than the '
      WRITE(6,*) ' MODE (time between arrivals), otherwise a 0 or '
      WRITE(6,*) ' negative time between arrivals could occur. '
      WRITE(6,*)
      WRITE(6,*) 'Please press RET to continue.'
      READ(6,*)
      WRITE(6,1000)IESC,IESC
      WRITE(6,*) 'EXAMPLE 1: '
      WRITE(6,*) ' The FROM/TO pair is Station 1 and Station 5. '
      WRITE(6,*) ' The shift is 420 minutes. '
      WRITE(6,*) ' The number of loads between the FROM/TO pair is 10 '
      * loads/shift. '
      WRITE(6,*) ' and the tolerance band width, X, is 0. '
      WRITE(6,*)
      WRITE(6,*) 'A request for transfer is generated every 42 minutes. '
      WRITE(6,*)
      WRITE(6,*) 'EXAMPLE 2: '
      WRITE(6,*)
      WRITE(6,*) 'Same as Example 1 except '
      WRITE(6,*) ' the tolerance band width, X, is 5 minutes. '
      WRITE(6,*)

```

```

WRITE(6,*)'A request for transfer is generated every 42 minutes
* +/- 5 minutes.'
WRITE(6,*)'More specifically, the time between arrivals is
WRITE(6,*)'sampled from a triangular distribution with a mode
WRITE(6,*)'of 42 minutes, a minimum of 37 minutes and a
WRITE(6,*)'maximum of 47 minutes.'
WRITE(6,*)'Please press RET to continue.'
READ(6,*)
RETURN
END

C*****
C
C      SUBROUTINE TASK2
C
C      THIS SUBROUTINE PROVIDES INFORMATION ON PICK/DROP TASK #2
C
C*****
1000  IESC=27
      WRITE(6,1000)IESC,IESC
      FORMAT(1X,A,'C0:0H',A,'E2J')
      WRITE(6,*)'PICK/DROP Task #2'
      WRITE(6,*)
      WRITE(6,*)'      This is a PICK/DROP task with the time between
      WRITE(6,*)'loads specified. The time between requests, Y, is
      WRITE(6,*)'specified by the user. A tolerance band width, X,
      WRITE(6,*)'may also be specified. If a tolerance band width
      * X, is
      WRITE(6,*)'specified, Y is the mode of a triangular
      * distribution
      WRITE(6,*)'defining the time between requests. The minimum of
      WRITE(6,*)'the distribution is defined by Y-X and the maximum
      WRITE(6,*)'is Y+X.'
      WRITE(6,*)
      WRITE(6,*)'Please note!'
      WRITE(6,*)'The TOLERANCE BAND WIDTH must be less than the
      WRITE(6,*)'MODE (time between arrivals), otherwise a 0 or
      WRITE(6,*)'negative time between arrivals could occur.'
      WRITE(6,*)
      WRITE(6,*)'Please press RET to continue.'
      READ(6,*)
      WRITE(6,1000)IESC,IESC
      WRITE(6,*)'EXAMPLE 1:'
      WRITE(6,*)
      WRITE(6,*)'The FROM/TO pair is Station 1 and Station 5.'
      WRITE(6,*)'The time between loads, Y, is 28 minutes.'
      WRITE(6,*)'the tolerance band width, X, is 0.'
      WRITE(6,*)
      WRITE(6,*)'A request for transfer is generated every 28
      * minutes'
      WRITE(6,*)
      WRITE(6,*)'EXAMPLE 2:'
      WRITE(6,*)
      WRITE(6,*)'Same as Example 1 except'
      WRITE(6,*)'the tolerance band width, X, is 5 minutes.'
      WRITE(6,*)
      WRITE(6,*)'A request is generated every 28 minutes plus or
      WRITE(6,*)'minus 5 minutes. More specifically, the time
      WRITE(6,*)'between requests is sampled from a triangular
      WRITE(6,*)'distribution with!'
      WRITE(6,*)'MODE = 28 minutes'
      WRITE(6,*)'MINIMUM = 23 minutes'
      WRITE(6,*)'MAXIMUM = 33 minutes'
      WRITE(6,*)
      WRITE(6,*)'Please press RET to continue.'
      READ(6,*)
      RETURN

```

```

END

C*****
C
C      SUBROUTINE TASK3
C
C      THIS SUBROUTINE PROVIDES INFORMATION ON PICK/DROP TASK #3
C*****
C      IESC=27
1000  WRITE(6,1000)IESC,IESC
      FORMAT(1X,A,'C030H',A,'C2J')
      WRITE(6,*)'PICK/DROP Task #3'
      WRITE(6,*)
      WRITE(6,*)'    This is a PICK/DROP task with the times between /
      WRITE(6,*)'arrivals of request for transport occur according to /
      WRITE(6,*)'a user defined distribution. When a new request is /
      WRITE(6,*)'generated, it is assigned a FROM/TO pair according to /
      WRITE(6,*)'a discrete probability distribution defined by the /
      WRITE(6,*)'user.'
      WRITE(6,*)
      WRITE(6,*)'EXAMPLE:'
      WRITE(6,*)
      WRITE(6,*)'    The time between requests is exponentially /
      WRITE(6,*)'distributed with a mean of 25 minutes. Sixty percent /
      WRITE(6,*)'of these requests are from Station 1 to Station 2.'
C*****
      WRITE(6,*)'The other 40% are from Station 2 to Station 3.'
      WRITE(6,*)
      WRITE(6,*)'The time between arrivals will be exponentially /
      WRITE(6,*)'distributed with a mean of 25 minutes. For /
      WRITE(6,*)'probability is .60 that a request is generated from /
      WRITE(6,*)'Station 1 to Station 2.'
      WRITE(6,*)
      WRITE(6,*)'Please press RET to continue.'
      READ(6,*)
      RETURN
END

C*****
C
C      SUBROUTINE ASSEM
C
C      THIS SUBROUTINE PROVIDES INFORMATION ON THE ASSEMBLY TASK
C*****
C      IESC=27
1000  WRITE(6,1000)IESC,IESC
      FORMAT(1X,A,'C030H',A,'C2J')
      WRITE(6,*)'ASSEMBLY Task'
      WRITE(6,*)
      WRITE(6,*)'    The time between arrival in an ASSEMBLY task occur /
      WRITE(6,*)'according to a user defined distribution. When a /
      WRITE(6,*)'part arrives, it is assigned a part type according to /
      WRITE(6,*)'a user-defined, discrete probability distribution. /
      WRITE(6,*)'Based on the part type, the part will be assigned a /
      WRITE(6,*)'sequence to follow. The part will proceed through a /
      WRITE(6,*)'series of moves from station to station with the SAM /
      WRITE(6,*)'vehicle.'
      WRITE(6,*)
      WRITE(6,*)'Please press RET to continue.'
      READ(6,*)
      WRITE(6,1000)IESC,IESC
      WRITE(6,*)'EXAMPLE:'
      WRITE(6,*)
      WRITE(6,*)'    The time between the arrival of parts is /
      WRITE(6,*)'exponentially distributed with mean of 15 minutes. /
      WRITE(6,*)

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```

WRITE(6,*)' Part type 1 = 40%'
WRITE(6,*)' Part type 2 = 40%'
WRITE(6,*)
WRITE(6,*)' Part type 1 sequence: 1 5 2'
WRITE(6,*)' Part type 2 sequence: 2 5 7 8'
WRITE(6,*)
WRITE(6,*)'The probability is .4 that an arrival will be part'
WRITE(6,*)'type 2. If an arrival is part type 2, the part will'
WRITE(6,*)'be loaded on to the vehicle at Station 2. The'
WRITE(6,*)'will carry the part to Station 5 where an operation'
WRITE(6,*)'will be performed according to a user defined'
WRITE(6,*)'distribution. Likewise, the vehicle will carry the'
WRITE(6,*)'part to Station 7 and Station 8. The part will be'
WRITE(6,*)'unloaded at Station 8 and the vehicle will be
* released'
WRITE(6,*)
WRITE(6,*)'Please press RET to continue.'
READ(6,*)
RETURN
END

```

```

      AGVINP.FOR
C*****
C
      SUBROUTINE INPUT
C*****
C
      THIS SUBROUTINE INTERACTIVELY DEFINES THE PARAMETERS NEEDED TO
      SIMULATE AN AGV SYSTEM. THE PROGRAM WILL READ FROM THE
      TERMINAL OR A FILE. IF THE INFORMATION IS ENTERED
      INTERACTIVELY THE INFORMATION CAN BE SAVED SO THAT THE
      INFORMATION NEED NOT BE ENTERED AGAIN.
C
      VARIABLES ARE DEFINED AS FOLLOWS:
C
      INTEGERS
      ESTNO - STATION NUMBER AT THE END OF TRACK SECTION 1
      INLOC(50) - ARRAY CONTAINING INITIAL LOCATIONS OF EACH AGV
      LU - LOGICAL UNIT NO. WHERE DATA FOR PROGRAM IS STORED
      MAXREQ - MAX REQUESTS ALLOWED IN SYSTEM SIMULTANEOUSLY
      NAGV - NUMBER OF AGVS IN THE SYSTEM
      NINTRST - NUMBER OF INTERSECTION
      NI - TEMPORARY VARIABLE
      NJ - TEMPORARY VARIABLE
      NK - TEMPORARY VARIABLE
      NPZ - NUMBER OF PARKING ZONES IN THE SYSTEM
      NRUN - NUMBER OF SIMULATION RUNS TO EXECUTE
      NSTAT - NUMBER OF STATIONS IN SIMAN MODEL
      NTRAKST - NUMBER OF TRACK SECTIONS
      STNO - STATION NUMBER AT BEGINNING OF TRACK SECTION 1
      TRKDIST(I) - LENGTH OF TRACK SECTION I
C
      CHARACTERS
      CLU - LOCATION OF INPUT FOR THIS PROGRAM
      DATE - DATE OF SIMULATION
      DEFIL - FILE CONTAINING INPUT TO THIS PROGRAM (EXT =.DAT)
      ESTTYP - STATION TYPE AT END OF TRACK SECTION 1
      FIL - SAME AS FILNAM EXCEPT .EXT IS NOT ATTACHED
      FILNAM - NAME OF SIMAN EXP FILE THAT THIS PROGRAM CREATES
      ISAT - BINARY VAR (Y/N) Y=DISCARD PREVIOUS OBSERVATIONS
      ISYS - BINARY VAR (Y/N) Y=REINITIALIZE BETWEEN RUNS
      NAME - NAME OF PROGRAMMER FOR OUTPUT REPORT
      STAT - STATUS OF THE SIMAN EXP FILE
      STTYP - STATION TYPE AT BEGINNING OF TRACK SECTION 1
      TITLE - TITLE OF SIMULATION FOR OUTPUT REPORT
C
      REAL
      RUNTIM - LENGTH OF SIMULATION RUNS
      TBEG - BEGINNING TIME OF THE 1ST SIMULATION RUN
      VEL - VELOCITY OF THE AGV'S
C*****
      COMMON/BLK6/NODE,NTRAKST,NPZST,NSTAT,RO,NPZ,NBD
      COMMON/BLK7/COUNT,FMAX
      COMMON/BLK3/LU,LUW,IF
      INTEGER INLOC(100),LU,MAXREQ,TRANS,FROM,TO,STNO,ESTNO,SHIFT,IDA
      INTEGER NI,NINTRST,NSTAT,NRUN,NTRAKST
      INTEGER NOV(100),FEW,ICAP(1000)
      LOGICAL EQUAL1,SUNT01
      DATA EQUAL1/.FALSE./
      REAL PRUB1(50),FROM2(50),RUNTIM,TBEG,VEL,P1,P2
      CHARACTER*12 CLU*1,DATE*10,DAY*2,DEFIL,FIL*8,STTYP*1,ESTTYP*1
      CHARACTER*20 ISAT*3,ISYS*3,MON*2,NAME,STAT*3,TITLE,RESP*1
      CHARACTER*2 CHDIST,YEAR*4,DISTYP*2
C*****
C      CLEAR THE SCREEN
C*****

```



```

      IESC=27
      WRITE(6,4000)IESC,IESC
C*****
C      READ INITIAL DATA, VEHICLE CHARACTERISTICS AND SIMULATION DATA
C*****
1      WRITE(6,*)'Do you wish to read '
      WRITE(6,*)'  Initial Data/'
      WRITE(6,*)'  Vehicle Characteristics/'
      WRITE(6,*)'  Simulation Data/'
      WRITE(6,*)'from the TERMINAL or a FILE ? '
      WRITE(6,*)
C*****
C      DETERMINE WHERE TO READ
C*****
      WRITE(6,*)'Enter T for terminal and F for file.'
      READ(6,1000) CLU
      WRITE(6,1000) CLU
      IF (CLU.EQ. 'T') THEN
        LU=6
        LUW=6
      ELSE IF (CLU.EQ. 'F') THEN
        WRITE(6,*)
        WRITE(6,*)'What is the name of the file ?'
        WRITE(6,*)
        WRITE(6,*)' Please include the extension. (i.e. .DAT)'
        READ(6,1000) DEFFIL
        OPEN(UNIT=36,STATUS='OLD',IOSTAT=IOERR,NAME=DEFFIL)
        LU=36
        IF (IOSTAT.NE. IOERR) THEN
          WRITE(6,*)'ERROR OPENING FILE ',DEFFIL
          CALL BOOBD0(IOERR,*1)
        ENDIF
        OPEN(UNIT=8,STATUS='OLD',IOSTAT=IOERR,NAME='JUNK.DAT')
        IF (IOSTAT.NE. IOERR) THEN
          WRITE(6,*)'ERROR OPENING FILE JUNK.DAT'
        ENDIF
        LUW=8
      ELSE
        WRITE(6,*)'YOUR ANSWER WAS NOT UNDERSTOOD. PLEASE
        * ENTER AGAIN,'
        GO TO 1
      ENDIF
C*****
C      OPEN SIMAN EXPERIMENT FILES
C*****
      WRITE(6,4000)IESC,IESC
      OPEN(UNIT=3,STATUS='UNKNOWN',IOSTAT=IOERR,NAME='PAR.EXP')
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*)'ERROR OPENING FILE PAR.EXP'
68      WRITE(6,*)'EXECUTION TERMINATED'
        STOP
      ENDIF
      OPEN(UNIT=4,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='AGVSIM1.EXP')
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*)'ERROR OPENING FILE AGVSIM1.EXP'
        CLOSE (3)
        CALL BOOBD0(IOERR,*68)
      ENDIF
      OPEN(37,STATUS='UNKNOWN',FILE='AGVSIM1.EXP',IOSTAT=IOERR)
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*)'ERROR OPENING FILE AGVSIM1.EXP'
        CALL BOOBD0(IOERR,*68)
      ENDIF
C*****
C      WRITE THE 'PROJECT' ELEMENT
C*****

```

```

WRITE(LUW,*)
WRITE(LUW,*)'Please enter the TITLE of the problem.'
WRITE(LUW,*)'Maximum = 20 ALPHANUMERIC CHARACTERS'
READ(LU,1000) TITLE
FORMAT(A)
1000 WRITE(LUW,*)
WRITE(LUW,*)'Enter the DATE.'
WRITE(LUW,1003)
1003 FORMAT('$',' MONTH (1-12): ')
READ(LU,1000) MON
WRITE(LUW,1004)
1004 FORMAT('$',' DAY (1-31): ')
READ(LU,1000) DAY
WRITE(LUW,1005)
1005 FORMAT('$',' YEAR : ')
READ(LU,1000) YEAR
DATE=MON//'/DAY//'/YEAR
WRITE(LUW,*)
WRITE(LUW,*)'Enter your NAME.'
WRITE(LUW,*)'Maximum = 20 ALPHANUMERIC CHARACTERS'
READ(LU,1000) NAME
WRITE(37,1010)
1010 FORMAT('BEGIN:')
WRITE(37,1020) TITLE,NAME,DATE
1020 FORMAT('PROJECT','A','A','A','A')
C*****
C
C GATHER INFORMATION FOR THE 'DISCRETE' ELEMENT
C*****
C
WRITE(LUW,4000) IESC,IESC
WRITE(LUW,*)'Please enter the followings.'
WRITE(LUW,*)
3 WRITE(LUW,1022)
1022 FORMAT('$',' Number of STATIONS: ')
READ(LU,*,IOSTAT=IOERR) NPDST
IF (IOERR.NE. 0) CALL BOOBOD(IOERR,*3)
4 WRITE(LUW,1024)
1024 FORMAT('$',' Number of PARKING ZONES: ')
READ(LU,*,IOSTAT=IOERR) NPZ
IF (IOERR.NE. 0) CALL BOOBOD(IOERR,*4)
5 WRITE(LUW,1026)
1026 FORMAT('$',' Number of INTERSECTIONS: ')
READ(LU,*,IOSTAT=IOERR) NNINIRST
IF (IOERR.NE. 0) CALL BOOBOD(IOERR,*5)
6 WRITE(LUW,1028)
1028 FORMAT('$',' Number of TRACK SEGMENTS: ')
READ(LU,*,IOSTAT=IOERR) NTRAKST
IF (IOERR.NE. 0) CALL BOOBOD(IOERR,*6)
NSTAT=NPDST+NPZ+NTRAKST+NNINIRST
NSTAT=NSTAT+1
WRITE(LUW,*)
7 WRITE(LUW,*)'Enter the maximum number ACTIVE REQUESTS for'
WRITE(LUW,*)'TRANSPORT allowed in the system at the same time.'
WRITE(LUW,*)
WRITE(LUW,*)'(Suggested input = 100)'
READ(LU,*,IOSTAT=IOERR) MAXREQ
IF (IOERR.NE. 0) CALL BOOBOD(IOERR,*7)
NPDST=NPDST+1
NODE=NPDST+NPZ+NNINIRST
NODE=NODE+1
WRITE(LUW,4000) IESC,IESC
WRITE(LUW,*)'Please enter the Vehicle Characteristics'
WRITE(LUW,*)
MAX=(150-2)/6
8 WRITE(LUW,1029)MAX
1029 FORMAT('$',' Number of ABVs (MAX=',I3,'): ')
READ(LU,*,IOSTAT=IOERR) NABV

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      IF (IOERR .NE. 0) CALL BOOROO(IOERR,*8)
9      WRITE(LUN,1032)
1032   FORMAT('$',' ',10) Unloaded Velocity: ' )
      READ(LU,*) VEL...U
      IF (IOERR .NE. 0) CALL BOOROO(IOERR,*9)
10      WRITE(LUN,1034)
1034   FORMAT('$',' ',10) Loaded Velocity: ' )
      READ(LU,*) VEL...L
      WRITE(LUN,*)
      IF (IOERR .NE. 0) CALL BOOROO(IOERR,*10)
      IP=1
      WRITE(3,1290)
1290   FORMAT('PARAMETERS:')
C*****
C      WRITE THE 'PARAMETERS' ELEMENT
C      WRITE THE 'TABLES' ELEMENT IF NECESSARY
C*****
      DO 150 I=1,NPOST+NPZ
        NOV(I)=0
150    CONTINUE
      WRITE(LUN,4000) IESC,IESC
      WRITE(LUN,*) 'Please enter the initial location of each vehicle.'
      WRITE(LUN,*) ' (Must be either a STATION or a PARKING ZONE)'
      WRITE(LUN,*) ' (Enter S for stations and Z for parking zones.)'
      DO 155 I=1,NAGV
12      WRITE(LUN,1288) I
1288   FORMAT('$',' ',10) AGV #',I4,' : ' )
      READ(LU,1280,IOSTAT=IOERR) STYP,STNO
1280   FORMAT(A,14)
      IF (IOERR .NE. 0) CALL BOOROO(IOERR,*12)
      INLOC(I)=TRANS(STYP,STNO,NOV(I))
      IF (NOV(I) .EQ. 1) GO TO 12
      NOV(INLOC(I))=NOV(INLOC(I))+1
155    CONTINUE
      WRITE(LUN,*)
      WRITE(LUN,*) 'Please enter the number of AGVs that may be in a
      * STATION.'
      WRITE(LUN,*) ' Be sure number is sufficient to contain the'
      WRITE(LUN,*) ' initial locations of AGVs.'
      DO 200 I=1,NPOST
13      WRITE(LUN,1310) I
1310   FORMAT('$',' ',10) STATION',I5,' : ' )
      READ(LU,*) IOSTAT=IOERR) ICAP(I)
      IF (IOERR .NE. 0) CALL BOOROO(IOERR,*13)
      IF (ICAP(I) .LT. NOV(I)) THEN
        WRITE(6,*) '*** CAPACITY OF STATION',I,' IS NOT LARGE
        * ENOUGH.'
        WRITE(6,*) 'CAPACITY MUST BE AT LEAST',NOV(I)
        WRITE(6,*) 'PLEASE ENTER AGAIN. ***'
        GO TO 13
      ENDIF
      WRITE(3,1320) IP,ICAP(I)
1320   FORMAT(5X,I5,' ',15,' : ' )
      IP=IP+1
200    CONTINUE
      WRITE(LUN,*)
      WRITE(LUN,*) 'Please enter the number of AGVs that may be in a
      * PARK ZONE.'
      WRITE(LUN,*) ' Be sure number is sufficient to contain the'
      WRITE(LUN,*) ' initial locations of AGVs.'
      DO 210 I=1,NPZ
14      WRITE(LUN,1340) I
1340   FORMAT('$',' ',10) PARK ZONE',I5,' : ' )
      READ(LU,*) IOSTAT=IOERR) ICAP(I+NPST)
      IF (IOERR .NE. 0) CALL BOOROO(IOERR,*14)
      IF (ICAP(I+NPST) .LT. NOV(NPOST+I)) THEN

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        WRITE(6,*)'*** CAPACITY OF PARKING ZONE',I,' IS NOT LARGE
* ENOUGH.'
        WRITE(6,*)'CAPACITY MUST BE AT LEAST',NOV(I*NPST)
        WRITE(6,*)'PLEASE ENTER AGAIN, ***'
        GOTO 14
    ENDF
    WRITE(3,1350)IF,ICAP(I*NPST)
1350    FORMAT(5X,15,'',15,'')
    IF=IF*1
210    CONTINUE
    WRITE(LUN,4000)IESC,IESC
    FORMAT(1X,A,'C0:0H',A,'C2J')
4000    WRITE(LUN,1380)
99    FORMAT(1X,'Transport Request Activity may be entered as
1380    * follows:')
    WRITE(LUN,*)
    WRITE(LUN,*)'1. PICK/DROP Task #1 -- FROM/TO loads distributed
* over
    WRITE(LUN,*)'    a shift 1/-X time
* units'
    WRITE(LUN,*)
    WRITE(LUN,*)'2. PICK/DROP Task #2 -- FROM/TO loads occur every Y'
    WRITE(LUN,*)'    time units 1/-X
* time units'
    WRITE(LUN,*)
    WRITE(LUN,*)'3. PICK/DROP Task #3 -- Time between requests for'
    WRITE(LUN,*)'    transport occur according to specified
* distribution.'
    WRITE(LUN,*)'    FROM-TO load assigned to request by discrete'
    WRITE(LUN,*)'    probability distribution.'
    WRITE(LUN,*)
    WRITE(LUN,*)'4. ASSEMBLY Task -- Time between part arrival occur
* according to
    WRITE(LUN,*)'    specified distribution. Part type assigned by'
    WRITE(LUN,*)'    discrete probability distribution. Part
* assigned'
    WRITE(LUN,*)'    sequence of stations to visit depending on part
* type.'
    WRITE(LUN,*)
    WRITE(LUN,*)'5. MORE INFORMATION'
    WRITE(LUN,*)
98    WRITE(LUN,*)'Please enter the appropriate number.'
    READ(LU,X)NI
    IF (NI .EQ. 1) THEN
        CALL LOAD1
    ELSE IF (NI .EQ. 2) THEN
        CALL LOAD3
    ELSE IF (NI .EQ. 3) THEN
        WRITE(4,1390)
        CALL LOAD2
    ELSE IF (NI .EQ. 4) THEN
1390        WRITE(4,1390)
        FORMAT('TABLES:')
        CALL LOAD4
    ELSE IF (NI .EQ. 5) THEN
        CALL INFO
        GOTO 99
    ELSE
        WRITE(LUN,*)'*** NUMBER MUST BE BETWEEN 1 AND 5,
* PLEASE ENTER AGAIN, ***'
        GOTO 98
    ENDF
    WRITE(LUN,4000) IESC,IESC
    WRITE(LUN,*)'Please enter load/unload information'
    WRITE(LUN,*)
    WRITE(LUN,*)'    Enter the distribution type for load/unload time.'
    DISTYP=CHDIST()
    OPEN(25,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='ASTAT1.MOD')

```

```

      IF (IOSTAT .NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ASTAT1.MOD'
        CALL BOOB00(IOERR,*68)
      ENDIF
C*****
C      WRITE STATEMENTS TO THE MODEL FILE WHICH PERTAIN SPECIFICALLY
C      TO THIS SIMULATION PROBLEM
C*****
      WRITE(25,1400) IP-1
1400      FORMAT('          ASSIGN: A(17)=', I8, '+N;')
      CLOSE(25)
      OPEN(25, IOSTAT=IOERR, STATUS='UNKNOWN', NAME='ASTAT3.MOD')
      IF (IOSTAT .NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ASTAT1.MOD'
        CALL BOOB00(IOERR,*68)
      ENDIF
      OPEN(26, IOSTAT=IOERR, STATUS='UNKNOWN', NAME='ASTAT8.MOD')
      IF (IOSTAT .NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ASTAT8.MOD'
        CALL BOOB00(IOERR,*68)
      ENDIF
      OPEN(27, IOSTAT=IOERR, STATUS='UNKNOWN', NAME='ASTAT5.MOD')
      IF (IOSTAT .NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ASTAT5.MOD'
        CALL BOOB00(IOERR,*68)
      ENDIF
      IF (DISTYP .EQ. 'CO') THEN
        WRITE(25,1410) DISTYP
1410      FORMAT(9X, 'DELAY:', A, '(A(17));', ')
        WRITE(27,1420) DISTYP
1420      FORMAT('USE      DELAY:', A, '(A(17));', ')
        WRITE(26,1430) DISTYP
1430      FORMAT('DROP      DELAY:', A, '(A(17));', ')
        ELSE
        WRITE(25,1440) DISTYP
1440      FORMAT(9X, 'DELAY:', A, '(A(17),6);')
        WRITE(27,1450) DISTYP
1450      FORMAT('USE      DELAY:', A, '(A(17),6);')
        WRITE(26,1460) DISTYP
1460      FORMAT('DROP      DELAY:', A, '(A(17),6);')
      ENDIF
C*****
C      ENTER THE DISTRIBUTION INFORMATION FOR THE LOAD AND UNLOAD STATIONS
C*****
      CALL PARA(DISTYP,NPDST)
      CLOSE(25)
      CLOSE(26)
      CLOSE(27)
C*****
C      WRITE THE 'REPLICATE' ELEMENT
C*****
      WRITE(LUM,4000) IESC, IESC
      WRITE(LUM,*) 'Please enter the Simulation Data.'
      WRITE(LUM,*)
15      WRITE(LUM,1462)
1462      FORMAT('$', '      Number of SIMULATION RUNS: ')
      READ(LU,*, IOSTAT=IOERR) NRUN
      IF (IOERR .NE. 0) CALL BOOB00(IOERR,*15)
16      WRITE(LUM,1464)
1464      FORMAT('$', '      START TIME of 1st run: ')
      READ(LU,*, IOSTAT=IOERR) I8EG
      IF (IOERR .NE. 0) CALL BOOB00(IOERR,*16)
17      WRITE(LUM,1466)
1466      FORMAT('$', '      LENGTH of the runs: ')

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```

READ(LU,*,IOSTAT=IOERR) RUNTIM
IF (IOERR.NE. 0) CALL BOOR00(IOERR,*18)
ISYS='NO'
ISTAT='NO'
IF (NRUN.GT. 1) THEN
18  WRITE(LUW,*) 'INITIALIZE SYSTEM between runs ? (Y=YES, N=NO)'
    READ(LU,1000) RESP
    IF (RESP.EQ. 'Y') THEN
        ISYS='YES'
    ELSEIF (RESP.EQ. 'N') THEN
        ISYS='NO'
    ELSE
        WRITE(6,*) '*** YOUR ANSWER WAS NOT UNDERSTOOD. PLEASE ENTER
        * Y FOR YES OR N FOR NO ***'
        GOTO 18
    ENDIF
19  WRITE(LUW,*) 'DISCARD previous OBSERVATIONS between runs ?
    * (Y=YES, N=NO)'
    READ(LU,1000) RESP
    IF (RESP.EQ. 'Y') THEN
        ISTAT='YES'
    ELSEIF (RESP.EQ. 'N') THEN
        WRITE(6,*) '***YOUR ANSWER WAS NOT UNDERSTOOD. PLEASE ENTER
        * Y FOR YES OR N FOR NO ***'
        GOTO 19
    ENDIF
    ENDIF
    WRITE(4,1470) NRUN,TREG,RUNTIM,ISYS,ISTAT
1470  FORMAT('REPLICATE',I4,'/',F10.3,'/',F12.3,'/',A,'/',A,'/')
C*****
C
C    WRITE THE 'TRACE' ELEMENT IF NECESSARY
C*****
22  WRITE(LUW,3) 'Do you want a TRACE? (Y=YES,N=NO)'
    WRITE(LUW,*) '(A trace is a detailed report of the processing of
    * the simulation)'
    READ(LU,1000)RESP
    IF (RESP.EQ. 'Y') THEN
        WRITE(4,*) 'TRACE,0,',RUNTIM,';'
    ELSEIF (RESP.NE. 'N') THEN
        WRITE(6,*) '*** YOUR ANSWER WAS NOT UNDERSTOOD. PLEASE ENTER
        * Y FOR YES OR N FOR NO ***'
        GOTO 22
    ENDIF
C*****
C
C    SELECT THE OPERATING RULES AND WRITE THE INFORMATION TO AGVCHSEL.F00
C*****
    WRITE(LUW,4000) IESC,IESC
    WRITE(LUW,*) 'Enter VEHICLE select rule.'
    WRITE(LUW,*)
    WRITE(LUW,*) 'If when a request for transport occurs, there is
    * more than 1 vehicle available,'
    WRITE(LUW,*)
    WRITE(LUW,*) 'How should the vehicle be selected? '
    WRITE(LUW,*)
    WRITE(LUW,*) '1 - Randomly select the vehicle'
    WRITE(LUW,*) '2 - Select the CLOSEST vehicle'
    WRITE(LUW,*) '3 - Select the FARTHEST vehicle'
    WRITE(LUW,*) '4 - Select the LONGEST IDLE vehicle'
    WRITE(LUW,*) '5 - Select the LEAST UTILIZED vehicle'
    WRITE(LUW,*)
20  WRITE(LUW,*) 'Please enter the appropriate number.'
    READ(LU,*,IOSTAT=IOERR)LPVH
    IF (IOERR.NE. 0) CALL BOOR00(IOERR,*20)
    IF (LPVH.GT. 5) THEN

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        WRITE(6,*)'YOUR SELECTION MUST BE BETWEEN 1 AND 5. PLEASE
* ENTER AGAIN.'
        GO TO 20
    ENDDIF
    OPEN(31,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='CHSQ1.FOR')
    IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*)'ERROR OPENING FILE CHSQ1.FOR'
        CALL B00B00(IOERR,*68)
    ENDDIF
    WRITE(31,1510)LPVH
    FORMAT(7X,'LPVH=',I1)
1510  WRITE(LUW,4000)IESC,IESC
    WRITE(LUW,*)'Enter the TASK select rule.'
    WRITE(LUW,*)
    WRITE(LUW,*)'If when a vehicle becomes available there is more
*than 1 request waiting'
    WRITE(LUW,*)' to be assigned to a vehicle.'
    WRITE(LUW,*)
    WRITE(LUW,*)'How should the
*request be assigned to the vehicle?'
    WRITE(LUW,*)
    WRITE(LUW,*)'1 - Select the request RANDOMLY'
    WRITE(LUW,*)'2 - Select the LONGEST WAITING (FCFS) request'
    WRITE(LUW,*)'3 - Select the CLOSEST request'
    WRITE(LUW,*)'4 - Select the FARTHEST request'
    WRITE(LUW,*)
21  WRITE(LUW,*)'Please enter the appropriate number.'
    READ(LU,*,IOSTAT=IOERR)LPRQ
    IF (IOERR.NE. 0) CALL B00B00(IOERR,*21)
    IF (LPRQ.GT. 4) THEN
        WRITE(6,*)'YOUR SELECTION MUST BE BETWEEN 1 AND 4. PLEASE
* ENTER AGAIN.'
        GO TO 21
    ENDDIF
    WRITE(31,1520)LPRQ
    FORMAT(7X,'LPRQ=',I1)
1520  IF (LPRQ.GT. 1) THEN
        WRITE(LUW,4000)IESC,IESC
        WRITE(LUW,*)'When a vehicle completes a task, which parking'
        WRITE(LUW,*)'zone should be selected?'
        WRITE(LUW,*)
        WRITE(LUW,*)'1 - Randomly select parking zone.'
        WRITE(LUW,*)'2 - Select the closest parking zone.'
        WRITE(LUW,*)'3 - Select the farthest parking zone.'
        WRITE(LUW,*)'4 - Select the parking zone with the largest
* remaining capacity.'
        WRITE(LUW,*)'5 - Select the parking zone with the largest
* capacity.'
        WRITE(LUW,*)'Please enter the appropriate number.'
        READ(LU,*,IOSTAT=IOERR)ICHPZ
        IF (IOERR.NE. 0) CALL B00B00(IOERR,*97)
        IF (ICHPZ.GT. 5) THEN
            WRITE(6,*)'YOUR SELECTION MUST BE BETWEEN 1 AND 5. PLEASE
* ENTER AGAIN.'
            GO TO 97
        ENDDIF
        WRITE(31,1538)ICHPZ
        FORMAT(7X,'ICHPZ=',I1)
1538  ENDDIF
        WRITE(LUW,*)
        WRITE(LUW,*)'Enter the BLOCK DISTANCE - '
        WRITE(LUW,*)' Minimum distance maintained between vehicles.'
        WRITE(LUW,*)' CANNOT be Zero. '
        WRITE(LUW,*)' Minimum value is length of vehicles.'
        WRITE(LUW,*)
        READ(LU,*,IOSTAT=IOERR)ILU
        IF (IOERR.NE. 0) CALL B00B00(IOERR,*11)
        ILU=LU

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```

      ILUW=LUW
C*****
C
C      ENTER THE NETWORK INFORMATION AND DETERMINE THE SHORTEST PATHS
C*****
C      CALL NETWORK
      LU=ILU
      LUW=ILUW
C*****
C      WRITE INFORMATION TO MODEL FILE THAT PERTAINS TO THIS SIMULATION PROBLEM
C*****
      OPEN(30, IOSTAT=IOERR, STATUS='UNKNOWN', FILE='AINIT7.MOD')
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE AINIT7.MOD'
        CALL BOOB00(IOERR, *68)
      ENDIF
      NSTA=NODE+INTRAKST
      NFIL=2*NODE+INROINAGU
      WRITE(30,1040) NFIL-NAGU
1040  FORMAT('Q2',7X,'QUEUE, H',15,'; MARK(2)')
      CLOSE(30)
      OPEN(30, IOSTAT=IOERR, STATUS='UNKNOWN', FILE='ASTAT3A.MOD')
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ASTAT3A.MOD'
        CALL BOOB00(IOERR, *68)
      ENDIF
      WRITE(30,1070)
1070  FORMAT(9X,'ASSIGN; J=5*X(1)+A(3)+2')
      WRITE(30,1080) VEL_LL
1080  FORMAT(9X,'ASSIGN; X(J)=',F10.2,';')
      CLOSE(30)
      OPEN(30, IOSTAT=IOERR, STATUS='UNKNOWN', FILE='ASTAT2.MOD')
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ASTAT2.MOD'
        CALL BOOB00(IOERR, *68)
      ENDIF
      WRITE(30,1070)
      WRITE(30,1080) VEL_LL
      CLOSE(30)
      OPEN(30, IOSTAT=IOERR, STATUS='UNKNOWN', NAME='ATRCK1A.MOD')
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ATRCK1A.MOD'
        CALL BOOB00(IOERR, *68)
      ENDIF
      WRITE(30,1090) NODE, NPDSTINPZ
1090  FORMAT(11X,'IF, X(J) .LE.,',15,'.AND, X(J) .GE.,',15,'.HAV')
      CLOSE(30)
      OPEN(30, IOSTAT=IOERR, STATUS='UNKNOWN', NAME='ATRCK4.MOD')
      IF (IOSTAT.NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ATRCK4.MOD'
        CALL BOOB00(IOERR, *68)
      ENDIF
      WRITE(30,1110) NPDSTINPZ
1110  FORMAT(11X,'IF, X(J) .LE.,',15,'.ST1')
      CLOSE(30)
      WRITE(31,1210) NPDST
1210  FORMAT(7X,'NPDST=',15)
      WRITE(31,1220) NODE
1220  FORMAT(7X,'NODE=',15)
      WRITE(31,1225) NPZ
1225  FORMAT(7X,'NPZ=',15)
C*****
C      WRITE THE 'STATION' BLOCKS TO THE MODEL FILE
C*****
      OPEN(15, IOSTAT=IOERR, STATUS='UNKNOWN', NAME='ASTAT0.MOD')

```



```

      IF (IOSTAT .NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE ASTATO.MOD'
        CALL BOOBB00(IOERR,*68)
      ENDIF
      WRITE(15,1530) NPDST
1530  FORMAT(2X,'STATION',1-',15,')
      CLOSE(15)
      OPEN(15,IOSTAT=IOERR,STATUS='UNKNOWN',FILE='APZO.MOD')
      IF (IOSTAT .NE. IOERR) THEN
        WRITE(6,*) 'ERROR OPENING FILE APZO.MOD'
        CALL BOOBB00(IOERR,*68)
      ENDIF
      IF (NPZ .GT. 0) THEN
        WRITE(15,1540) NPDST1,NPDST1+NPZ
1540  FORMAT(2X,'STATION',',15,','-',15,')
        ELSE IF (NPZ .EQ. 0) THEN
          WRITE(15,1550)
1550  FORMAT('END;')
        ENDIF
        CLOSE(15)
        OPEN(15,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='AINTFO.MOD')
        IF (IOSTAT .NE. IOERR) THEN
          WRITE(6,*) 'ERROR OPENING FILE AINTFO.MOD'
          CALL BOOBB00(IOERR,*69)
        ENDIF
        WRITE(15,1560) NPDST1+NPZ,NODE
1560  FORMAT(2X,'STATION',',15,','-',15,')
        CLOSE(15)
        OPEN(15,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='AIRCKO.MOD')
        IF (IOSTAT .NE. IOERR) THEN
          WRITE(6,*) 'ERROR OPENING FILE AIRCKO.MOD'
          CALL BOOBB00(IOERR,*69)
        ENDIF
        WRITE(15,1570) NODE1,NSIAT
1570  FORMAT(2X,'STATION',',15,','-',15,')
        CLOSE(15)
C*****
C      WRITE THE 'TALLIES', 'COUNTERS' AND 'OUTPUT' ELEMENTS
C*****
      WRITE(4,*) 'TALLIES:1, TIME IN SYSTEM;'
      WRITE(4,*) '                2, TIME WAIT FOR AGV;'
      WRITE(4,*) '                3, TIME WAIT FOR TRACK;'
      WRITE(4,*) '                4, TIME WAIT FOR STATION;'
      WRITE(4,*) '                5, TIME WAIT FOR INTER;'
      WRITE(4,*) 'OUTPUT:1, TAUG(1),S7;2, TAUG(2),S8;'
      WRITE(4,*) 'COUNTERS:1, COMPLETED REQ;'
      WRITE(4,*) '                2, INITIATED REQ;'
C*****
C      WRITE THE 'DSTAT' ELEMENT
C*****
      WRITE(4,*) 'DSTAT: 1,NQ(1),0 FOR AGV ASSIGN;'
      DO 220 I=1,NPDST
        NI=I+2
        WRITE(4,1580) NI-1,NI,I
1580  FORMAT(7X,15,','NQ(',15,')',LINE FOR S',15,')
220  CONTINUE
      DO 230 I=1, NPZ
        NI=I+NPDST+2
        WRITE(4,1590) NI-1,NI,I
1590  FORMAT(7X,15,','NQ(',15,')',LINE FOR Z',15,')
230  CONTINUE
      DO 240 I=NPDST1+NPZ,NODE
        NI=I+2
        WRITE(4,1600) NI-1,NI,I-NPDST

```

```

1600     FORMAT(7X,I5,' ',NR(' ',I5,' '),LINE FOR I',I5,' ')
1620     CONTINUE
      NI=NODE+1
      NJ=4*NAGV+2
      DO 1630 I=1,NAGV
        WRITE(4,1620)NI+I,NJ+1,I
1620     FORMAT(7X,I5,' ',X(' ',I5,' '),TIME AGV',I5,' EMPTY:')
1630     CONTINUE
      WRITE(4,1630) NI+1+NAGV
1630     FORMAT(7X,I5,' ',NI(1),UTIL OF AGVS:')
C*****
C
C      WRITE THE 'DISCRETE' ELEMENT
C*****
C      WRITE(37,1030) MAXREQ,NFIL,NSTA
1030     FORMAT('DISCRETE',I6,' ',23,' ',I6,' ',I6,' ')
C*****
C
C      WRITE THE 'INITIALIZE' ELEMENT
C*****
C      WRITE(37,1250)
1250     FORMAT('INITIALIZE,')
      NI=5*NAGV+2
      DO 1260 I=1,NAGV
        WRITE(37,1260) NI+I,VEL_U
1260     FORMAT(5X,'X(',I4,')=',F10.2,' ')
100     CONTINUE
1265     WRITE(37,1265)ED
1265     FORMAT(5X,'X(2)=',F8.2,' ')
      WRITE(37,1270) NAGV
1270     FORMAT(5X,'X(1)=',I4,' ')
      NI=NAGV+NODE
C*****
C
C      WRITE THE 'RESOURCES' ELEMENT
C*****
C      WRITE(37,1300) NODE+NRD
1300     FORMAT('RESOURCES:1-',I5,' ',NODE,' ')
      DO 1330 J=1,NPDST+NPZ
        WRITE(37,1330) ICAP(J)-NOV(J)
1330     FORMAT(15,' ')
100     CONTINUE
1370     WRITE(37,1370)
1370     FORMAT('1:')
C*****
C
C      WRITE THE 'TRANSPORTERS' ELEMENT
C*****
C      WRITE(4,1480) NAGV,VEL_U
1480     FORMAT('TRANSPORTERS:1,AGV',I5,' ',I,' ',F10.2,' ')
      DO 1490 NI=1,NAGV-1
        WRITE(4,1490)INLOC(NI)
1490     FORMAT(15,'-A',' ')
1215     CONTINUE
      WRITE(4,1500) INLOC(NAGV)
1500     FORMAT(15,'-A',' ')
C*****
C
C      WRITE THE 'END' STATEMENT
C*****
C      IF (NPZ .GT. 0) THEN
3000     WRITE(4,3000)
      FORMAT('END:')

```

```
ENDIF  
WRITE(6,4000)IESC,IESC  
WRITE(6,*)'INPUT COMPLETE,  PLEASE WAIT,'  
CLOSE(10)  
CLOSE(8)  
CLOSE(4)  
CLOSE(3)  
CLOSE(31)  
RETURN  
END
```

```

AGVKSHEC.FOR
SUBROUTINE KSHRT(MISERR)
C*****
C
C      SUBROUTINE KSHRT SEARCHES FOR THE 10 SHORTEST PATHS FROM
C      ALL STATIONS AND INTERSECTIONS TO ALL OTHER STATIONS AND
C      INTERSECTIONS IN THE AGV NETWORK. SUBROUTINES KSHRT, USWP,
C      XNULT AND TRACE ARE TAKEN AND SLIGHTLY MODIFIED FROM THE
C      DOUBLE SWEEP ALGORITHM AS DEFINED BY DOUGLAS R. SHIER IN
C      "COMPUTATIONAL EXPERIENCE WITH AN ALGORITHM FOR FINDING THE
C      K SHORTEST PATHS IN A NETWORK" FOUND IN THE JOURNAL OF RESE
C      RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, VOL. 78B, NO. 3
C      PP. 139-145. SUBROUTINE TRACE WAS MODIFIED SO THAT ONLY
C      10 SHORTEST PATH WITHOUT CYCLES ARE IDENTIFIED AS SUGGESTED BY ????
C      ON PAGE 82 OF ?????. THESE SUBROUTINES ARE ALSO LISTED IN
C      THEIR ENTIRETY AT THE END OF THAT TEXT.
C
C      THE SIZE OF THE PROBLEM IS LIMITED TO 1000 NODES. THE NUMBER
C      OF ARCS (I,J) WITH  $I < J$  IS LIMITED TO 5000. THE NUMBER OF
C      THE NUMBER OF ARCS (I,J)  $I > J$  IS LIMITED TO 5000.
C      10 SHORTEST PATH DISTANCES ARE FOUND
C      UP TO 10 SHORTEST PATH WITHOUT CYCLES MAY BE TRACED
C      THERE ARE TWO RESTRICTIONS ON THE NETWORK
C      1 - NO SELF-LOOPS
C      2 - ALL CIRCUITS IN THE NETWORK MUST HAVE A POSITIVE LENGTH
C      THESE RESTRICTIONS SHOULD NOT LIMIT THE NETWORK IN AN AGV
C      APPLICATION.
C
C      INPUT IS FROM RAW.DAT WHICH IS WRITTEN BY SUBROUTINE NETWORK
C      SUBROUTINE ORDER SORTS RAW.DAT USING THE VAX SORT/MERGE
C      UTILITY AND OUTPUTS THE SORTED NETWORK INFORMATION TO SORT.DAT
C      SUBROUTINE KSHRT READS THE SORTED DATA AND THE ARRAYS NEEDED
C      FOR USWP AND XNULT ARE CREATED.
C
C      THE VARIABLES IN COMMON ARE:
C      N      - NUMBER OF NODES IN THE NETWORK (<1000)
C
C      MU     - NUMBER OF ARC (I,J) SUCH THAT  $I < J$  (<5000)
C      ML     - NUMBER OF ARCS (I,J) SUCH THAT  $I > J$  (<5000)
C      LLEN   - ARRAY WHOSE JTH ENTRY IS THE NUMBER OF ARCS (I,J)
C              WITH  $J < I$ 
C      LINC   - ARRAY CONTAINING THE NODES I INCIDENT TO NODE J WITH
C               $I > J$ , LISTED IN INCREASING ORDER OF J
C      LVAL   - ARRAY CONTAINING THE ARC LENGTH VALUES CORRESPONDING
C              TO ARCS IN LINC
C      ULLEN  - ARRAY WHOSE JTH ENTRY IS THE NUMBER OF ARCS (I,J)
C              WITH  $I < J$ 
C      UINC   - ARRAY CONTAINING THE NODES I INCIDENT TO NODE J WITH
C               $I < J$ , LISTED IN ORDER OF INCREASING J
C      UVAL   - ARRAY CONTAINING THE ARC LENGTH VALUES CORRESPONDING
C              TO ARCS IN UINC
C      INF    - A NUMBER LARGER THAN ANY PATH LENGTH. NON-EXISTENT
C              PATHS ARE ASSIGNED THE LENGTH INF.
C      START  - ARRAY WHOSE JTH ELEMENT INDICATES THE 1ST POSITION
C              IN INC WHERE NODES INCIDENT TO NODE J ARE LISTED
C      INC    - ARRAY CONTAINING NODES I WHICH ARE INCIDENT TO NODE J.
C              LISTED IN ORDER OF INCREASING J
C      VAL    - ARRAY CONTAINING ARC LENGTH VALUES CORRESPONDING TO
C              ARCS IN INC
C      TRACK  - ARRAY CONTAINING THE SIMAN STATION NUMBER FOR THE
C              FOR TRACK OR ARC(I,J)
C      NODE   - NUMBER OF NODES IN THE NETWORK, NUMBER OF STATIONS+
C              NUMBER OF PARKING ZONES+NUMBER OF INTERSECTION
C      NARCS  - NUMBER OF ARCS IN THE NETWORK, (TRACK SEGMENTS)
C      COUNT  - NUMBER OF THE PATH JUST GENERATED, USED IN THE
C              SEQUENCE ELEMENT
C      K      - THE NUMBER OF SHORTEST PATHS TO BE FOUND (= 10)
C      I3     - MAXIMUM NUMBER OF DOUBLE SWEEP ITERATIONS ALLOWED

```

```

C      NS,NF -- INITIAL AND FINAL NODES OF THE K PATHS BEING CURRENTLY
C      BEING GENERATED
C
C      THE VARIABLE IN THE CALLING SEQUENCE:
C
C      MISERR -- 1 -- ERROR ENTERING NETWORK, A PATH COULD NOT BE FOUND
C      RETURN TO SUBROUTINE NETWORK AND ENTER THE NETWORK
C      INFORMATION
C      0 -- NO ERROR IN DETERMINING ALL PATHS
C
C*****
C      DIMENSION LLEN(1000),LINC(5000),LVAL(5000)
C      INTEGER PMAX,COUNT,DEST,SEQ
C      INTEGER ULEN(1000),UINC(5000),UVAL(5000),START,UAI,TRACK
C      COMMON/BLK1/N,MU,ML,LLEN,LINC,LVAL,ULEN,UINC,UVAL
C      COMMON/BLK2/INF,K
C      COMMON/BLK4/START(1001),INC(10000),VAL(10000),TRACK(10000)
C      COMMON/BLK6/NODE,NARCS,NPDSI,NSTAT,RO,NPZ,NBD
C      COMMON/BLK7/COUNT,PMAX
C      COMMON/BLK8/LU,LUV,IF
C*****
C      SORT FILE RAW.DAT SUCH THAT THE ARC ENDING NODES ARE IN
C      INCREASING ORDER
C*****
C      CALL ORDER(NODE,NARCS)
C      INF=99999999
C      J=0
C      NU=0
C      ML=0
C      NPREV=0
C      N=0
C*****
C      READ THE SORTED DATA FROM UNIT 12, FILE SORT.DAT AND
C      CREATE THE ARRAYS AND VARIABLES REQUIRED BY DSMF AND TRACE
C      EACH RECORD REPRESENTS AND ARC WHERE:
C      NA -- STARTING NODE
C      NB -- ENDING NODE
C      LEN -- LENGTH OF THE ARC, (DISTANCE OF TRACK SEGMENT)
C      NT -- STANAN STATION NUMBER FOR THE TRACK SEGMENT
C*****
C      OPEN(UNIT=12,IOSTAT=IOERR,STATUS='OLD',FILE='SORT.DAT')
C      IF (IOERR.NE.0) THEN
C        WRITE(6,*) 'ERROR OPENING FILE SORT.DAT'
C        CALL BOOBDIO(IOERR,*6B)
68      WRITE(6,*) 'EXECUTION TERMINATED'
C        STOP
C      ENDIF
C      DO 30 I=1,NARCS
C        READ(12,*) NB,NA,LEN,NT
C        IF(NB.GT. N) THEN
C          N=NB
C        ENDIF
C        IF(NA.GT. N) THEN
C          N=NA
C        ENDIF
C        IF(NA.NE. NPREV) THEN
C          IF (NA.NE. NPREV+1) THEN
C            L1=NPREV+1
C            L2=NA-1
C            DO 2 L=L1,L2
C              START(L)=0
C              ULEN(L)=0
C              LLEN(L)=0
2          CONTINUE
C        ENDIF
C        IF(NA.EQ. NPREV+1) THEN
C          IF (J.NE.0) THEN
C            ULEN(NPREV)=JU

```

```

        LLEN(NPREV)=JL
      ENDDIF
      START(MA)=J+1
      JU=0
      JL=0
      NPREV=NA
    ENDDIF
  ENDDIF
  J=J+1
  INC(J)=NB
  VAL(J)=LEN
  TRACK(J)=NT
  IF (NR,LT, NA) THEN
    MU=MU+1
    UINC(MU)=NB
    UVAL(MU)=LEN
    JU=JU+1
  ENDDIF
  IF (NR,GT, NA) THEN
    ML=ML+1
    LINC(ML)=NB
    LVAL(ML)=LEN
    JL=JL+1
  ENDDIF
30  CONTINUE
    START(NPREV+1)=J+1
    ULN(NPREV)=JU
    LLEN(NPREV)=JL
    K=10
    I3=500
    CLOSE(12)
C*****
C  INITIALIZE COUNT, THE SEQUENCE NUMBER COUNTER FOR THE SIMAN
C  SEQUENCE ELEMENT
C
C  OPEN THE APPROPRIATE FILE
C*****
    COUNT=1
    OPEN(13,IOSTAT=IOERR,STATUS='UNKNOWN',ORGANIZATION='RELATIVE',
    *RECL=1,ACCESS='DIRECT',FILE='SEQ.DAT')
    IF (IOERR,NE, 0) THEN
      WRITE(6,*)'ERROR OPENING FILE SEQ.DAT'
      CALL BOOB00(IOERR,**68)
    ENDDIF
    OPEN(14,IOSTAT=IOERR,STATUS='UNKNOWN',ORGANIZATION='RELATIVE',
    *RECL=4,ACCESS='DIRECT',FILE='DEST.DAT')
    IF (IOERR,NE, 0) THEN
      WRITE(6,*)'ERROR OPENING FILE DEST.DAT'
      CALL BOOB00(IOERR,**68)
    ENDDIF
    OPEN(15,IOSTAT=IOERR,STATUS='UNKNOWN',ORGANIZATION='RELATIVE',
    *RECL=1,ACCESS='DIRECT',FILE='DIST.DAT')
    IF (IOERR,NE, 0) THEN
      WRITE(6,*)'ERROR OPENING FILE DIST.DAT'
      CALL BOOB00(IOERR,**68)
    ENDDIF
    DO 130 NS=1,NODE
C*****
C  CALCULATE THE 10 SHORTEST PATH LENGTHS FROM NS TO ALL OTHER
C  NODES
C
C  RECORD THE FIRST SEQUENCE NUMBER WITH STARTING NODE NS
C  ON UNIT 13 IN SEQ.DAT
C*****
      CALL BSWP(NS,I3)
      WRITE(13,REC=NS) COUNT
      DO 123 NF=1,NODE
        IF (NF,NE, NS) THEN

```

```

C*****
C  TRACE PMAX PATHS FROM NS TO ALL OTHER NODES
C*****
      CALL TRACE(NS,NF,PMAX,COUNT,NFEST,NODE,MISERR)
      IF (MISERR .EQ. 1) THEN
        WRITE(6,*)'*** NETWORK INFORMATION IS NOT COMPLETE ***'
        WRITE(6,*)'CHECK TO MAKE SURE THE INFORMATION ABOUT
* THE'
        WRITE(6,*)'BEGINNING AND ENDING NODE OF EACH TRACK '
        WRITE(6,*)'IS CORRECT AND ENTER THE NETWORK
* INFORMATION'
        WRITE(6,*)'AGAIN.'
        WRITE(6,*)
        WRITE(6,*)'Press RET to continue.'
        READ(LU,*)
        RETURN
      ENDIF
      CONTINUE
123  CONTINUE
130  WRITE(13,REC=NODE+1) COUNT+1
      CLOSE(13)
      CLOSE(14)
      RETURN
      END
      SUBROUTINE ORDER(NODE,NARCS)
C*****
C  SUBROUTINE ORDER READS THE NETWORK INFORMATION FROM
C  RAW.DAT AND CREATES SORT.DAT WHICH KSHORT CAN READ.
C  THIS SUBROUTINE UTILIZES THE SORT/MERGE UTILITIES OF THE
C  VAX.
C  THE DATA IS SORTED SUCH THAT THE ENDING NODE IS IN INCREASING
C  ORDER AND SECONDLY SUCH THAT THE STARTING NODE IS IN INCREASING
C  ORDER.
C
C  IT IS LIKELY THAT THIS ROUTINE WILL HAVE TO BE MODIFIED IN
C  ORDER TO TRANSPORT THIS PROGRAM TO THE MICROVAX
C
C  PLEASE SEE THE VAX SORT/MERGE MANUAL FOR INFORMATION
C*****
      CHARACTER*2 INPUT
      CHARACTER*8 OUTPUT
      INTEGER*2 KEYBUF(9)
      INTEGER*4 SOR$PASS,FILES,SOR$INIT_SORT,SOR$SORT_MERGE
      INTEGER*4 SOR$END_SORT,ISTATUS
      DATA INPUT,OUTPUT/'RAW.DAT','SORT.DAT'/
      DATA KEYBUF/2,1,0,11,10,1,0,1,10/
      ISTATUS=SOR$PASS_FILES(INPUT,OUTPUT)
      IF (ISTATUS) THEN
        ISTATUS=SOR$INIT_SORT(KEYBUF)
        IF (ISTATUS) THEN
          ISTATUS=SOR$SORT_MERGE()
          IF (ISTATUS) THEN
            ISTATUS=SOR$END_SORT()
          ENDIF
        ENDIF
      ENDIF
      IF (.NOT. ISTATUS) THEN
        WRITE(6,*) ISTATUS
      ENDIF
      OPEN(UNIT=12,IOSTAT=IOERR,STATUS='OLD',FILE='SORT.DAT')
      IF (IOERR .NE. 0) THEN
        WRITE(6,*)'ERROR OPENING FILE SORT.DAT'
        CALL D00R00(IOERR,$$)
68  WRITE(6,*)'EXECUTION TERMINATED'

```

```

      STOP
    ENDIF
    CLOSE(UNIT=12)
    CLOSE(UNIT=10)
    RETURN
  END

  SUBROUTINE DSWF(NS,IMAX)
C*****
C  SUBROUTINE DSWF IMPLEMENTS THE DOUBLE SWEEP ALGORITHM
C  AND CALCULATES THE 10 SHORTEST PATH LENGTHS AND STORES
C  THEM IN ARRAY X. (PATH LENGTHS MAY BE PRINTED TO UNIT 6
C  IF COMMENT DESIGNATION IS REMOVED FROM THE APPROPRIATE
C  STATEMENTS)
C
C  THE VARIABLES IN THE CALLING SEQUENCE ARE
C    NS - SOURCE NODE, NODE FROM WHICH ALL PATHS START
C    IMAX - MAXIMUM NUMBER OF ITERATION ALLOWED FOR THE DOUBLE
C          SWEEP ALGORITHM
C
C  THE VARIABLES IN COMMON ARE:
C    N - NUMBER OF NODES IN THE NETWORK (<1000)
C
C    MU - NUMBER OF ARCS (I,J) SUCH THAT I < J (<5000)
C    ML - NUMBER OF ARCS (I,J) SUCH THAT I > J (<5000)
C    LLEN - ARRAY WHOSE JTH ENTRY IS THE NUMBER OF ARCS (I,J),J
C          WITH J < I
C    LINC - ARRAY CONTAINING THE NODES I INCIDENT TO NODE J WITH
C          I > J, LISTED IN INCREASING ORDER OF J
C    LVAL - ARRAY CONTAINING THE ARC LENGTH VALUES CORRESPONDING
C          TO ARCS IN LINC
C    ULEN - ARRAY WHOSE JTH ENTRY IS THE NUMBER OF ARCS (I,J),I
C          WITH I < J
C    UINC - ARRAY CONTAINING THE NODES I INCIDENT TO NODE J WITH
C          I < J, LISTED IN ORDER OF INCREASING J
C    UVAL - ARRAY CONTAINING THE ARC LENGTH VALUES CORRESPONDING
C          TO ARCS IN UINC
C    INF - A NUMBER LARGER THAN ANY PATH LENGTH. NON-EXISTENT
C          PATHS ARE ASSIGNED THE LENGTH INF.
C
C    X - ARRAY WHOSE (I,J)TH ENTRY WILL CONTAIN THE JTH
C        SHORTEST DISTINCT PATH LENGTH FROM NODE NS TO NODE I
C
C  ADDITIONAL VARIABLES
C    ITNS - NUMBER OF ITERATIONS PERFORMED
C    INDX - VARIABLE RETURNED FROM XMULT WHICH =1 IF CONVERGENCE
C          WAS OBTAINED OTHERWISE IT =0
C*****
    DIMENSION LLEN(1000),LINC(5000),LVAL(5000)
    INTEGER ULEN(1000),UINC(5000),UVAL(5000),X
    LOGICAL CNT
    COMMON/BLK1/N,MU,ML,LLEN,LINC,LVAL,ULEN,UINC,UVAL
    COMMON/BLK2/INF,K
    COMMON/BLK3/X(1000,20)
    NI=N-1
C*****
C    THE INITIAL APPROXIMATION OF X IS MADE
C*****
    DO 20 I=1,N
      DO 20 J=1,K
        X(I,J)=INF
      20 CONTINUE
    X(NS,1)=0
    ITNS=1

```



```

      CNT=.TRUE.
C*****
C      ALTERNATELY MULTIPLY THE UPPER AND LOWER TRIANGULAR
C      PORTIONS OF THE ARC LENGTH MATRIX WITH X UNTIL THERE IS
C      CONVERGENCE OF X (A PATH IS FOUND) OR THE NUMBER OF ITERATIONS
C      EXCEEDS THE MAXIMUM ALLOWABLE (IMAX)
C*****
      DO WHILE(ITNS .LE. IMAX .AND. CNT)
        IFIN=ML
        INDX=1
C*****
C      THE CURRENT X IS MODIFIED THROUGH MATRIX MULTIPLICATION WITH
C      THE LOWER TRIANGULAR PORTION OF THE ARC LENGTH MATRIX
C*****
        DO 40 I=N1,1,-1
          IF (LLEN(I) .NE. 0) THEN
            IS=IFIN-LLEN(I)+1
            CALL XMULT(I,IS,IFIN,LINC,LVAL,INDX)
            IFIN=IS-1
          ENDIF
40      CONTINUE
          IF (ITNS .NE. 1) THEN
            IF (INDX .EQ. 1) THEN
              CNT=.FALSE.
            ENDIF
          ENDIF
          IF (CNT) THEN
            ITNS=ITNS+1
            IS=1
            INDX=1
C*****
C      THE CURRENT X IS MODIFIED THROUGH MATRIX MULTIPLICATION WITH
C      THE UPPER TRIANGULAR PORTION OF THE ARC LENGTH MATRIX
C*****
            DO 60 I=2,N
              IF (ULEN(I) .NE. 0) THEN
                IFIN=IS+ULEN(I)-1
                CALL XMULT(I,IS,IFIN,UINC,UVAL,INDX)
                IS=IFIN+1
              ENDIF
60      CONTINUE
              IF (INDX .NE. 1) THEN
                ITNS=ITNS+1
              ELSE
                CNT=.FALSE.
              ENDIF
            ENDIF
          ENDIF
          IF (ITNS .LT. IMAX) THEN
            WRITE(6,200) K,NS
C900      FORMAT(1H1,10X,'K= ',I3,1X,'SHORTEST PATH LENGTHS FROM NODE',
C      *I4//,2X,'TO',1X,'NODE')
C      DO 130 I=1,N
C902      WRITE(6,202) I,(X(I,J),J=1,K)
C130      FORMAT(' ',I3,6X,(10I5))
C      CONTINUE
C903      WRITE(6,203) ITNS
C      FORMAT(//1H0,'NO. OF ITNS. REQUIRED FOR CONVERGENCE =',I5)
C901      ELSE
        WRITE(6,201) IMAX
        FORMAT('NO. OF ITNS EXCEEDS ',I5)
      ENDIF

```

200 RETURN
 END

```

SUBROUTINE XMULT(I,IS,IFIN,INC,VAL,INDX)
*****
C
C   SUBROUTINE XMULT PERFORMS THE APPROPRIATE MATRIX MULTIPLICATION
C   OF X BY THE ITH COLUMN OF THE LOWER (OR UPPER) PORTION OF THE
C   ARC LENGTH MATRIX.
C   ESSENTIALLY, THE CURRENT K SHORTEST PATH LENGTHS ASSOCIATED
C   WITH NODE I ARE ADJUSTED BY CONSIDERING NODES WHICH ARE
C   INCIDENT TO NODE I. IF AN IMPROVEMENT CAN BE MADE, THE VAR
C   VARIABLE INDX WILL RETURN WITH THE VALUE 0.
C
C   THE VARIABLES AND ARRAYS IN THE CALLING SEQUENCE ARE
C   I    - COLUMNS OF THE ARC LENGTH MATRIX TO BE MULTIPLIED ON
C         ON THE LEFT BY X. THE CURRENT K SHORTEST PATH LENGTHS
C         WILL BE IMPROVED IF POSSIBLE
C
C   IS   - STARTING POSITIONS IN LISTS INC AND VAL WHERE ARC
C         INFORMATION FOR NODE I CAN BE FOUND
C   IFIN  - THE FINAL POSITION IN LISTS INC AND VAL WHERE ARC
C         INFORMATION FOR NODE I CAN BE FOUND
C   INC   - ARRAY CONTAINING NODE INCIDENCE INFORMATION, EITHER
C         LINC OR UINC
C   VAL   - ARRAY CONTAINING ARC LENGTH INFORMATION, EITHER
C         LVAL OR UVAL
C   INDX  - VARIABLE WHICH IS SET EQUAL TO 0 IF AN IMPROVEMENT
C         CAN BE MADE IN THE K SHORTEST PATH LENGTHS TO NODE I
C
C   THE VARIABLES AND ARRAYS IN COMMON ARE:
C   INF   - A NUMBER LARGER THAN ANY PATH LENGTH
C   K     - THE NUMBER OF DISTINCT PATH LENGTHS REQUIRED
C   X     - CURRENT APPROXIMATION MATRIX FOR K SHORTEST PATH LENGTHS
C         FROM A GIVEN NODE TO ALL NODES OF THE NETWORK
C
C   ADDITIONAL VARIABLE AND ARRAYS ARE:
C   A     - AUXILIARY ARRAY USED IN FINDING THE K SMALLEST DISTI
C         DISTINCT ELEMENTS OF A SET
C   MAX   - THE CURRENT MAXIMUM ELEMENT OF ARRAY A
C   IXV   - A FEASIBLE PATH LENGTH TO NODE I FROM THE GIVEN NODE
C
C*****
C   DIMENSION INC(5000)
C   INTEGER VAL(5000),A(20),X
C   LOGICAL LINMX,NOTED
C   COMMON/BLK2/INF,K
C   COMMON/BLK3/X(1000,20)
C*****
C   INITIALIZE A TO THE CURRENT K SHORTEST PATH LENGTHS FOR NODE
C   I, IN STRICTLY INCREASING ORDER
C*****
C   DO 10 J=1,K
C      A(J)=X(I,J)
C   10  CONTINUE
C      MAX=A(K)
C*****
C   EACH NODE OF INC INCIDENT TO NODE I IS EXAMINED
C*****
C   DO 100 L=IS,IFIN
C      II=INC(L)
C      IV=VAL(L)
C      LINMX=.TRUE.
C      M=1

```

```

DO WHILE (LINMX .AND. M .LE. K)
  NOTED=.TRUE.
  IX=X(I,I,M)
C*****
C
C  TEST TO SEE IF IXV CAN BE INSERTED IN TO A
C*****
  IF (IX .GE. INF) THEN
    LINMX=.FALSE.
  ELSE
    IXV=IX+IV
    IF (IXV .GE. MAX) THEN
      LINMX=.FALSE.
    ELSE
      JI=0
      J=K
      NOTEND=.TRUE.
C*****
C
C  IDENTIFY THE POSITION INTO WHICH IXV CAN BE INSERTED
C*****
      DO WHILE (NOTEND .AND. J .GE. 2)
        IF (IXV .GT. A(J-1)) THEN
          JI=J
          NOTEND=.FALSE.
        ELSEIF (IXV .EQ. A(J-1)) THEN
          NOTED=.FALSE.
          NOTEND=.FALSE.
        ENDIF
        J=J-1
      ENDDO
C*****
C
C  INSERT IXV INTO THE APPROPRIATE POSITION
C*****
      IF (NOTED) THEN
        IF (JI .EQ. 0) THEN
          JI=1
        ENDIF
        JJ=K
        DO WHILE (JJ .GT. JI)
          A(JJ)=A(JJ-1)
          JJ=JJ-1
        ENDDO
        A(JI)=IXV
        INDX=0
        MAX=A(K)
      ENDIF
      M=M+1
    ENDIF
  ENDDO
100  CONTINUE
C*****
C
C  IF AN INSERTION HAS BEEN MADE, UPDATE THE K SHORTEST PATHS
C  LENGTHS TO NODE I
C*****
  IF (INDX .EQ. 0) THEN
    DO 110 J=1,K
      X(I,J)=A(J)
110  CONTINUE
  ENDIF
120  RETURN

```

```

END

SUBROUTINE TRACE(NS,NF,PMAX,COUNT,NFDST,NONE,MISERR)
C*****
C
C SUBROUTINE TRACE WILL TRACE OUT THE PATHS CORRESPONDING TO I TO
C THE K DISTINCT, NON-CYCLIC SHORTEST PATH LENGTHS FROM NODE
C NS TO NF. AT MOST PMAX SUCH PATHS WILL BE GENERATED. ONLY
C PATHS HAVING LESS THAN 5000 ARCS WILL BE GENERATED. AN ERROR
C MESSAGE WILL INDICATE WHEN THIS CONDITION IS NOT FULFILLED.
C THE REQUIRED PATHS ARE WRITTEN TO THE SEQUENCE ELEMENT ON UNIT
C 4 AND THE PARAMETERS ELEMENT ON UNIT 3 FOR THE EXPERIMENT FILE.
C THE SHORTEST DISTANCE BETWEEN ALL PAIRS OF NODES IS WRITTEN
C TO DIST.DAT.
C
C THE VARIABLES OF THE CALLING SEQUENCE ARE
C NS,NF - INITIAL AND FINAL NODES OF ALL KSHORTEST PATHS
C        BEING GENERATED.
C PMAX - MAXIMUM NUMBER OF PATHS TO BE GENERATED BETWEEN
C        NODES NS AND NF
C COUNT - SEQUENCE NUMBER OF THE PATH GENERATED
C NFDST - NUMBER OF STATIONS IN THE NETWORK
C NONE - NUMBER OF NODES IN THE NETWORK
C MISERR - 1 - ERROR ENTERING NETWORK, A PATH COULD NOT BE FOUND
C          RETURN TO SUBROUTINE NETWORK AND REENTER THE NETWORK
C          INFORMATION
C          0 - NO ERROR IN DETERMINING ALL PATHS
C
C VARIABLES AND ARRAYS IN COMMON ARE
C INF - A NUMBER LARGER THAN ANY PATH LENGTH
C K - THE NUMBER OF DISTINCT PATHS REQUIRED
C X - ARRAY WHOSE (I,J)TH ENTRY IS THE JTH SHORTEST
C    PATH LENGTH FROM NODE NS TO NODE I
C START - AN ARRAY WHOSE JTH ELEMENT INDICATES THE FIRST
C         POSITION ON INC WHERE NODE INCIDENT TO J ARE LISTED
C INC - ARRAY CONTAINING NODE I WHICH ARE INCIDENT TO J
C VAL - ARRAY CONTAINING THE ARC LENGTH VALUES CORRESPONDING
C       TO ARCS IN INC
C TRACK - ARRAY CONTAINING THE SIMAN STATION NUMBER OF THE ARC
C
C ADDITIONAL VARIABLES AND ARRAYS ARE
C JJ - INDEX OF THE PATH LENGTH FROM NS TO NF BEING EXPLORED
C NP - NUMBER OF PATHS FROM NS TO NF ALREADY FOUND
C KK - CURRENT POSITION OF LIST P
C P - ARRAY CONTAINING NODES ON A POSSIBLE PATH FROM NS TO NF
C Q - ARRAY WHOSE ITH ELEMENT GIVES THE POSITION RELATIVE
C    TO START, OF NODE P(I) ON THE INC LIST FOR P(I-1)
C PV - ARRAY WHOSE ITH ELEMENT IS THE ARC LENGTH EXTENDING
C      FROM NODE P(I) TO NODE P(I-1)
C*****
C INTEGER TRACK,COUNT
C INTEGER P(5000),Q(5000),PV(5000),START,VAL,X,PMAX,I(5000)
C LOGICAL TUSO,T070,T080,OUT,CNT,SKIP
C COMMON/BLK2/INF,K
C COMMON/BLK3/X(1000,20)
C COMMON/BLK4/START(1001),INC(10000),VAL(10000),TRACK(10000)
C COMMON/BLK8/LU,LUV,IP
C*****
C
C INITIALIZATION PHASE
C
C DO 10 I=1,5000
C   P(I)=0
C   Q(I)=0
C   PV(I)=0
10 CONTINUE

```

```

      JJ=1
      IF (NS .EQ. NF) THEN
        JJ=2
      ENDIF
      NF=0
      IF (X(NF,JJ) .GE. INF) THEN
        WRITE(6,909) NS,NF
909      FORMAT(1H1,'THERE ARE NO PATHS FROM NODE',I4,'TO ',I4)
        MISERR=1
        RETURN
      ENDIF
C15      WRITE(6,901) NS,NF
C901      FORMAT('///','THE K SHORTEST PATHS FROM NODE',I4,'TO ',I4//1H0,
C          *'PATH LENGTH NODE SEQUENCE'//)
C*****
C          THE JJTH DISTINCT PATH LENGTH IS BEING EXPLORED
C*****
      DO WHILE (JJ .LE. K)
        KK=1
        LAB=X(NF,JJ)
        IF (LAB .EQ. INF) THEN
          RETURN
        ENDIF
        LL=LAB
        P(1)=NF
        CNT=.TRUE.
        LAST=0
C*****
C          NODE INCIDENT TO NODE P(KK) ARE SCANNED
C*****
        DO WHILE (CNT)
          NT=P(KK)
          IS=START(NT)
          ND=NT
          DO 45 WHILE (ND .LE. 1000 .AND. START(ND+1) .EQ. 0)
            ND=ND+1
45          CONTINUE
48          ISF=START(ND+1)-1
          II=IS+LAST
          T050=.TRUE.
          T080=.FALSE.
          DO WHILE (II .LE. ISF .AND. T050 .AND. .NOT. T080)
            NI=INC(II)
            NV=VAL(II)
            NT=TRACK(II)
            LT=LAB-NV
            J=1
            T070=.FALSE.
            OUT=.FALSE.
C*****
C          TEST TO SEE IF THE CURRENT PATH CAN BE EXTENDED BACK TO
C          NODE NI AND TEST TO MAKE SURE THE PATH DOES NOT HAVE A CYCLE
C*****
            DO 30 WHILE (J.LE.K .AND. .NOT. OUT)
              IF (X(NI,J) .EQ. LT) THEN
                DO 181 IA=1+KK
                  IF (NI .EQ. P(IA)) THEN
                    OUT=.TRUE.
                    T070=.TRUE.
                  ENDIF
                CONTINUE
                OUT=.TRUE.
181              CONTINUE
            30 CONTINUE
          ENDIF
          T070=.FALSE.
          OUT=.FALSE.
          CNT=.NOT. CNT
        END DO
        JJ=JJ+1
      END DO

```

```

        IF (T070) THEN
            T080=.FALSE.
        ELSE
            T080=.TRUE.
        ENDIF
    ENDIF
    IF (X(NI,J) .GT. LT) THEN
        OUT=.TRUE.
        T070=.TRUE.
    ENDIF
    IF (X(NI,J) .LT. LT) THEN
        J=J+1
    ENDIF
60    CONTINUE
    IF (T070) THEN
        II=II+1
        T050=.TRUE.
    ELSE
        T050=.FALSE.
    ENDIF
    ENDDO
    SKIP=.FALSE.
    IF (II .LE. ISF) THEN
        KK=KK+1
        IF (KK .GT. 5000) THEN
911    WRITE(6,911)
            FORMAT(1H0,'NO. OF ARCS IN PATH EXCEEDS 5000')
            RETURN
        ENDIF
        P(KK)=NI
        T(KK)=NT
        Q(KK)=II-IS+1
        PV(KK)=NV
        LAB=LT
        IF (LAB .NE. 0) THEN
            SKIP=.TRUE.
            LAST=0
        ENDIF
        IF (NI .NE. NS) THEN
            SKIP=.TRUE.
            LAST=0
        ENDIF
        IF (.NOT. SKIP) THEN
            NP=NP+1
            ITEMP=(KK-1)*2
C*****
C    WRITE THE ENDING NODE OF THE PATH TO DEST.DAT ON UNIT 14
C*****
            WRITE(14,REC=COUNT) NP,IP,ITEMP
C*****
C    WRITE(6,*) NP,(P(J),J=KK,1,-1)
C    IF (ITEMP .GT. 13) THEN
C        I13=13
C        IVE=ITEMP/I13
C        IVE2=JMOD(ITEMP,I13)
C        IF (IVE2 .GE. 1) THEN
C*****
C    WRITE THE PATH TO THE SEQUENCE ELEMENT OF THE SIHAN EXPERIMENT
C    FILE
C*****
C*****
            WRITE(4,903) COUNT,(P(J),I(J),J=KK,2,-1),P(1)
903    FORMAT(14,' ',<IVE>(13(I3,'/'),/),<IVE2>(13,'/'),
            *I3,';')
C*****
C

```

```

C      WRITE THE PATH TO THE PARAMETER ELEMENT OF THE SIMAN
C      EXPERIMENT FILE
C
C*****
901  *I3,'')
      ELSE
905  *I3,'')
      WRITE(3,906) IP,(P(J),T(J),J=KK,2,-1),P(1)
906  *I3,'')
      FORMAT(I6,'',<IUF>(I3(I3,''),/),<IUF2>(I3,''),
      WRITE(4,905) COUNT,(P(J),T(J),J=KK,2,-1),P(1)
      FORMAT(I6,'',<IUF-1>(I3(I3,''),/),I3,I3(''),
      WRITE(3,906) IP,(P(J),T(J),J=KK,2,-1),P(1)
      FORMAT(I6,'',<IUF-1>(I3(I3,''),/),I3,I3(''),
      ENDIF
      ELSE
902  WRITE(4,902) COUNT,(P(J),T(J),J=KK,2,-1),P(1)
      FORMAT(I6,'',I3,<ITEMP>('',I3),'')
900  WRITE(3,900) IP,(P(J),T(J),J=KK,2,-1),P(1)
      FORMAT(I6,'',I3,<ITEMP>('',I3),'')
      ENDIF
      IP=IP+1
      COUNT=COUNT+1
      IRCL=(NS-1)*NODE+NF
      WRITE(38,REC=IRCL)X(NF,1)
      IF(NP.GE.PNAX) THEN
        RETURN
      ENDIF
      ENDIF
      ENDIF
      IF (.NOT. SKIP) THEN
        LAST=0(KK)
        F(KK)=0
        T(KK)=0
        LAB=LAB+PV(KK)
        KK=KK-1
        IF(KK.GT. 0) THEN
          CNT=.TRUE.
        ELSE
          CNT=.FALSE.
        ENDIF
      ENDIF
      ENDIF
      ENDDO
      JJ=JJ+1
100  ENDDO
      RETURN
      END

```

```

      AGVLOAD.FOR
      SUBROUTINE LOAD1
C*****
C      SUBROUTINE LOAD1 PROMPTS FOR INPUT REQUIRED FOR PICK/DROP #1.
C      THIS SUBROUTINE IS CALLED FROM SUBROUTINE INPUT.
C
C      VARIABLES
C
C      DISTYP -- DISTRIBUTION TYPE FOR THE TIME BETWEEN ARRIVALS, EITHER
C              CONSTANT ('CO') OR TRIANGULAR ('TR')
C      FROM -- ORIGINATION OF A FROM/TO PAIR, SIMAN STATION NUMBER
C      IP -- CURRENT INDEX INTO THE SIMAN PARAMETERS ELEMENT
C      MAX -- MAXIMUM OF THE TRIANGULAR DISTRIBUTION
C      MIN -- MINIMUM OF THE TRIANGULAR DISTRIBUTION
C      SHIFT -- NUMBER OF TIME UNITS IN A SHIFT
C      STNO -- STATION NUMBER
C      STYP -- STATION TYPE, IN THIS SUBROUTINE THE VALUES IS ONLY 'SC'
C      TBA -- TIME BETWEEN ARRIVALS OR LOADS, EXPRESSED IN TIME UNITS
C      TBW -- TOLERANCE BAND WIDTH EXPRESSED IN TIME UNITS
C      TO -- DESTINATION OF A FROM/TO PAIR, SIMAN STATION NUMBER
C*****
      COMMON/BLK6/NODE,NTRAKST,NPDST,NSTAT,BD,NFZ,NRD
      COMMON/BLK8/LU,LUM,IF
      INTEGER FROM,TO,LEA,TBW,SHIFT,STNO,ESTNO,IOTLOAD,TRANS
      CHARACTER*1 STYP,ESTYP,DISTYP*2
C*****
C      CLEAR THE SCREEN
C*****
      IESC=27
      WRITE(LUM,1001)IESC,IESC
1001  FORMAT(1X,A,'CO:OH',A,'C2J')
C*****
C      READ THE NUMBER OF TIME UNITS IN A SHIFT
C*****
1    WRITE(LUM,1909)
1909  FORMAT('$','Number of time units in a shift: ')
      READ(LU,*,IOSTAT=IOERR)SHIFT
      WRITE(LUM,*)
      IF (IOERR .NE. 0) CALL BOOBOO(IOERR,*1)
C*****
C      OPEN MODEL FILE
C*****
      OPEN(UNIT=21,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='A)NITS.MOD')
      IF (IOERR .NE. 0) THEN
        WRITE(6,*)'ERROR OPENING FILE AINITS.MOD'
        CALL BOOBOO(IOERR,*48)
68    WRITE(6,*)'EXECUTION TERMINATED'
        STOP
      ENDIF
C*****
C      ENTER ALL FROM/TO PAIRS, THE NUMBER OF LOADS PER SHIFT AND
C      THE TOLERANCE BAND WIDTH. ENTER 'X' WHEN ALL FROM/TO INFORMATION
C      HAS BEEN ENTERED.
C*****
      WRITE(LUM,*)'Please enter the FROM/TO pairs and the number of
      WRITE(LUM,*)'loads during a shift for each FROM/TO pair.'
      WRITE(LUM,*)
      WRITE(LUM,*)'Please remember that the naming convention is as
      * follows:'
      WRITE(LUM,*)
      WRITE(LUM,*)'S5 - station 5'
      WRITE(LUM,*)'S10 - station 10'
      WRITE(LUM,*)
      WRITE(LUM,*)'Enter X when all FROM/TO pairs have been entered.'
      DO WHILE (STYP .NE. 'X')
        WRITE(LUM,*)

```



```

2      WRITE(LUW,1971)
1971  FORMAT('$','Pickup Station ( X to end): ')
      READ(LU,1972,IOSTAT=IOERR) STTYP,STNO
      IF (IOERR.NE. 0) CALL BOOBDU(IOERR,*2)
      IF (STTYP.NE. 'X') THEN
        FROM=TRANS(STTYP,STNO,NODERR)
      ENDIF
      IF (NODERR.EQ. 1) GOTO 2
1972  FORMAT(A,15)
C*****
C      IF 'X' HAS NOT BEEN ENTERED THEN READ THE DROPOFF STATION
C*****
      IF (STTYP.NE. 'X') THEN
3      WRITE(LUW,1973)
1973  FORMAT('$',' Dropoff Station: ')
      READ(LU,1973,IOSTAT=IOERR) ESTTYP,ESTNO
      IF (IOERR.NE. 0) CALL BOOBDU(IOERR,*3)
      TO=TRANS(ESTTYP,ESTNO,NODERR)
      IF (NODERR.EQ. 1) GOTO 3
4      WRITE(LUW,1974)
1974  FORMAT('$',' Number of loads per shift: ')
      READ(LU,4,IOSTAT=IOERR) NL
      IF (IOERR.NE. 0) CALL BOOBDU(IOERR,*4)
C*****
C      DEFINE THE TIME BETWEEN ARRIVALS (OR LOADS) TO BE THE NUMBER OF TIME
C      UNITS IN A SHIFT DIVIDED BY THE NUMBER OF LOADS TO OCCUR IN A SHIFT
C*****
      TBA=SHIFT/NL
      WRITE(LUW,1991)STTYP,STNO,ESTTYP,ESTNO
1991  FORMAT(1X,'Requests for transfer from ',A,I4,' TO ',A,I4)
      WRITE(LUW,1992)TBA
1992  FORMAT(1X,'will occur every',I6,' time units,')
      WRITE(LUW,*)
C*****
C      READ THE TOLERANCE BAND WIDTH
C*****
99      WRITE(LUW,2018)
2018  FORMAT('$','Enter the tolerance band width: ')
      READ(LU,99,IOSTAT=IOERR)TRW
      IF (IOERR.NE. 0) CALL BOOBDU(IOERR,*99)
C*****
C      TO ENSURE THAT A NEGATIVE TIME BETWEEN ARRIVALS IS NOT POSSIBLE,
C      THE TOLERANCE BAND WIDTH (TRW) MUST BE LESS THAN THE TIME BETWEEN
C      ARRIVALS (TBA)
C*****
      IF (TRW.GT. TBA) THEN
        WRITE(LUW,*)'*** TOLERANCE BAND WIDTH MUST BE LESS THAN'
        WRITE(LUW,*)TBA,' PLEASE ENTER AGAIN ***'
        GOTO 99
      ENDIF
C*****
C      IF THE TOLERANCE BAND WIDTH IS 0, THEN THE TIME BETWEEN ARRIVALS IS
C      CONSTANT, WRITE THIS INFORMATION TO THE MODEL FILE
C*****
      IF (TRW.EQ. 0) THEN
        DISTYP='CO'
        WRITE(3,2019) IF,TBA
2019  FORMAT(16,' ',I6,' ')
        WRITE(21,2023) DISTYP,IF
2023  FORMAT(9X,'CREATE',A,'('',I6,'')':MARK(7)')
C*****
C      IF THE TOLERANCE BAND WIDTH IS GREATER THAN 0, THEN THE TIME
C      BETWEEN ARRIVALS IS TRIANGULAR DISTRIBUTED, WRITE THIS
C      INFORMATION TO THE MODEL FILE.
C*****
      ELSE
        DISTYP='TR'
        MIN=TBA-TRW

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```

                MAX=TRA+TRW
                WRITE(3,2029) IP,MIN,TRA,MAX
                FORMAT(15,3(' ',15),':')
                WRITE(21,2024) DUSTYP,IP
2024             FORMAT(9X,'CREATE:',A,'(',16,',5)MARK(7):')
            ENDIF
C*****
C             WRITE THE ASSIGNMENT STATEMENTS TO THE MODEL FILE THAT DEFINE
C             THE PICKUP AND DROPOFF POINTS OF EACH LOAD.
C*****
                WRITE(21,2022)FROM
                FORMAT(9X,'ASSIGN:A(1)=',15,':')
2022             WRITE(21,2021)TO
2021             FORMAT(9X,'ASSIGN:A(2)=',15,':NEXT(START):')
                IP=IP+1
            ENDIF
        ENDDO
        CLOSE(21)
        RETURN
    END
C*****
C
C             SUBROUTINE LOAD2
C
C             THIS SUBROUTINE PROMPTS FOR INFORMATION PERTAINING TO PICK/DROP
C             TASK #3. IT IS CALLED FROM SUBROUTINE INPUT. LOAD2 CALLS
C             SUBROUTINE ARRIVE. TWO WORKING DATA FILES ARE CREATED IN THIS
C             SUBROUTINE, LOAD2.DAT AND LOAD2A.DAT.
C
C             VARIABLES:
C
C             DEC      - DECIMAL REPRESENTATION OF XNL
C             FROM     - ORIGINATION OF A FROM/TO PAIR, SIMAN STATION NUMBER
C             IND       - COUNTS THE NUMBER OF FROM/TO PAIRS THAT ARE ENTERED
C             IP        - INDEX OF THE SIMAN PARAMETERS ELEMENT
C             FL        - USED TO CHECK TO SEE IF THE PERCENTAGES ENTERED ADD TO 1
C             STNO      - STATION NUMBER
C             STYP       - STATION TYPE, ONLY 'S' FOR THIS SUBROUTINE
C             TO        - DESTINATION OF A FROM/TO PAIR, SIMAN STATION NUMBER
C             XNL        - RELATIVE FREQUENCY OF A PARTICULAR FROM/TO PAIR, EXPRESSED
C                       AS A PERCENT OF ALL LOADS
C*****
C             COMMON/BLK6/NODE,NTRAKST,NPDST,NSTAT,RD,NF2,NRD
C             COMMON/BLK8/LU,LUW,IP
C             REAL P1,P2,PL
C             INTEGER FROM,TO,STNO,ESTNO,TRANS
C             CHARACTER*1 DUSTYP*2,STYP,ESTYP
C             LOGICAL EQUAL1
C*****
C             OPEN DATA FILES LOAD2A.DAT AND LOAD2.DAT
C*****
1             OPEN(24,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='LOAD2A.DAT')
            IF (IOERR .NE. 0) THEN
                WRITE(6,*)'ERROR OPENING FILE LOAD2A.DAT'
                CALL R00B000(IOERR,*68)
58             WRITE(6,*)'EXECUTION TERMINATED'
                STOP
            ENDIF
            OPEN(22,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='LOAD2.DAT')
            IF (IOERR .NE. 0) THEN
                WRITE(6,*)'ERROR OPENING FILE LOAD2.DAT'
                CALL R00B000(IOERR,*68)
            ENDIF
C*****
C             INITIALIZE COUNTER IND AND VARIABLE PL
C*****
            IND=1

```

```

      FL=0
C*****
C      CLEAR THE SCREEN
C*****
      IESC=27
      WRITE(LUW,1001) IESC, IESC
1001    FORMAT(IX,A,'E0;0H',A,'E2J')
C*****
C      ENTER THE FROM/TO PAIRS AND THEIR RELATIVE FREQUENCIES
C*****
      WRITE(LUW,*) 'Please enter the FROM/TO pairs and the Percent
      * of total loads that are for this FROM/TO pair.'
      WRITE(LUW,*)
      WRITE(LUW,*) 'Enter X when all FROM/TO pairs have been entered.'
      WRITE(LUW,*)
      DO WHILE (STYP .NE. 'X')
        WRITE(LUW,*)
C*****
C      ENTER AND READ THE PICKUP STATION
C*****
      WRITE(LUW,1971)
1971    FORMAT('$','Pickup Station ( X to end): ')
      READ(LU,1972,IOSTAT=IOERR) STYP,STNO
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*2)
C*****
C      IF 'X' IS ENTERED THEN ALL PAIRS HAVE BEEN ENTERED
C*****
      IF (STYP .NE. 'X') THEN
        FROM=TRANS(STYP,STNO,NODERR)
        IF (NODERR .EQ. 1) GOTO 2
1972    FORMAT(A,15)
C*****
C      ENTER AND READ THE DROPOFF STATION
C*****
      WRITE(LUW,1973)
1973    FORMAT('$','Dropoff Station: ')
      READ(LU,1972,IOSTAT=IOERR) ESTYP,ESTNO
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*3)
      TO=TRANS(ESTYP,ESTNO,NODERR)
      IF (NODERR .EQ. 1) GOTO 3
C*****
C      ENTER THE RELATIVE FREQUENCY
C*****
      WRITE(LUW,1974)
1974    FORMAT('$','Percent of TOTAL LOADS: ')
      READ(LU,*,IOSTAT=IOERR) XNL
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*4)
C*****
C      ADD RELATIVE FREQUENCY TO THE CUMULATIVE FREQUENCY
C*****
      PL=XNL+PL
C*****
C      WRITE FROM/TO INFORMATION TO TEMPORARY FILE
C*****
      WRITE(22,5030) FROM,TO
5030    FORMAT(I10,I10)
      DEC=PL/100.
C*****
C      WRITE FREQUENCY INFORMATION TO TEMPORARY FILE
C*****
      WRITE(24,4020) DEC,IND
4020    FORMAT(F7.3,I6)
      IND=IND+1
      ENDDO
      PL=PL/100.
C*****
C      DID CUMULATIVE FREQUENCY EXCEED 1.0?

```

```

C      IF YES, PLEASE ENTER FROM/TO INFORMATION AGAIN.
C*****
      IF (PL.GT. 1.0) THEN
        WRITE(LUN,*)'*** TOTAL EXCEED 100%. PLEASE ENTER AGAIN ***'
        STYPE=5
        CLOSE(22)
        CLOSE(24)
        GO TO 1
      ENDIF
      CLOSE(22)
      CLOSE(24)
      OPEN(22, IOSTAT=IOERR, STATUS='OLD', NAME='LOAD2.DAT')
      IF (IOERR.NE. 0) THEN
        WRITE(6,*)'ERROR OPENING FILE LOAD2.DAT'
        CALL BOOROO(IOERR,*68)
      ENDIF
C*****
C      WRITE THE TABLE ELEMENT WHICH STORE THE
C      RELATIVE FREQUENCY OF THE FROM/TO PAIRS
C      ONE TABLE STORE THE BEGINNING POINT THE
C      OTHER TABLE STORES THE DESTINATION POINT
C*****
      WRITE(4,*)'1,1.0,1.0,'
      DO 10 I=1,IND-2
        READ(22,5035) FROM
        FORMAT(I10)
        WRITE(4,5040) FROM
        FORMAT(I5,' ')
5035      CONTINUE
5040      READ(22,5035) FROM
        WRITE(4,5045) FROM
        FORMAT(I5,' ')
5045      CLOSE(22)
      WRITE(4,*)'2,1.0,1.0,'
      OPEN(22, IOSTAT=IOERR, STATUS='OLD', NAME='LOAD2.DAT')
      IF (IOERR.NE. 0) THEN
        WRITE(6,*)'ERROR OPENING FILE LOAD2.DAT'
        CALL BOOROO(IOERR,*68)
      ENDIF
      DO 20 I=1,IND-2
        READ(22,5050) TO
        FORMAT(I10)
        WRITE(4,5040) TO
5050      CONTINUE
        READ(22,5050) TO
        WRITE(4,5055) TO
        FORMAT(I5,' ')
5055      OPEN(24, IOSTAT=IOERR, STATUS='OLD', NAME='LOAD2A.DAT')
        IF (IOERR.NE. 0) THEN
          WRITE(6,*)'ERROR OPENING FILE LOAD2A.DAT'
          CALL BOOROO(IOERR,*68)
        ENDIF
C*****
C      ENTER THE ARRIVAL PATTERN OF LOADS
C      CALL SUBROUTINE ARRIVE
C*****
      CALL ARRIVE
      WRITE(3,5020) IP
5020      FORMAT(I6,' ')
C*****
C      WRITE THE FREQUENCY INFORMATION TO THE PARAMETERS ELEMENT
C*****
      DO 30 I=1,IND-1
        READ(24,4020) PL,IND
        IF (PL.NE. 1.0) THEN
          WRITE(3,5402) PL,IND
          FORMAT(F7.3,' ','16',' ')
5402        ELSE

```

```

      WRITE(3,4025) FL,IND
      FORMAT(F7.3,' ',Y6,' ')
4025      ENDIF
30      CONTINUE
C*****
C      WRITE ASSIGNMENT STATEMENTS TO MODEL FILE
C*****
      WRITE(21,5060) IP
5060      FORMAT(2X,'ASSIGN:J=IP(',I6,',4)')
      WRITE(21,*)'      ASSIGN:A(1)=IF(1,J);'
      WRITE(21,*)'      ASSIGN:A(2)=IF(2,J);'
      IP=IP+1
      RETURN
      END
C*****
C      SUBROUTINE LOAD3
C
C      THIS SUBROUTINE PROMPTS FOR INFORMATION PERTAINING TO PICK/DROP
C      TASK #2. THE SUBROUTINE IS CALLED FOR SUBROUTINE INPUT.
C
C      VARIABLES:
C
C      ESTYP - STATION TYPE, ONLY POSSIBLE VALUE IS 'S' IN THIS ROUTINE
C      IP - INDEX INTO THE PARAMETERS ELEMENT
C      MAX - MAXIMUM OF THE TRIANGULAR DISTRIBUTION
C      MIN - MINIMUM OF THE TRIANGULAR DISTRIBUTION
C      TRA - TIME BETWEEN ARRIVALS OF REQUESTS FOR TRANSPORT FOR A
C            PARTICULAR FROM/TO PAIR
C      TRW - TOLERANCE BAND WIDTH, DEFINES THE WIDTH OF THE TRIANGULAR
C            DISTRIBUTION
C      STTYP - STATION TYPE, ONLY POSSIBLE VALUE IS 'S' IN THIS ROUTINE
C*****
COMMON/BLK6/NODE,NTRAKST,NPDST,NSTAT,RD,NPZ,NRD
COMMON/BLK8/LU,LW,IF
INTEGER FROM,TO,TRA,TRW,STNO,ESTNO,TRANS
CHARACTER*1 STTYP,ESTTYP,DISTYP*2
OPEN(UNIT=21,IOSTAT=IOERR,STATUS='OLD',NAME='AUNIT5.HDD')
IF(IOERR.NE.0) THEN
      WRITE(6,*)'ERROR OPENING FILE AUNIT5.HDD'
      CALL B00000(IOERR,368)
68      WRITE(6,*)'EXECUTION TERMINATED'
      STOP
      ENDIF
C*****
C      CLEAR SCREEN
C*****
      IESC=27
      WRITE(LW,1001)IESC,IESC
1001      FORMAT(1X,A,'C0:0H',A,'E2J')
C*****
C      READ FROM/TO PAIRS AND THE TIME BETWEEN LOADS
C*****
      WRITE(LW,*)'Please enter the FROM/TO pairs and the time between'
      WRITE(LW,*)'loads for each FROM/TO pair.'
      WRITE(LW,*)
      WRITE(LW,*)'Enter X when all FROM/TO pairs have been entered.'
      DO WHILE (STTYP.NE.'X')
        WRITE(LW,*)
C*****
C      READ THE PICKUP STATION
C*****
1      WRITE(LW,1971)
1971      FORMAT('$','Pickup Station ( X to end): ')
      READ(LU,1972,IOSTAT=IERR) STTYP,STNO
      IF (IERR.NE.0) CALL B00000(IOERR,*1)
C*****
C      IF AN 'X' WAS ENTERED FOR PICKUP STATION THEN ALL PAIRS HAVE BEEN

```

```

C          ENTERED, OTHERWISE READ THE DROPOFF STATION.
C*****
C          IF (STYP .NE. 'X') THEN
C*****
C          TRANSLATE USER INPUT TO SIMAN STATION NUMBER
C*****
C          FROM=TRANS(STYP,STNO,NODERR)
C          IF (NODERR .EQ. 1) GOTO 1
1972      FORMAT(A,I5)
C*****
C          READ THE DROP OFF STATION
C*****
C          WRITE(LUW,1973)
2      FORMAT(' ', 'Drop-off Station: ')
1973      READ(LU,1972,IOSTAT=IOERR) ESTYP,ESINO
C          IF (IOERR .NE. 0) CALL BOOBDU(IOERR,*2)
C*****
C          TRANSLATE THE DROPOFF STATION TO A SIMAN STATION NUMBER
C*****
C          TO=TRANS(ESTYP,ESTNO,NODERR)
C          IF (NODERR .EQ. 1) GOTO 2
C*****
C          READ THE TIME BETWEEN REQUESTS FOR TRANSPORTS
C*****
3      WRITE(LUW,1974) STYP,SINO,ESTYP,ESTNO
1974      FORMAT(' ', 'What is the time between loads for ',A,I3,' and ',
C          *A,I3,'? ')
C          READ(LU,*,IOSTAT=IOERR) TRA
C          IF (IOERR .NE. 0) CALL BOOBDU(IOERR,*3)
C*****
C          ENTER THE TOLERANCE BAND WIDTH
C*****
4      WRITE(LUW,2018)
2018      FORMAT(' ', 'Tolerance band width: ')
C          READ(LU,*,IOSTAT=IOERR) TBW
C          IF (IOERR .NE. 0) CALL BOOBDU(IOERR,*4)
C*****
C          TO INSURE THAT A NEGATIVE TIME BETWEEN ARRIVALS IS NOT POSSIBLE,
C          CHECK TO MAKE SURE THE TOLERANCE BAND WIDTH IS SMALLER THAN THE
C          TIME BETWEEN REQUESTS FOR TRANSPORT
C*****
C          IF (TBW .GT. TRA) THEN
C              WRITE(LUW,*) '*** TOLERANCE BAND WIDTH MUST BE LESS THAN '
C              WRITE(LUW,*) TRA, ' PLEASE ENTER AGAIN ***'
C              GOTO 4
C          ENDIF
C*****
C          IF THE TOLERANCE BAND WIDTH IS 0 THEN THE TIME BETWEEN REQUESTS
C          FOR TRANSPORT IS CONSTANT.
C*****
C          IF (TBW .EQ. 0) THEN
C              DISTYP='CO'
C              WRITE(3,2019) IF=TRA
2019      FORMAT(I6,' ',I6,' ')
C              WRITE(21,2023) DISTYP,IF
2023      FORMAT(9X,'CREATE:',A,'(',I6,')!MARK(7):')
C          ELSE
C*****
C          IF THE TOLERANCE BAND WIDTH IS GREATER THAN 0 THEN THE TIME
C          BETWEEN REQUESTS IS DISTRIBUTED BY THE TRIANGULAR DISTRIBUTION
C*****
C          DISTYP='TR'
C          MIN=TRA-TBW
C          MAX=TRA+TBW
C          WRITE(3,2026) IF,MIN,TRA,MAX
2026      FORMAT(I6,3(' ',I6),')')
C          WRITE(21,2024) DISTYP,IF
2024      FORMAT(9X,'CREATE:',A,'(',I6,')!MARK(7):')

```

```

      ENDIF
C*****
C      WRITE THE STATEMENTS TO ASSIGN THE ORIGIN AND DESTINATION OF EACH
C      REQUEST, WRITTEN TO THE MODEL FILE.
C*****
      WRITE(21,2022)FROM
2022      FORMAT(9X,'ASSIGN:A(1)=' ,I5,';')
      WRITE(21,2021)TO
2021      FORMAT(9X,'ASSIGN:A(2)=' ,I5,';NEXT(START);')
      IF=IP+1
      ENDDO
      CLOSE(21)
      RETURN
      END
C*****
C      SUBROUTINE LOAD4
C
C      THIS SUBROUTINE PROMPTS FOR AND READS THE INFORMATION FOR THE
C      ASSEMBLY TASK.
C
C      VARIABLES:
C
C      NST      - NUMBER OF STATIONS IN A SEQUENCE FOR A PARTICULAR PART TYPE
C      PART_TYPE - THE NUMBER OF DIFFERENT PART TYPES
C      PC       - RELATIVE FREQUENCY OF A PART TYPE
C      PT       - CUMULATIVE FREQUENCY OF ALL PART TYPES
C      SQ(50)   - ARRAY CONTAINING THE SEQUENCE OF A PARTICULAR PART TYPE
C      SUM1     - A LOGICAL VARIABLE WHICH IS TRUE IF ALL PART TYPES HAVE
C                BEEN ENTERED AND THE CUMULATIVE FREQUENCY = 1.0
C*****
      COMMON/BLK6/NODE,NTRAKST,NPDST,NSTAT,BD,NFZ,NBD
      COMMON/BLK8/LU,LW,IF
      INTEGER PART_TYP,SQ(50)
      REAL PT,PC
      LOGICAL SUM1
C*****
C      OPEN END.DAT. THIS FILE STORES THE LAST STATION TO VISIT IN EACH
C      PART SEQUENCE.
C*****
      OPEN(15,IOSTAT=IOERR,STATUS='UNKNOWN',ORGANIZATION='RELATIVE',
      *RECL=1,ACCESS='DIRECT',NAME='END.DAT')
      IF(IOERR.NE.0) THEN
        WRITE(6,*)'ERROR OPENING FILE END.DAT'
        CALL X00B00(IOERR,*68)
68      WRITE(6,*)'EXECUTION TERMINATED'
        STOP
      ENDIF
C*****
C      CLEAR THE SCREEN
C*****
      IESC=27
      WRITE(LW,1001)IESC,IESC
1001  FORMAT(1X,A,'C0)OH',A,'C2J')
C*****
C      READ THE NUMBER OF PART TYPES
C*****
      I
8000  WRITE(LW,7000)
7000  FORMAT('$','Number of part types: ')
      READ(LU,*,IOSTAT=IOERR)PART_TYP
      IF (IOERR.NE.0) CALL X00B00(IOERR,*1)
C*****
C      ENTER THE SEQUENCE OF STATIONS TO BE VISITED FOR EACH PART TYPE
C*****
      WRITE(LW,*)
      WRITE(LW,*)'The station numbers in the part sequence should be

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```

* entered as follows:'
WRITE(LUW,*)'If the sequence for a part type is STATION 1,'
WRITE(LUW,*)'STATION 4,STATION 9, STATION 2 then enter'
WRITE(LUW,*)
WRITE(LUW,*)' 1 4 9 2'
DO 20 I=1,PART.TYP
  WRITE(LUW,*)'Please enter the station sequence for PART',I
  WRITE(LUW,*)
  WRITE(LUW,*)'(Up to 50 station in a sequence are permissible.)'
  WRITE(LUW,*)
2  WRITE(LUW,8100)
8100  FORMAT(' ', ' How many stations are in the sequence? ')
  READ(LU,*,IOSTAT=IOERR)NST
  IF (IOERR .NE. 0) CALL BOO800(IOERR,*2)
  WRITE(LUW,*)
3  WRITE(LUW,*)' Enter the station sequence.'
  READ(LU,*,IOSTAT=IOERR)(SQ(J),J=1,NST)
  IF (IOERR .NE. 0) CALL BOO800(IOERR,*3)
  WRITE(15,REC=I)SQ(NST)
C*****
C  WRITE THE SEQUENCE TO THE TABLES ELEMENT
C*****
  IF (I .NE. PART.TYP) THEN
    WRITE(4,7001) I,(SQ(J),J=1,NST)
7001  FORMAT(I3,' ',1,1,' ',I3,<NST-1>(' ',I3),' ')
    ELSE
      WRITE(4,7002) I,(SQ(J),J=1,NST)
7002  FORMAT(I3,' ',1,1,' ',I3,<NST-1>(' ',I3),' ')
  ENDIF
20  CONTINUE
  CLOSE(15)
C*****
C  ENTER THE INFORMATION FOR THE ARRIVAL OF REQUESTS FOR TRANSPORT
C*****
  CALL ARRIVE
  WRITE(3,6995) IF
6995  FORMAT(I6,' ')
C*****
C  READ THE RELATIVE FREQUENCY OF EACH PART TYPE
C*****
  WRITE(LUW,*)'Enter the following information for each PART TYPE:'
  SUM1=.FALSE.
  DO WHILE (.NOT. SUM1)
    PT=0
    DO 10 I=1,PART.TYP
      WRITE(LUW,6996)I
6996  FORMAT(' ', 'What PER CENT of all parts is PART TYPE',
    *I3,'? ')
      READ(LU,*,IOSTAT=IOERR)PC
      IF (IOERR .NE. 0) CALL BOO800(IOERR,*5)
      PT=PC/100.+PT
C*****
C  WRITE THE RELATIVE FREQUENCIES TO THE PARAMETERS ELEMENTS
C*****
  IF (I .NE. PART.TYP) THEN
    WRITE(3,7021) PT,I
7021  FORMAT(F5.3,' ',I3,' ')
    ELSE
C*****
C  IF THE RELATIVE FREQUENCY OF EACH PART TYPE HAS BEEN ENTERED
C  CHECK TO SEE THAT THE SUM OF ALL FREQUENCIES ADD TO 1.0
C*****
    IF (PT .EQ. 1) THEN
      SUM1=.TRUE.
      WRITE(3,7005)PT,I
7005  FORMAT(F5.3,' ',I3,' ')
    ELSE
      WRITE(6,*)'*** DOES NOT SUM TO 1.0, PLEASE ENTER AGAIN'
    
```



```

      ENDIF
10      ENDIF
      CONTINUE
      ENDDO
C*****
C      WRITE THE ASSIGNMENT STATEMENTS FOR PART TYPE AND ORIGIN OF PART SEQUENCE
C      IN THE MODEL FILE.
C*****
      WRITE(21,7009)IP
7009      FORMAT(9X,'ASSIGN:A(6)=DP('',I6,'',6));')
      WRITE(21,7010)
7010      FORMAT(9X,'ASSIGN:A(15)=1;')
      WRITE(21,7015)
7015      FORMAT(9X,'ASSIGN:A(1)=IF(A(6),A(15));')
      WRITE(21,7020)
7020      FORMAT(9X,'ASSIGN:A(16)=A(1);')
      IF=IP+1
      RETURN
      END
C*****
C      SUBROUTINE ARRIVE
C*****
      COMMON/BLK6/NODE,NIRAKST,NFST,NSTAT,RD,NPZ,NRD
      COMMON/BLK8/LU,LW,IF
      REAL P1,P2
      INTEGER FROM,TO,STNO,ESTNO,TRANS
      CHARACTER*1 DISTYP*2,STTYP,ESTTYP,CHDIST*2
      LOGICAL EQUAL1
      IESC=27
1000      FORMAT(1X,A,'E0:0H',A,'E2J')
      WRITE(LW,1000)IESC,IESC
      WRITE(LW,*)'Please describe the ARRIVAL PATTERN of parts.'
      OPEN(21,IOSTAT=IOERR,STATUS='OLD',NAME='AINITS.MOD')
      IF (IOERR .NE. 0) THEN
        WRITE(6,*)'ERROR OPENING FILE AINITS.MOD'
        CALL B00B00(IOERR,*68)
68      WRITE(6,*)'EXECUTION TERMINATED'
        STOP
      ENDIF
      DISTYP=CHDIST()
      IF (DISTYP .EQ. 'CO') THEN
1      WRITE(LW,5002)
5002      FORMAT(' ', 'What is the CONSTANT time between arrivals? ')
      READ(LU,*,IOSTAT=IOERR)P1
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*1)
      WRITE(3,5005) IF,P1
5005      FORMAT(I6,' ',F10.3,' ')
      WRITE(21,5010) DISTYP,IF
5010      FORMAT(10X,'CREATE:',A,'('',I6,'')MARK(7);')
      ELSE IF (DISTYP .EQ. 'UN') THEN
        WRITE(LW,*)'What is the MIN and MAX of the UNIFORM
        * distribution? '
2      WRITE(LU,1985)
1985      FORMAT(' ', 'Minimum: ')
      READ(LU,*,IOSTAT=IOERR)P1
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*2)
3      WRITE(LW,1990)
1990      FORMAT(' ', 'Maximum: ')
      READ(LU,*,IOSTAT=IOERR)P2
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*3)
      WRITE(3,5000) IF,P1,P2
5000      FORMAT(I6,2(' ',F10.3),' ')
      WRITE(21,5015) DISTYP,IF
5015      FORMAT(9X,'CREATE:',A,'('',I6,'',6)MARK(7);')
      ELSE IF (DISTYP .EQ. 'EX') THEN
4      WRITE(LW,5016)

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5016      FORMAT(' ', 'What is the MEAN of the EXPONENTIAL
* Distribution? ')
      READ(LU,*,IOSTAT=IOERR) P1
      IF (IOERR .NE. 0) CALL BOOBR00(IOERR,*4)
      WRITE(3,5005) IP,P1
      WRITE(21,5015) DISTYP,IP
      ELSE IF (DISTYP .EQ. 'RN') THEN
        WRITE(LUW,*) 'Enter the MEAN and STD. DEV. of the NORMAL
* Distribution? '
5      WRITE(LUW,1995)
1995      FORMAT(' ', 'Mean: ')
      READ(LU,*,IOSTAT=IOERR) P1
      IF (IOERR .NE. 0) CALL BOOBR00(IOERR,*5)
6      WRITE(LUW,2000)
2000      FORMAT(' ', 'Standard Deviation: ')
      READ(LU,*,IOSTAT=IOERR) P2
      IF (IOERR .NE. 0) CALL BOOBR00(IOERR,*6)
      DISTYP='RN'
      WRITE(3,5000) IP,P1,P2
      WRITE(21,5015) DISTYP,IP
      ELSEIF (DISTYP .EQ. 'DP') THEN
        EQUAL1=.FALSE.
        WRITE(21,5015) DISTYP,IP
        DO WHILE (.NOT. EQUAL1)
          SUM1=0
          WRITE(LUW,*) 'Please enter the DISCRETE probabilities
* distribution.'
          WRITE(LUW,*)
          WRITE(LUW,*) 'When all probabilities have been entered,
* TYPE -1'
          DO WHILE (P2 .NE. -1)
7          WRITE(LUW,*) 'Enter a possible value of the time between
* arrivals.'
            READ(LU,*,IOSTAT=IOERR) P2
            IF (IOERR .NE. 0) CALL BOOBR00(IOERR,*7)
            IF (P2 .NE. -1) THEN
8              WRITE(LUW,2005) P2
2005              FORMAT(' ', 'What is the PROB(' ,15,')? ')
              READ(LU,*,IOSTAT=IOERR) P1
              IF (IOERR .NE. 0) CALL BOOBR00(IOERR,*8)
              SUM1=SUM1+P1
              IF (SUM1 .NE. 1) THEN
2010                WRITE(4,2010) P1,P2
                FORMAT(F10.3, ' ', F10.2, ' ', ' ')
              ELSE
2015                WRITE(4,2015) P1,P2
                FORMAT(F10.3, ' ', F10.2, ' ', ' ')
              ENDIF
            ENDIF
          ENDDO
          IF (SUM1 .NE. 1) THEN
            EQUAL1=.FALSE.
            WRITE(6,*) '*** PROBABILITIES DO NOT ADD TO ONE ***'
            WRITE(6,*) 'PLEASE ENTER AGAIN'
            ELSE
              EQUAL1=.TRUE.
            ENDIF
          ENDDO
        ELSEIF (DISTYP .EQ. 'TR') THEN
          WRITE(LUW,*) 'Please enter the parameters for the
* TRIANGULAR distribution'
          WRITE(LUW,*)
9          WRITE(LUW,1985)
          READ(LU,*,IOSTAT=IOERR) P1
          IF (IOERR .NE. 0) CALL BOOBR00(IOERR,*9)
10          WRITE(LUW,9012)
9012          FORMAT(' ', 'Mode: ')
          READ(LU,*,IOSTAT=IOERR) P2

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11      IF (IOERR .NE. 0) CALL B00B00(IOERR,*10)
      WRITE(LUN,1990)
      READ(LU,*,IOSTAT=IOERR)P3
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*11)
9040    WRITE(3,9040) IP,P1,P2,P3
      FORMAT(I6,3(' ',F10.3), ' ')
      WRITE(21,5015)DISTYP,IP
      ELSEIF (DISTYP .EQ. 'ER') THEN
      WRITE(LUN,*)'Please enter the parameters of the
12    * ERLANG distribution'
      WRITE(LUN,1995)
      READ(LU,*,IOSTAT=IOERR)P1
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*12)
13    WRITE(LUN,9045)
9045    FORMAT(' ', '          K: ')
      READ(LU,*,IOSTAT=IOERR)P2
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*13)
      WRITE(3,5000)IP,P1,P2
      WRITE(21,5015)DISTYP,IP
      ELSEIF (DISTYP .EQ. 'RL') THEN
14    * LOGNORMAL distribution'
      WRITE(LUN,1995)
      READ(LU,*,IOSTAT=IOERR)P1
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*14)
15    WRITE(LUN,2000)
      READ(LU,*,IOSTAT=IOERR)P2
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*15)
      WRITE(3,5000)IP,P1,P2
      WRITE(21,5015)DISTYP,IP
      ELSEIF (DISTYP .EQ. 'GA') THEN
      WRITE(LUN,*)'Please enter the parameters
16    * of the GAMMA distribution'
9055    WRITE(LUN,9055)
      FORMAT(' ', '      Alpha: ')
      READ(LU,*,IOSTAT=IOERR)P1
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*16)
17    WRITE(LUN,9060)
9060    FORMAT(' ', '      Beta: ')
      READ(LU,*,IOSTAT=IOERR)P2
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*17)
      WRITE(3,5000)IP,P1,P2
      WRITE(21,5015)DISTYP,IP
      ELSEIF (DISTYP .EQ. 'RE') THEN
      WRITE(LUN,*)'Please enter the parameters
18    * of the BETA distribution'
9065    WRITE(LUN,9065)
      FORMAT(' ', '      Theta: ')
      READ(LU,*,IOSTAT=IOERR)P1
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*18)
19    WRITE(LUN,9070)
9070    FORMAT(' ', '      Phi: ')
      READ(LU,*,IOSTAT=IOERR)P2
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*19)
      WRITE(3,5000)IP,P1,P2
      WRITE(21,5015)DISTYP,IP
      ELSEIF (DISTYP .EQ. 'WE') THEN
      WRITE(LUN,*)'Please enter the parameters
20    * of the WEIBULL distribution'
      WRITE(LUN,9055)
      READ(LU,*,IOSTAT=IOERR)P1
      IF (IOERR .NE. 0) CALL B00B00(IOERR,*20)
      WRITE(LUN,9060)
      READ(LU,*)P2
      WRITE(3,5000)IP,P1,P2
      WRITE(21,5015)DISTYP,IP
      ENDIF
      IP=IP+1
      RETURN
      END

```



```

IESC=27
1001 WRITE(6,1001) IESC,IESC
      FORMAT(1X,A,'(0;0H',A,'(2J',///)
      WRITE(6,*) 'NAME CONVENTIONS:'
      WRITE(6,*)
      * referenced' Stations, intersections and parking zones are
      WRITE(6,*) ' by the letters S, I, Z, respectively and a
      * number,'
      WRITE(6,*) ' All stations, intersections and parking zones
      * must be' numbered consecutively from 1. For
      * example,'
      WRITE(6,*)
      WRITE(6,*) ' PROBLEM:'
      WRITE(6,*) ' 2 stations 3 intersections 1 parking
      * zone'
      WRITE(6,*)
      WRITE(6,*) ' Stations should be referred to as '
      WRITE(6,*) ' S1'
      WRITE(6,*) ' S2'
      WRITE(6,*) ' Intersections should be referred to as '
      WRITE(6,*) ' I1'
      WRITE(6,*) ' I2'
      WRITE(6,*) ' I3'
      WRITE(6,*) ' Parking zones should be referred to as '
      WRITE(6,*) ' Z1'
      WRITE(6,*) 'Please press RET to continue.'
1000 READ(6,1000) RESP
      FORMAT(A)
      WRITE(6,1001) IESC,IESC
      WRITE(6,*) 'UNITS:'
      WRITE(6,*)
      * does' It is recommended that MINUTES be used for the'
      WRITE(6,*) ' unit of time and either METERS or YARDS be'
      WRITE(6,*) ' used for the unit of distance. This package
      * consistently' not assume a system of units. It does assume '
      WRITE(6,*) ' that the units of time and distance are used
      WRITE(6,*) ' throughout the package.'
      * units' For example:'
      WRITE(6,*) ' If minutes and meters are used for the
      * units' of time and distance respectively, then the
      * units' for'
      WRITE(6,*) ' Velocity are meters/minute'
      WRITE(6,*) ' Mean Load Time are minutes'
      WRITE(6,*) ' Length of '
      WRITE(6,*) ' Track Segment are meters'
      WRITE(6,*)
      WRITE(6,*) 'Please press RET to continue.'
      READ(6,1000) RESP
      WRITE(6,1001) IESC,IESC
      WRITE(6,*)
      WRITE(6,*) 'One final definition:'
      WRITE(6,*)
      * on' TRACK SEGMENT refers to a continuous section of '
      WRITE(6,*) ' track, uninterrupted by station, intersection
      WRITE(6,*) ' parking zone. Travel is in one direction only.'
      WRITE(6,*) ' This direction is designated by entering a '
      WRITE(6,*) ' beginning node and an ending node.'
      WRITE(6,*)
      WRITE(6,*) 'As the above definition implies, care must be taken'

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    WRITE(6,*)'to enter ALL track segments with the proper
* direction'
    WRITE(6,*)'of travel.'
    WRITE(6,*)
    WRITE(6,*)'FINALLY, it is strongly recommended that the user
* have'
    WRITE(6,*)'          at the workstation a sketch of the track'
    WRITE(6,*)'          with stations, parking zones, intersections'
    WRITE(6,*)'          and track segments clearly labeled.'
    WRITE(6,*)
    WRITE(6,*)'Please press RET to begin entering the data.'
    READ(6,1000) RESP
    WRITE(6,1001) IESC, IESC
    RETURN
    END

```

```

AGUNET.FOR
C*****
C
SUBROUTINE NETWRK
C
C THIS SUBROUTINE ASKS FOR THE NETWORK TOPOLOGY AND CALL THE SHORTEST
C PATH ALGORITHM
C
C VARIABLES
C   BD      - BLOCK DISTANCE
C   ESTNO   - NUMBER OF NODE
C   ESTYP   - TYPE OF NODE, EITHER 'S' FOR STATION
C             'Z' FOR PARKING ZONE
C             'I' FOR INTERSECTION
C   IP      - INDEX INTO THE PARAMETERS
C   ISEGS   - INTEGER NUMBER OF BLOCK DISTANCES IN A TRACK SEGMENT
C   LASTSEG - LENGTH OF THE LAST PART OF TRACK SEGMENT
C   NI      - TEMPORARY VARIABLE
C   NODE    - THE NUMBER OF NODES IN THE SYSTEM (STATIONS, INTERSECTIONS
C             AND PARKING ZONES)
C   NTRAKST - NUMBER OF TRACK SEGMENT IN A SYSTEM
C   STNO    - NUMBER OF THE NODE
C   STYP    - TYPE OF NODE, EITHER 'S' FOR STATION
C             'Z' FOR PARKING ZONE
C             'I' FOR INTERSECTION
C   TRKDIST - LENGTH OF A TRACK SEGMENT
C*****
COMMON/BLK6/NODE,NTRAKST,NPDST,NSTAT,BD,NPZ,NBD
COMMON/BLK7/COUNT,PMAX
COMMON/BLK8/CLU,LU,LUM,IP
REAL TRKDIST
INTEGER NI,NINTRST,STNO,ESTNO,TRANS
INTEGER NSTAT,NTRAKST,NODE,NPDST,PMAX,COUNT
CHARACTER*1 CLU,DEFFIL*12,RESP,STYP,ESTYP
LOGICAL ERR
C*****
C ENTER BEGINNING AND ENDING NODES OF ALL TRACK SECTIONS
C*****
OPEN(UNIT=4,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='AGVSIM2.EXP')
IF (IOERR .NE. 0) THEN
  WRITE(6,*) 'ERROR OPENING FILE AGVSIM2.EXP'
  CALL D00B00(IOERR,*68)
68  WRITE(6,*) 'EXECUTION TERMINATED'
  STOP
ENDIF
WRITE(4,2040)
2040 FORMAT('SEQUENCE:')
ERR=.TRUE.
DO WHILE (ERR)
  IESC=27
  WRITE(LUM,1001)iesc,iesc
1001  FORMAT(1X,A,'C090H',A,'E2J')
  1  WRITE(6,*) 'Do you wish to read the NETWORK INFORMATION from the'
  WRITE(6,*) 'from the terminal or a file? (F=FILE, T=TERMINAL)'
  1000  READ(6,1000) CLU
  FORMAT(A)
  IF (CLU .EQ. 'T') THEN
    LU=6
    LUM=6
  ELSE IF (CLU .EQ. 'F') THEN
    79  WRITE(6,*) 'What is the NAME of the file?'
    READ(6,1000,IOSTAT=IOERR) DEFFIL
    IF (IOERR .NE. 0) CALL D00B00(IOERR,*79)
    OPEN(UNIT=12,IOSTAT=IOERR,STATUS='OLD',NAME=DEFFIL)
    IF (IOERR .NE. 0) THEN

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```

        WRITE(6,*)'ERROR OPENING FILE',DEFFIL
        CALL BOOB00(IOERR,*1)
    ENDIF
    LU=12
    OPEN(UNIT=8,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='JUNK.DAT')
    IF (IOERR.NE.0) THEN
        WRITE(6,*)'ERROR OPENING FILE AGUS(M2,EXP'
        CALL BOOB00(IOERR,*68)
    ENDIF
    LUW=8
    ELSE
        WRITE(6,*)'*** YOUR ANSWER WAS NOT UNDERSTOOD. PLEASE
* ENTER AGAIN ***'
        GOTO 1
    ENDIF
    WRITE(LUW,*)'Please remember that all TRACK SEGMENTS are ONE WAY'
    WRITE(LUW,*)
    WRITE(LUW,*)'Enter the following for each TRACK SEGMENT:'
    WRITE(LUW,*)
    WRITE(LUW,*)'    Beginning Point'
    WRITE(LUW,*)'    Ending Point'
    WRITE(LUW,*)'    Length'
    WRITE(LUW,*)
    WRITE(LUW,*)'Be sure to use the correct notation:'
    WRITE(LUW,*)'    S1 - STATION NUMBER 1'
    WRITE(LUW,*)'    Z3 - PARKING ZONE NUMBER 3'
    WRITE(LUW,*)'    I5 - INTERSECTION NUMBER 5'
    WRITE(LUW,*)
    WRITE(LUW,*)'Please not!'
    WRITE(LUW,*)'    The LENGTH of a track segment must be GREATER'
    WRITE(LUW,*)'    THAN the BLOCK DISTANCE'
    OPEN(UNIT=11,IOSTAT=IOERR,STATUS='UNKNOWN',FILE='RAW.DAT')
    IF (IOERR.NE.0) THEN
        WRITE(6,*)'ERROR OPENING FILE RAW.DAT'
        CALL BOOB00(IOERR,*68)
    ENDIF
1010  FORMAT(A,I5)
    OPEN(30,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='ATRCK2.MOD')
    IF (IOERR.NE.0) THEN
        WRITE(6,*)'ERROR OPENING FILE ATRCK2.MOD'
        CALL BOOB00(IOERR,*68)
    ENDIF
    WRITE(30,4445)IF=NODE-1
4445  FORMAT(9X,'ASSIGN:A(19)=('',I6,'')','',I4)
    CLOSE(30)
    OPEN(30,IOSTAT=IOERR,STATUS='UNKNOWN',NAME='AINTF4B.MOD')
    IF (IOERR.NE.0) THEN
        WRITE(6,*)'ERROR OPENING FILE AINTF4B.MOD'
        CALL BOOB00(IOERR,*68)
    ENDIF
    WRITE(30,4446)IF=NODE-1
4446  FORMAT(9X,'ASSIGN:A(19)=('',I6,'')','',I4)
    CLOSE(30)
    NRB=NODE+1
    DO 30 NI=1,NTRAKST
        WRITE(LUW,*)
        WRITE(LUW,1019)NI
1019  FORMAT(1X,'Track Segment #',I4)
23    WRITE(LUW,1020)
1020  FORMAT('$','    BEGINNING POINT: ')
        READ(LU,1010,IOSTAT=IOERR)SITYP,SINO
        IF (IOERR.NE.0) CALL BOOB00(IOERR,*23)
C*****
C
C    TRANSLATE STATIONS, INTERSECTIONS, AND TRACK SEGMENTS
C    INTO THE NUMBERING SYSTEM OF THE PROGRAM
C
C*****

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```

      NB=TRANS(STTYP,STNO,NODERR)
      IF (NODERR .EQ. 1) GOTO 23
      WRITE(LUW,1030)
24      FORMAT(' ', '      ENDING POINT: ')
1030      READ(LU,1010)ESTTYP,ESTNO
      NA=TRANS(ESTTYP,ESTNO,NODERR)
      IF (NODERR .EQ. 1) GOTO 24
25      WRITE(LUW,1040)
1040      FORMAT(' ', '      LENGTH: ')
      READ(LU,*,10STAT=IOERR)TRKDIST
      IF (IOERR .NE. 0) THEN
        WRITE(LUW,*)'*** PLEASE NOTE: DISTANCE MUST BE AN INTEGER
* ***'
        CALL BOO800(IOERR,*25)
      ENDIF
      IF (TRKDIST .LE. RD) THEN
        WRITE(LUW,*)'*** LENGTH OF THE TRACK SEGMENT MUST BE AT'
        WRITE(LUW,*)'GREATER THAN THE BLOCK DISTANCE',RD,' ***'
        GOTO 25
      ENDIF
      ISEGS=TRKDIST/RD-1
      LASTSEG=AMOD(TRKDIST,RD)+RD
      WRITE(3,4450) IP,NRD,ISEGS,LASTSEG
4450      FORMAT(I6,' ',I5,' ',I5,' ',I5,' ')
C*****
C      STORE NETWORK INFORMATION IN RAW.DAT TO BE SORTED
C*****
C      WRITE(11,1005)NB,NA,TRKDIST,NINODE
1005      FORMAT(I10,I10,F10.2,I10)
      NBD=NRD+ISEGS+1
      IF=IF+1
30      CONTINUE
      NBD=NBD-NODE
      CLOSE(11)
C*****
C      DETERMINE THE NUMBER OF SHORTEST PATHS THAT MUST BE FOUND
C*****
      WRITE(LUW,*)
      WRITE(LUW,*)'If the SHORTEST path for a trip is BLOCKED, '
26      WRITE(LUW,*)' should another path be checked?'
      READ(LU,1000)RESP
      IF (RESP .EQ. 'Y') THEN
        WRITE(LUW,*)
27      WRITE(LUW,*)'How many paths should be considered?'
        WRITE(LUW,*)'      Maximum = 10'
        READ(LU,*,10STAT=IOERR) PMAX
        IF (IOERR .NE. 0) CALL BOO800(IOERR,*27)
        ELSEIF (RESP .EQ. 'N') THEN
          PMAX=1
        ELSE
          WRITE(6,*)'*** YOUR ANSWER WAS NOT UNDERSTOOD. PLEASE ENTER
* Y FOR YES OR N FOR NO'
          GOTO 26
        ENDIF
        WRITE(6,1001)IFSC,IFSC
        WRITE(LUW,*)
        WRITE(6,*)'PLEASE WAIT'
C*****
C      WRITE THE 'SEQUENCE' ELEMENT
C*****
      OPEN(28,10STAT=IOERR,STATUS='UNKNOWN',FILE='AINT4.MOD')
      IF (IOERR .NE. 0) THEN

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        WRITE(6,*)'ERROR OPENING FILE AINTE4.MOD'
        CALL BOOEROO(IOERR,*68)
    ENDIF
    WRITE(28,2041) IF=1
2041  FORMAT(7X,'ASSIGN:A(5)=NST',I6,','')
    CLOSE(28)
    OPEN(28,ISTAT=IOERR,STATUS='UNKNOWN',FILE='CHSQ1A.FOR')
    IF (IOERR.NE. 0) THEN
        WRITE(6,*)'ERROR OPENING FILE CHSQ1A.FOR'
        CALL BOOEROO(IOERR,*68)
    ENDIF

    WRITE(28,2042) IF=1
2042  FORMAT(7X,'NPS=',I6)
    CLOSE(28)
    MISERR=0
C*****
C
C    CALL SHORTEST PATH ALGORITHM
C*****
C    CALL KSHRT(MISERR)
C*****
C    WAS THERE AN ERROR IN THE SHORTEST PATH ROUTINE ?
C*****
    IF (MISERR.NE. 0) THEN
        ERR=.FALSE.
    ELSE
        LU=6
        LUN=6
    ENDIF
    ENDDO
    CLOSE(12)
C**  WRITE A FAKE RECORD SO I CAN COMPLETE THE SEQUENCE ELEMENT
C
    WRITE(4,2045) COUNT
2045  FORMAT(I6,','1/1')
    WRITE(3,2047) IF
2047  FORMAT(I6,','1,1')
C*****
C
C    WRITE THE 'DISTANCES' ELEMENT
C*****
    WRITE(4,2050) NSTAT
2050  FORMAT('DISTANCES:1,1-',I5,','')
    DO 20 I=1,NSTAT-1
        IF (I.LT. NSTAT-1) THEN
C
C**  DETERMINE IF THE DATA IS TOO LONG TO FIT IN ONE RECORD
C
            IF (NSTAT-1-1 .GT. 16) THEN
                I16=16
                IUF=(NSTAT-1-1)/I16
                IA1=NSTAT-I-1
                IUF2=JMOD(IA1,I16)
                IF (IUF2.GT. 1) THEN
                    WRITE(4,2053)
2053  FORMAT('0',,<IUF>(16('0,')/,), '0',<IUF2-1>('0,')/,)
                    ELSE IF (IUF2.EQ. 1) THEN
                        WRITE(4,2054)
2054  FORMAT('0',,<IUF>(16('0,')/,), '0',/)
                    ELSEIF (IUF2.LT. 1) THEN
                        WRITE(4,2056)
2056  FORMAT('0',,<IUF-1>(16('0,')/,), '0',15('0,')/,)
                    ENDDIF
                ELSE
                    WRITE(4,2055)

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2055         FORMAT('0'<NSTAT-I-1>('','0'),'/')
           ENDIF
           ELSE
2060             WRITE(4,2060)
             FORMAT('0')
           ENDIF
20       CONTINUE
       IZERO=0
       OPEN(38,ACCESS='DIRECT',Iostat=IOERR,STATUS='OLD',FILE='DIST.DAT')
       IF (IOERR.NE.0) THEN
           WRITE(6,*)'ERROR OPENING FILE DIST.DAT'
           CALL BOOB00(IOERR,#68)
       ENDIF
       DO 40 I=1,NODE
           IRCL=(I-1)*NODE+I
           WRITE(38,REC=IRCL) IZERO
40       CONTINUE
       CLOSE(38)
       RETURN
       END
C*****
C       FUNCTION TRANS(STYP,STNO,NODERR)
C
C       THIS FUNCTION TRANSLATES USER SPECIFIED STATION, INTERSECTION
C       AND PARKING ZONE NUMBERS INTO THE NUMBERING SYSTEM OF THE SIMAN
C       SIMULATION MODEL
C*****
C       COMMON/BLK6/NODE,NTRAKST,NPDST,NSTAT,BD,NFZ,NBD
C       COMMON/BLK8/LU,LW,IP
C       CHARACTER*1 STYP
C       INTEGER TRANS,STNO
C*****
C       STATIONS
C*****
       IF (STYP.EQ.'S') THEN
           IF (STNO.LE.NPDST) THEN
               TRANS=STNO
               NODERR=0
           ELSE
               WRITE(LW,*)'*** STATION NUMBER MUST BE',NPDST,' OR LESS'
               WRITE(LW,*)' PLEASE ENTER AGAIN ***'
               NODERR=1
           ENDIF
C*****
C       PARKING ZONES
C*****
       ELSEIF (STYP.EQ.'Z') THEN
           IF (STNO.LE.NFZ) THEN
               TRANS=STNO+NPDST
               NODERR=0
           ELSE
               WRITE(LW,*)'*** PARKING ZONE NUMBER MUST BE',NFZ,' OR
* LESS. PLEASE ENTER AGAIN. ***'
               NODERR=1
           ENDIF
C*****
C       INTERSECTIONS
C*****
       ELSEIF (STYP.EQ.'I') THEN
           NIN=NODE-NPDST-NFZ
           IF (STNO.LE.NIN) THEN
               TRANS=STNO+NPDST+NFZ
               NODERR=0
           ELSE
               WRITE(LW,*)'*** INTERSECTION NUMBER MUST BE',NIN,
* ' OR LESS. PLEASE ENTER AGAIN. ***'

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                NODERR=1
            ENDIF
C*****
C    IF ANYTHING OTHER THAN AN 'S', 'Z', OR 'I' IS ENTERED - ERROR
C*****
            ELSE
                WRITE(6,*)'*** PLEASE ENTER THE STATION, PARKING ZONE
* OR INTERSECTION AGAIN, BE SURE YOU ARE USING THE CORRECT
* NAMING CONVENTION. ***'
                WRITE(6,*)' STATION NUMBERS ARE PREFACED WITH S,
* STATION 1 - S1'
                WRITE(6,*)' INTERSECTION NUMBERS ARE PREFACED WITH I,
* INTERSECTION 5 - I5'
                WRITE(6,*)' PARKING ZONE NUMBERS ARE PREFACED WITH Z,
* PARKING ZONE 10 - Z10'
                NODERR=1
            ENDIF
            RETURN
        END

```

```

AGVP.MOD
BEGIN;
; THIS SIMAN PROGRAM SIMULATES AN AGV SYSTEM. 5 SUB-MODELS DEFINE
; THE MODEL: PICKUP STATIONS, DROPOFF STATIONS, INTERSECTIONS,
; PARKING ZONES AND TRACK SEGMENTS. 22 ATTRIBUTES ARE USED AND
; 6*(NO. OF VEHICLES)+2 OF THE SYSTEM VARIABLE X ARE DEFINED. THE ATTRIBUTES
; AND SYSTEM VARIABLE X ARE DEFINED AS FOLLOWS:
; A(1) - INITIAL STATION IN A PATH SEQUENCE
; A(2) - FINAL STATION IN A PATH SEQUENCE
; A(3) - VEHICLE NUMBER ASSIGNED TO THE REQUEST FOR TRANSFER
; A(4) - TEMPORARY STORAGE
; A(5) - TEMPORARY STORAGE
; A(6) - FOR ASSEMBLY TASK, THE PART TYPE
; A(7) - TIME FROM THE CREATION OF A REQUEST UNTIL THE REQUEST IS SATISFIED
; A(8) - DENOTES PURPOSE OF VEHICLE TRIP 1=PICKUP, 2=DROPOFF, 3=PARKING
; ZONE, 4=EXCHANGE ENTITIES
; A(9) - TIME FROM THE INITIAL REQUEST FOR A VEHICLE UNTIL A VEHICLE IS
; ALLOCATED TO THE REQUEST
; A(10) - TIME FROM THE INITIAL REQUEST FOR A TRACK SEGMENT UNTIL THE TRACK
; SEGMENT IS AVAILABLE TO THE VEHICLE
; A(11) - TIME FROM THE INITIAL REQUEST FOR A PICKUP STATION UNTIL THE
; PICKUP STATION IS AVAILABLE TO THE VEHICLE
; A(12) - TEMPORARY STORAGE
; A(13) - TIME FROM THE INITIAL REQUEST FOR AN INTERSECTION UNTIL THE
; INTERSECTION IS AVAILABLE TO THE VEHICLE
; A(14) - USED FOR ASSEMBLY TASK ONLY, DENOTES PICKUP TRIP OR WORK TRIP
; A(15) - USED FOR ASSEMBLY TASK ONLY, INDEX INTO THE ROUTINE SEQUENCE
; A(16) - USED FOR ASSEMBLY TASK ONLY, INDICATES THE NEXT WORK STOP
; A(17) - INDEX INTO THE PARAMETERS ELEMENT FOR WORK STATION TIMES
; A(18) - LENGTH OF THE LAST BLOCK DISTANCE ON A TRACK SEGMENT
; A(19) - INDEX INTO THE PARAMETERS ELEMENT FOR THE NUMBER OF BLOCK
; DISTANCES IN A TRACK SEGMENT
; A(20) - NUMBER OF BLOCK DISTANCES IN A TRACK SEGMENT REMAINING TO BE
; TRAVELED
; A(21) - NOT USED
; A(22) - QUEUE RANK OF THE NEXT REQUEST FOR TRANSPORT TO BE ASSIGNED TO A
; WAITING VEHICLE
;
; X(1): NUMBER OF VEHICLES IN THE SYSTEM
; X(2): SIZE OF THE BLOCK DISTANCE
; X(3) - X(NAGV+2): DENOTES THE PREVIOUS LOCATION OF NTH AGV WHERE NAGV
; REPRESENTS THE NUMBER OF AGVS.
; X(NAGV+3) - X(2*NAGV+2): 1= BUSY VEHICLE, 0= VEHICLE WITHOUT TASK
; X(2*NAGV+3) - X(3*NAGV+2): RECORD LOCATION OF ENTITY CONTROLLING THE VEHICLE
; X(3*NAGV+3) - X(4*NAGV+2): TIME WHEN VEHICLE LAST BECAME IDLE
; X(4*NAGV+3) - X(5*NAGV+2): TOTAL IDLE TIME OF EACH VEHICLE
; X(5*NAGV+3) - X(6*NAGV+2): SPEED OF EACH VEHICLE
;
; CREATE ENTITIES OR DEMANDS FOR TRANSPORT
;
; CREATE:TR( 10,5):MARK(7);
; ASSIGN:A(1)= 1;
; ASSIGN:A(2)= 8:NEXT(START);
; CREATE:TR( 11,5):MARK(7);
; ASSIGN:A(1)= 2;
; ASSIGN:A(2)= 4:NEXT(START);
; CREATE:TR( 12,5):MARK(7);
; ASSIGN:A(1)= 3;
; ASSIGN:A(2)= 6:NEXT(START);
; CREATE:CO( 13):MARK(7);
; ASSIGN:A(1)= 1;
; ASSIGN:A(2)= 5:NEXT(START);
; CREATE:TR( 14,5):MARK(7);
; ASSIGN:A(1)= 1;
; ASSIGN:A(2)= 7:NEXT(START);
START COUNT:2,1;
; ASSIGN:M=A(1);
;

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; ASSIGN A VEHICLE TO THE ENTITY IF A VEHICLE IS AVAILABLE
;
    EVENT:2;
    BRANCH:1;
    IF, M, EQ, -1, FRE;
    ELSE, NTEST;
;
; IF THE VEHICLE IS ALREADY IN THE CORRECT STATION TO PICKUP THE REQUEST
; FREE THE VEHICLE FROM ITS PREVIOUS ENTITY
;
FRE    FREE:AGV(A(4));
      ASSIGN:M=A(4);NEXT(Q2);
;
; IF NO VEHICLES ARE AVAILABLE THEN WAIT FOR A VEHICLE TO BE ASSIGNED IN
; QUEUE 1 OTHERWISE WAIT FOR THE ARRIVAL OF THE VEHICLE THAT HAS BEEN
; ASSIGNED IN THE QUEUE 2.
;
NTEST  BRANCH:1;
      IF, M, EQ, 0, Q1;
      ELSE, Q2;
Q1     ASSIGN:M=A(1);
      QUEUE,1;MARK(9);DETACH;
      QUEUE,2;
ALLOCA  ALLOCATE:AGV(M);
      ASSIGN:A(8)=1;NEXT(THR);
Q2     QUEUE,M; 113;MARK(9);
      ALLOCATE:AGV(M);
      ASSIGN:A(8)=1;
THR     ASSIGN:J=X(1)+A(3)+2;
;
; SET THE VEHICLE STATUS TO BUSY
;
      ASSIGN:X(J)=1;
;
; TALLY THE TOTAL IDLE TIME
;
      ASSIGN:J=4*X(1)+A(3)+2;
      ASSIGN:A(4)=J-X(1);
      ASSIGN:X(J)=X(J)+TNOW-X(A(4));
;
; DETERMINE THE CURRENT LOCATION OF THE VEHICLE
;
      ASSIGN:J=A(3)+2;
      ASSIGN:X(J)=LT(1,A(3));
;
; IF THE VEHICLE IS IN THE CORRECT STATION THEN GO TO THE STATION SUB-MODEL
;
      BRANCH:1;
      IF, A(1), NE, X(J), GETAGV;
      ELSE, PCK;
PCK     ROUTE:,A(1);
;
; IF THE VEHICLE IS NOT IN THE CORRECT STATION THEN DETERMINE THE PATH SEQUENCE
; NUMBER FROM THE VEHICLES CURRENT LOCATION TO THE STATION OF THE REQUEST
;
GETAGV  ASSIGN:A(14)=0;
;
; RECORD THE TRIP AS A TRIP TO PICKUP A REQUEST
      ASSIGN:A(8)=1;
      EVENT:1;
      ASSIGN:IS=1;
      ROUTE:,SER;
;
;
; STATION SUB-MODEL
;
      STATION, 1-- 0;
      ASSIGN:A(17)= 14PM;

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;
; DETERMINE IF THE VEHICLE IS ON A PICK UP TRIP
;
    BRANCH,1;
    IF, A(8) ,EQ. 1,CHECK;
    ELSE,CNT2;
;
; IF THE VEHICLE IS ON A PICKUP TRIP, CHECK TO SEE IF THE VEHICLE IS ALREADY
; LOCATED IN THE STATION, IF SO, GO TO PICKUP
;
CHECK    ASSIGN:J=A(3)+2;
    BRANCH,1;
    IF, A(1) ,EQ. X(J) ,PICKUP;
    ELSE,CNT2;
;
; OTHERWISE, SEIZE THE STATION
;
CNT2    QUEUE,M+2;MARK(11);
    SEIZE:NODE(M);
    TALLY:4,INT(11);
;
; TRAVEL THE LAST BLOCK DISTANCE INTO THE STATION
;
    ASSIGN:J=5*X(1)+A(3)+2;
    DELAY:A(18)/X(J);
    ASSIGN:J=A(3)+2;
    MOVE:AGV(A(3)),M;
;
; RELEASE THE PREVIOUS TRACK SEGMENT
;
    ASSIGN:A(23)=M;
    ASSIGN:M=A(12);
    RELEASE:NODE(M);
    ASSIGN:M=A(23);
    ASSIGN:X(J)=M;
;
; DETERMINE IF THE VEHICLES IS TO 1) PICK UP A LOAD 2) WAIT FOR AN ASSEMBLY
; TASK BE PERFORMED 3) DROP OFF A LOAD 4) RECEIVE A NEW TASK BECAUSE IT IS
; TRAVELING EMPTY 5) EXCHANGE ENTITIES THAT ARE CONTROLLING IT BECAUSE IT IS
; TRAVELING EMPTY AND HAS A NEW TASK ASSIGNED TO IT 6) PASS THROUGH THE
; STATION WITHOUT STOPPING.
;
    BRANCH,1;
    IF, M ,EQ. A(1) ,AND, A(8) ,EQ. 1,PICKUP;
    IF, A(14) ,EQ. 1 ,AND, A(16) ,EQ. M, USE;
    IF, M ,EQ. A(2) ,AND, A(8) ,EQ. 2,DROP;
    IF, A(2) ,NE. M ,AND, A(8) ,EQ. 3, SET;
    IF, A(2) ,EQ. M ,AND, A(8) ,EQ. 4, EXCH;
    ELSE,EXITS;
;
; ASSIGN THE VEHICLE ITS NEW TASK AND SEQUENCE TO FOLLOW
;
SET    EVENT:4;
    ASSIGN:J=X(1)+A(3)+2;
    ASSIGN:A(J)=M;
    ASSIGN:X(J)=1;
    ASSIGN:A(8)=4;NEXT(NW);
;
; RELEASE THE VEHICLE SO THAT THE NEW TASK MAY CONTROL THE VEHICLE AND DISPOSE
; OF THE OLD ENTITY
;
EXCH    FREE:AGV(A(3));DISPOSE;
;
; PICKUP A LOAD
;
PICKUP    TALLY:2,INT(9);
    DELAY:EX(A(17),6);
    ASSIGN:J=5*X(1)+A(3)+2;

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        ASSIGN:X(J)=      60.00;
;
; DETERMINE IF THE VEHICLE IS PERFORMING A VEHICLE TASK
;
        BRANCH,1;
        IF, A(6) ,NE. 0, L2;
        ELSE, NWSQ;
;
; PERFORM AN ASSEMBLY TASK
;
USE      DELAY:EX(A(17),6);
;
; IF AN ASSEMBLY TASK IS BEING PERFORMED, THEN DETERMINE THE NEXT
; STATION TO BE VISITED PART TYPE ROUTING
;
L2      ASSIGN:A(14)=1;
        ASSIGN:A(1)=A(14);
        ASSIGN:A(15)=A(15)+1;
        ASSIGN:A(16)=IF(A(6),A(15));
;
; DESIGNATE THE TRIP AS A DROPOFF TRIP
;
NWSQ    ASSIGN:A(8)=2;
;
; DETERMINE THE NEW PATH SEQUENCE TO FOLLOW TO THE NEW DESTINATION
;
NW      ASSIGN:IS=1;
        EVENT:1;NEXT(EXITS);
;
; DROPOFF THE LOAD
;
DROP    DELAY:EX(A(17),6);
        ASSIGN:J=5*X(1)+A(3)+2;
        ASSIGN:X(J)=      80.00;
        COUNT:1,1;
        TALLY:1,INT(7);
        ASSIGN:J=3*X(1)+A(3)+2;
        ASSIGN:X(J)=TNOW;
;
; IS THERE A NEW TASK FOR THE VEHICLE TO PERFORM
;
        BRANCH,1;
        IF, NR(1) ,GT. 0, RE;
        ELSE, DEPOT;
;
; IF THERE IS MORE THAN 1 TASK WAITING, SELECT A TASK FOR THE VEHICLE
; TO PERFORM
;
RE      EVENT:5;
        REMOVE:A(22),1,ALLOC;
DISP    FREE:AGV(A(3));DISPOSE;
;
; IF THERE ARE NO TASKS WAITING, THEN SEND THE VEHICLE TO A PARKING ZONE
; IF THERE IS A PARKING ZONE AVAILABLE
;
DEPOT   ASSIGN:J=X(1)+A(3)+2;
        ASSIGN:X(J)=0;
        EVENT:6;
;
; IF THERE ARE NO PARKING ZONES AVAILABLE THEN LEAVE THE VEHICLE IN THE STATION
; AND DISPOSE OF THE ENTITY
;
        BRANCH,1;
        IF, A(2) ,EQ. 0, DISP;
        ELSE, EVEN;
;
; DETERMINE THE SEQUENCE THE VEHICLE SHOULD FOLLOW TO THE PARKING ZONE
;

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EVEN    ASSIGN:A(1)=M#
        ASSIGN:IS=1#
        ASSIGN:A(14)=0#
        EVENT:1#
EXITS   ROUTE:1,SEQ#                                PROCEED TO NEXT SECTION OF TRACK
;
;
; INTERSECTION SUB-MODEL
;
;     STATION,      10--    14#
;
; DETERMINE IF A NEW DESTINATION FOR AN EMPTY VEHICLE HAS BEEN SPECIFIED
; IF SO, SET THE VEHICLE BUSY, AND DETERMINE THE NEW SEQUENCE TO FOLLOW
; OTHERWISE GOTO CT5
;
;     BRANCH,1:
;         IF, A(8).EQ. 3, SR2:
;         ELSE,CT5#
SR2     EVENT:4#
        ASSIGN:A(1)=M#
        ASSIGN:J=X(1)+A(3)+2#
        ASSIGN:X(J)=1#
        ASSIGN:A(8)=4#
        ASSIGN:IS=1#
        EVENT:1#
;
; DETERMINE THE TRACK SEGMENT AFTER THE INTERSECTION THAT THE VEHICLE
; IS TRAVELING TO.
;
CT5     ASSIGN:A(4)=IS+1#
        ASSIGN:A(5)=NS# 40#
        ASSIGN:J=F(A(5),A(4)):MARK(10)#
        ASSIGN:A(19)=( 8)+J#
        ASSIGN:A(12)=F(A(19),1)#
        ASSIGN:A(23)=M#
        ASSIGN:M=A(12)#
;
; SEIZE THE TRACK SEGMENT AFTER THE INTERSECTION
;
        QUEUE,M+2#;
        SEIZE:NODE(M)#
        ASSIGN:M=A(23)#
ALT3    TALLY:3,INT(10)#
;
; SEIZE THE INTERSECTION
;
        QUEUE,M+2:MARK(13)#
        SEIZE:NODE(M)#
        TALLY:5,INT(13)#
;
; TRAVEL THE LAST BLOCK DISTANCE INTO THE INTERSECTION
;
        ASSIGN:J=5*X(1)+A(3)+2#
        DELAY:A(18)/X(J)#
        MOVE:AGV(A(3)),M#
        ASSIGN:A(23)=M#
        ASSIGN:J=A(3)+2#
;
; RELEASE THE PREVIOUS TRACK SEGMENT JUST BEFORE THE INTERSECTION
        ASSIGN:M=X(J)#
REL2    RELEASE:NODE(M)#
        ASSIGN:M=A(23)#
;
; DETERMINE IF AN EMPTY VEHICLE HAS RECEIVED A NEW TASK. IF SO,
; SET THE VEHICLE STATUS BUSY AND DETERMINE THE NEW SEQUENCE THE VEHICLE
; SHOULD FOLLOW
; OTHERWISE, GO TO OUT1
;

```

```

        BRANCH,1:
        IF, A(8) ,ER. 3, SQ1:
        ELSE,OUT1;
SQ1    EVENT:4;
        ASSIGN:A(1)=M;
        ASSIGN:J=X(1)+A(3)+2;
        ASSIGN:X(J)=1;
        ASSIGN:A(8)=4;
        ASSIGN:IS=1;
        EVENT:1;
OUT1   ASSIGN:J=A(3)+2;
        ASSIGN:X(J)=M;
        ROUTE:5,SEG;
;
; TRACK SEGMENT SUB-MODEL
;
        STATION, 15-- 32;
        ASSIGN:A(19)=( 8)+M;
; DETERMINE WHETHER OR NOT THE PREVIOUS SERVER WAS AN INTERSECTION
;
        ASSIGN:J=A(3)+2;
        BRANCH,1:
        IF, X(J) ,LE. 14,AND, X(J) ,GE. 10,HAV:
        ELSE,CNT4;
CNT4   ASSIGN:A(12)=P(A(19),1);
        ASSIGN:A(23)=M;
        ASSIGN:M=A(12);
; SEIZE THE FIRST BLOCK DISTANCE OF THE TRACK SEGMENT
;
        QUEUE,M+2;MARK(10);
        SEIZE:NODE(M);
        TALLY:3,INT(10);
        ASSIGN:M=A(23);
HAV    ASSIGN:A(20)=P(A(19),2);
        MOVE:AGV(A(3)),M;
; DETERMINE WHICH SERVER TO RELEASE AND RELEASE IT
;
        ASSIGN:J=A(3)+2;
        BRANCH,1:
        IF, X(J) ,LE. 9,ST1:
        ELSE,INT1;
; RELEASE THE INTERSECTION IF IT WAS THE PREVIOUS SERVER
;
INT1   RELEASE:NODE(X(J));NEXT(C1);
ST1    ASSIGN:A(4)=X(J);
; DETERMINE WHETHER OR NOT TO RELEASE THE STATION OR CHANGE ITS
; CAPACITY IF A STATION WAS THE LAST SERVER
;
        BRANCH,1:
        IF, MR(A(4)) ,LT. P(A(4),1),INC:
        ELSE,REL;
REL    RELEASE:NODE(X(J));NEXT(CT);
INC    ALTER:NODE(X(J)),1;
CT     ASSIGN:A(18)=P(A(19),3);
; TEST TO SEE IF ALL BUT THE LAST BLOCK DISTANCES HAVE BEEN TRAVELED FOR THAT
; TRACK SEGMENT
;
TEST   BRANCH,1:
        IF, A(20) ,ER. 0,OUT:
        ELSE,TRAVEL;
;

```

```

; TRAVEL THE NEXT BLOCK DISTANCE
;
TRAVEL  ASSIGN:J=5*X(1)+A(3)+2;
        DELAY:X(2)/X(J);
        ASSIGN:A(20)=A(20)-1;
        ASSIGN:A(12)=A(12)+1;
        ASSIGN:A(23)=M;
        ASSIGN:M=A(12);
;
; SEIZE THE NEXT BLOCK DISTANCE
;
        QUEUE,M+2;
        SEIZE:NODE(M);
        RELEASE:NODE(M-1);
;
; GO TO TEST TO SEE IF ALL BUT THE LAST BLOCK DISTANCE HAS BEEN TRAVELED
;
        ASSIGN:M=A(23):NEXT(TEST);
;
; EXIT THE TRACK SEGMENT SUB-MODEL WHEN ALL BUT THE LAST BLOCK DISTANCE
; HAS BEEN TRAVELED
;
OUT     ASSIGN:J=A(3)+2;
        ASSIGN:X(J)=A(12);
        ROUTE:SER;
;
;
; PARKING ZONE SUB-MODEL
;
        STATION, 9-- 9;
;
; SEIZE THE PARKING ZONE
;
        QUEUE,M+2;
        SEIZE:NODE(M);
;
; TRAVEL THE LAST BLOCK DISTANCE ON THE TRACK SEGMENT BEFORE THE PARKING
; ZONE AND INTO THE PARKING ZONE
;
        ASSIGN:J=5*X(1)+A(3)+2;
        DELAY:A(18)/X(J);
        MOVE:AGV(A(3)),M;
;
; RELEASE THE PREVIOUS TRACK SEGMENT
;
        ASSIGN:J=A(3)+2;
        RELEASE:NODE(X(J));
;
; DETERMINE IF THERE IS A NEW TASK FOR AN EMPTY VEHICLE, IF SO,
; SET THE VEHICLE STATUS TO BUSY AND DETERMINE THE NEW SEQUENCE TO FOLLOW
;
        BRANCH,1;
        IF, A(8) .EQ. 3 .AND. A(2) .NE. M, SQ3;
        ELSE,CT7;
SQ3     EVENT:4;
        ASSIGN:A(1)=M;
        ASSIGN:J=X(1)+A(3)+2;
        ASSIGN:X(J)=1;
        ASSIGN:A(8)=4;
        ASSIGN:IS=1;
        EVENT:1;
;
; DETERMINE IF THE VEHICLE'S DESTINATION IS THE PARKING ZONE
; OR IF IT IS JUST PASSING THROUGH
;
CT7     BRANCH,1;
        IF, A(2) .EQ. M, RUI;
        ELSE,EX;

```

```
;
; IF THE PARKING ZONE IS THE DESTINATION, THEN FREE THE VEHICLE AND DISPOSE
; OF THE ENTITY, OTHERWISE EXIT THE PARKING ZONE.
;
QUI    FREE:AGV(A(3));DISPOSE;
EX     ASSIGN:J=A(3)+2;
        ASSIGN:X(J)=M;
        ROUTE:;SEQ;
END;
```

```

      ASP.COM
$LINK AGVMHIN,AGVINP,AGVLOAD,AGVINFO,AGVDIST,AGVNET,AGVKSHT
$RUN AGVMHIN
$WRITE SYS$OUTPUT "   Processing experiment file..."
$PURGE SORT.DAT
$QAPP
$FOR AGVCHSER
$QEXP AGVSIM1 Y
$WRITE SYS$OUTPUT "   Processing model file..."
$QMOD AGVP Y
$WRITE SYS$OUTPUT "   Linking file..."
$PLNK AGVP AGVSIM1
$FOR AGVSIM1,E,AGVP.MOD,AGVMHIN.EXE,AGVSIM1.ELS,AGVP.MLS
$WRITE SYS$OUTPUT "   Executing simulation..."
$SUB/NOT SIN/PAR=(AGVSIM1,AGVCHSER,0,Y)

```

```

      APP.COM
$COPY AINIT0.MOD AINIT.MOD
$APPEND AINIT5.MOD,AINIT6.MOD,AINIT7.MOD,AINIT9.MOD AINIT.MOD
$COPY ASTAT0.MOD ASTAT.MOD
$APPEND ASTAT1.MOD,ASTAT2.MOD,ASTAT3.MOD,ASTAT3A.MOD,-
      ASTAT4.MOD,ASTAT5.MOD,ASTAT6.MOD,ASTAT8.MOD,ASTAT9.MOD,ASTAT9A.MOD-
      ASTAT.MOD
$COPY AINTE0.MOD AINTE.MOD
$APPEND AINTE1.MOD,AINTE4.MOD,AINTE4A.MOD,AINTE4B.MOD,AINTE5.MOD AINTE.MOD
$COPY ATRCK0.MOD ATRCK.MOD
$APPEND ATRCK2.MOD,ATRCK1.MOD,ATRCK1A.MOD,-
      ATRCK3.MOD,ATRCK4.MOD,ATRCK5.MOD ATRCK.MOD
$COPY APZ0.MOD APZ.MOD
$APPEND APZ9.MOD APZ.MOD
$COPY AINJT.MOD AGVF.MOD
$APPEND ASTAT.MOD,AINTE.MOD,ATRCK.MOD,APZ.MOD,AGVF.MOD
$APPEND AGVSIN.EXP,PAR.EXP,AGVSIN2.EXP,AGVSIN1.EXP
$EAPPCH

```

APFCH.COM
\$COPY CHSQ0.FOR AGUCHSEQ.FOR
\$APPEND CHSQ1.FOR,CHSQ1A.FOR,CHSQ2.FOR AGUCHSEQ.FOR

APPENDIX F

AGVS Installations

No. of AGV's	Capacity (pounds)	Speed (ft/min)	Truck Type	No. of Stations	Path Length (feet)	2-way Track	Function	Industry	Source
**	20000	**	Unit Load	**	**	**	Carries assemblies thru sequence of w/s connects two w/h: Ship and Rec'y	Mfg. crop tractors	16
3	24000	**	Tow	21	**	No	Delivery between mfg. and w/h; use elevator	Grocery Wholesaler	16
**	12500	176	Tow	24	5500	No	Interfaces with AS/RS	Mfg. residential controls	16
6	22000	**	Tow	23	4350	No	Delivery from disassembly rebuild areas	Mfg. office furniture	16
12	1500	**	**	**	**	No	Interfaces with AS/RS, docks, assembly, test	Aircraft rework facility	16
**	**	**	Pallet	250	**	**	Interfaces with AS/RS, process and inspection	Medium-sized mfg. plant	16
4	8000	**	Unit Load	**	**	Yes	Interfaces with AS/RS and manual transit	Paper mfg.	16
4	**	**	Unit Load	**	**	Yes	Delivers from staging area to machines	Automotive mfg.	16
3	**	**	Unit Load	**	**	**	Material movement in w/h	Food processor	16
13	**	**	Pallet	13	6000	**	Semi-automatic bin picking	Auto parts distribution	16
19	**	**	Stock selector	**	**	**	Interfaces with AS/RS, w/h, mfg.	Air Force W/H for repair parts	16
14	**	**	Unit Load	24	**	Yes	Interfaces with AS/RS and	Mfg. hydraulics components	16
2	**	**	Unit Load	4	**	**	Interfaces with mfg. and w/h	Mfg. metal parts	16
28	4000	**	Unit Load	14	3700	No	Interfaces with AS/RS and mfg.	Cosmetic mfg.	16
15	**	**	Pallet	**	**	**	Interfaces with AS/RS, shipping and rec'y	Hydraulics Facility John Deere & CO.	30
6/12	**	**	**	**	**	**	Transportation in mfg.	Keebler Co.	31
4	**	3.28	**	27	1000	**	All transportation within the plant	Sheet metalworking	28
3	1500 kips	40-200	**	136	7500	YES	Carries engine thru	Fujitsu Fanuc	59
100	440	**	Unit Load	**	2700	NO		Opel Russelsheim Car	54

No. of AGV's.	Capacity (pounds)	Speed (ft/min)	Truck Type	No. of Stations	Path Length (feet)	2-way Track	Function	Industry	Source
10	**	500	**	**	**	**	engine dress-up interface with AS/RS and picking lines	Final Assembly Steele Case Furniture	60
5	8000	**	**	**	**	**	Move large rolls of paper from mill to AS/RS	Eastman Kodak Paper for film	
**	**	197	Pallet	**	**	**	Interfaces with an AS/RS	Murata Machinery	3
95	**	**	Unit Load	40	7500	NO	Carries engine thru engine dress assembly	Oldsmobile GM-Front wheel drive cars	6
32-33	**	**	Unit Load	13	1200	NO	2 systems, merge chassis with engine	Oldsmobile GM-Front wheel drive cars	6
1	2000	132-352	Unit Load	**	**	YES	Carries fixtured parts to inspection stations	Boeing Aerospace	29
22	6000	**	**	**	24000	**	Provide transport from docks to assembly line	General Motors Model C cars	4
2	**	238	Unit Load	11	1400	NO	Transportation between departments	DEC Printed wiring boards	5
1	500	100	Tow	22	2800	YES	Carries laminated panels for F-16 aircraft mfg. department	General Dynamics F-16 Aircraft	2
70	2000	68-230	Unit Load	**	3000	NO	Transportation in returns	Freeman (U.K.)- Mail order distributor	44
1	2000	180	Tow	**	2150	**	Move hot loads from heat treatment to next stop	GKN Screws and Fasteners (U.K.)	33
50	1500	69-138	Unit Load	15	**	NO	Carries auto bodies thru welding stations	Fiat Torino and Cassinos	51
4	**	**	Tow	21	2300	NO	Supply and disposal of material	Mfg. of electrical equipment	43
**	**	100	**	**	500	**	Integrated assembly production	Auto Manufacturer	43
40	**	**	**	100	2000	NO	Interface with AS/RS	Publishing Company	43
30	**	**	**	**	1250	**	Order pick lower level of storage racks	Food Warehouse	43
17	**	**	Unit Load	7	3280	**	Supply and disposal of material	Wasabroed (Sweden) Crisp bread wafer	
40	30000	**	Tow	**	46000	**	Transport of press sheets	Auto Manufacturer	
30	**	**	Pallet	68	686	NO	Supply and disposal of pallets	Aust. Phillips Ind. video recorders	