UNIVERSITY OF CAPE TOWN

DEPARTMENT OF MECHANICAL ENGINEERING

A SIMULATION STUDY OF A CHEMICAL DISTRIBUTION SYSTEM

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September 1988

Submitted to the University of Cape Town in partial fulfillment of the requirements for the degree of Master of Science in Industrial Engineering.

DECLARATION

I, Nicolas Koenig, submit this thesis for the degree of Master of Science in Industrial Engineering. I claim that this is my original work and that it has not been submitted in this or in a similar form for a degree at any University.

ABSTRACT

There has been a great deal of interest recently in using the simulation approach to analyse and optimize industrial systems. Applications of simulation techniques in the South African field are however limited and there is an urgent need for further work.

This thesis provides industry an illustrative example of a simulation model of a chemical distribution system. It is concerned with the handling of raw materials and products at the African Explosives and Chemical Industries (AECI), situated in Somerset West. The model objectives were threefold; firstly, to establish the application of the simulation concept in the distribution field; secondly, to analyse the whole distribution system and to provide the factory with thorough details on its distribution performance; and finally, to identify any potential future strategies to minimize distribution cost.

At AECI, a variety of chemical products are delivered every day to customers, using trucks, mechanical horses and trailers. Some of the vehicles are also dedicated to carry Ammonium Nitrate to the factory. Distribution is influenced mainly by the following factors, which are incorporated into the model:

1. The size and number of orders for each product.
2. The time at which orders are placed.
3. The target time to satisfy the customers.
4. The vehicle/product allocation rules.
5. The vehicle and load utilizations.
6. The mechanical horse/trailer allocation rules.
7. The loading and unloading resource utilization.
8. The frequency of vehicle breakdowns and maintenance policy.
9. The journey time.
10. The overtime policy.

In an initial phase, the products were classified into 5 groups. Using the SLAM II simulation language, orders for each product group were modelled as entities. These are scheduled to be introduced into the SLAM network at random times during working hours. They are then combined into batch entities, according to the desired vehicle load utilization, waiting time of the orders and vehicle availability.

After having been assigned to a vehicle resource, the batch entities undergo a series of delays, representing the various activities involved in transferring loads from the warehouse to the customers, and taking empties back to the factory when necessary.

The data employed by the model is based on distribution during January and February 1988. The model was designed to provide information on the customer service, resource utilization and distribution costs. In general, the results correlated well with information on the actual situation. Owing to the flexibility of the model, a number of alternative strategies were simulated to evaluate the impact of certain variables on distribution effectiveness. The following conclusions were drawn from the results:

1. By increasing the actual vehicle load utilization of 70 % to 80 %, customers would be satisfied in an average time of 49 hours. This policy could be achieved by batching more orders together and would represent the best compromise between customer service, resource utilization and distribution costs. The remaining policies are based on an 80 % load utilization.
2. By extending the time to satisfy the demand from 48 to 72 hours, overtime would be reduced by 14 %, while the customers would be satisfied in a mean time of 53 hours.
3. The influence of varying the maintenance frequency and duration for vehicles could not be fully investigated. In this regard, the maintenance rules employed by the model need to be improved.
4. No significant improvements were obtained by altering the present 6-hour policy with respect to the maximum overtime per journey.
5. Variation of the frequency of breakdowns for vehicles did not yield consistent results, as the approach employed is not sophisticated enough.
6. Morning inspection of vehicles had a significantly adverse influence on the satisfaction of demand time. Ideally, it should be effected outside delivery hours.
7. The effect of delaying vehicles during delivery hours for changing the mechanical horse/trailer combination can considerably increase the satisfaction of demand time and overtime. The optimal solution would be to effect these changes outside delivery hours.
8. The present mechanical horse/trailer allocation rules constrain distribution. By allowing all possible combinations, the average time to satisfy the demand would be reduced from 49 to 45 hours, together with a reduced number of trips and a 2,3 % saving in fuel consumption.

9. By discarding TRUCK 412 from the system and concentrating loads on larger vehicles, the average satisfaction of demand time would be reduced from 49 to 42 hours, with a 9 % saving in overtime. Alternately, removal of TRUCK 469 would increase the mean satisfaction of demand time by 1 hour and overtime by 6 %. However, a 3,2 % saving in fuel consumption would be achieved, as well as a reduction in human resources. The last potential alternative would be to discard TRAILER 453. This would increase the mean satisfaction of demand time by 2 hours and overtime by 20 %.

In conclusion, the model has achieved its objectives and proved to be a powerful and versatile systems analysis tool. It is hoped that further development will be pursued in the simulation field.

ACKNOWLEDGEMENTS

I wish to thank the following people for their advice and guidance in the development of this thesis:

Mr. G. Lister, Senior Lecturer in the Department of Mechanical Engineering at the University of Cape Town, and
Prof. T. J. Stewart, Professor in the Department of Mathematical Statistics at the University of Cape Town.

Thanks are also due to Mr. T. Botha, the Transport Manager at AECI (Somerset West), for allowing me undertake the project at his department, and the CSIR, for the research grant.

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CHAPTER ONE

INTRODUCTION

Since the beginning of this century, industrial societies have developed sophisticated manufacturing, commercial and management systems. With the ever-advancing technology and the existing instability in political, social and economic environments, decision making tends to be poor and costly. This is particular true when considering expansion programmes and improving system performances, where the degree of certainty about future strategies is not well defined. The necessity to develop effective techniques to analyse systems then becomes evident.

Simulation may be defined as a general activity performed to answer the question "What if ..." in order to find the optimal solution to a specific problem, before actually setting out on a specific course of action. In the industrial engineering context, simulation is a technique which can effectively promote communication between management and the specialist seeking a solution to a problem. Extensive studies have shown that computer simulation is the most widely used quantitative modelling technique in industry in the United States. Simulation has already been applied to a wide range of disciplines in the industrial field, including manufacturing operations, transportation systems, computer and communioation systems, project planning and control, and financial planning.

In the South African context, however, the concept of simulating industrial processes is fairly new, and the need for further work still exists. This thesis provides an illustrative example of the application of simulation in industry. It is essentially concerned with the distribution of raw materials and products at the African Explosives and Chemical Industries (AECI), situated in Somerset West.

AECI has a certain number of vehicles that are dedicated to the distribution of raw materials to the factory and products to different customers. Distribution is affected by a number of inter-related factors. Presently, the distribution efficiency is not well known, but is suspected to be relatively low. The ongoing model carries the following objectives:

1. To establish the application of the simulation concept in the distribution field.
2. To analyse the whole distribution system and to provide the factory with thorough details on its distribution performance.
3. Using simulation techniques, to identify any potential future strategies to minimize distribution cost.

The model utilizes the SLAM II simulation language, a powerful and versatile package available on the mainframe at the University of Cape Town. SLAM is a FORTRAN-based Simulation Language that allows Alternative approaches to Modelling, and lends itself well to the present situation.

The following Chapter reviews some of the research that has been carried out so far in the simulation and distribution fields. Chapter 3 formulates the problem by studying the actual situation at AECI and specifying detailed objectives of the model. An analysis of the model construction is then presented in Chapter 4, with emphasis on preliminary assumptions, modelling concepts and data analysis. Chapter 5 follows with the simulation results obtained, as well as a discussion on their significance. Alternative strategies are then presented and potential improvements identified. Finally, Chapter 6 makes some recommendations on further research. The development of the areas of the project, in the order mentioned, will provide a basis for drawing conclusions and making recommendations as to the effectiveness of the simulation technique in industry.

CHAPTER TWO

LITERATURE SURVEY

This chapter comprises three sections. Section 2.1 reviews some articles outlining the importance of simulation in industry. Section 2.2 follows with real-world applications of simulation in South Africa. Finally, the the third section describes a number of models that have been developed in other countries.

2.1 Simulation in Industry

Jamieson[1] reviews the history of the development of simulation methods and outlines the significance of simulation in the industrial engineering field in South Africa. Jamieson mentions that there has been a great amount of model building activity, which has been successful. Some of the proven modelling computer programs available include the following activities:

1. Demand forecasting.
2. Inventory control.
3. Aggregate planning.
4. Production planning.
5. Financial planning.
6. Factory location.
7. Machine location in factories.
8. Replacement of assets.
9. Planning of customer deliveries using road networks.
10. Production schedule optimization.

However, substantial benefits can still be achieved from simulation of future operations in large-scale industrial systems. It is also pointed out that senior management should be future oriented by getting involved in effective long term planning.

Some of the most ambitious models currently being processed are those which attempt to simulate the operations of large manufacturing organizations. Goldie[2] warns, however, these organizations using simulation for the first time. In his paper, Goldie states:

"Simulation models can assist and often times improve the planning and decision making process. Properly used, they can relieve many frustrations and tensions. But, just as any new medicine may produce unsuspected adverse side-effects, so can simulation upset the manager, especially when he uses it for the first time."

The author identifies the following irritations:

1. The final model does not have the responsiveness and the ability to inspire confidence in its results.
2. Models take a long time to build.
3. It takes a long time to incorporate a change or an improvement.
4. The data necessary for the simulation is not always readily available.
5. The model is never quite complete, or quite right.
6. The problem to be solved has to be translated from the manager's terms to the model's terms.
7. The model can not be explained in understandable terms.
8. The process being simulated changes faster than the model can be changed.
9. There is often difficulty in defining the probable range of error.
10. The claims of model builders to be able to simulate perfectly any real life situation.

However, the above comments should not inhibit the model building activities in South Africa.

2.2 Local Applications

Kruger et al.[3] provide an excellent example of the application of simulation in the South African industry. In their SLAM II model of a materials handling subsystem in a packaging plant of the South African Breweries, the authors investigated the following:

1. The impact of the number of loading/unloading docks on the time spent in the system by the trucks, the number of trucks waiting, and the amount of in-process inventory.
2. The effect of varying the size of forklift truck fleet on the delays experienced by the trucks caused by the non-availability of forklift trucks.

The model showed that four loading/unloading docks and four forklift trucks should be adequate. Kruger also points out that such an advanced simulation language like SLAM II can be a very powerful system modelling approach and provides an efficient systems analysis tool.

The Ohlsson's Brewery in Cape Town has operated from the Newlands site since the last century. In 1978, the site was somewhat congested. A model was built by Cutler[(4)] to simulate the loading of vehicles and the distribution of beer to customers. The objective was to allow management to test alternative operation strategies and predict the ultimate distribution capacity of the site.

The model was built using the HOCUS system (Hand Or Computer Universal Simulator). It was designed, then, to overcome the problem of accurate communication between the manager and the Operation Research specialist.

A number of factors relating to beer distribution was considered. These included the seasonality of the sales, handling facilities, size of vehicle fleet, constraints on delivery time and working hours, layout of the warehouse and loading/unloading times. In addition to indicating the site capacity, the results revealed the ratio of forklift truck to vehicles that was required to minimize warehouse turnaround time, as well as the optimum warehouse layout.

Chadwick[(5)] undertook an extensive survey on the distribution of food products of 10 companies. His objectives were to develop delivery time standards and to analyse the distribution operations of each company. The author identified the major problem areas and evaluated the delivery vehicle efficiency, labour efficiency, and economical delivery size. It was shown that the major contribution to improving the utilization of vehicles was the better utilization of potential delivery hours. From the distributor point of view, the following recommendations were made:

1. Move the vehicle loading operation to evening shift/overtime when the vehicle fleet consisted of 10 vehicles or more. This would result in a saving of 1 vehicle per 10 vehicles in the fleet.
2. Use unit loads. This would reduce the loading and unloading time required, and enable the retailer to load and unload the vehicle in an efficient manner.

From the retailer point of view, the following actions were recommended:

1. Accept unit loads, which would reduce the checking procedures while the vehicle waits. A drop of 10 minutes in the receiving time would reduce the queuing time from 41 to 5 minutes.
2. Extend operating hours of receiving facilities at specified outlets. 1, 2, and 3 hours extension would reduce queuing time from 41 to 30, 24, and 20 minutes respectively. However, further increases in operational hours would only decrease the queuing time marginally.

2.3 International Applications

A manufacturer of castings desired to achieve a production goal of 3140 parts per week with the Flexible Manufacturing System (FMS) shown in Figure 1 below. Musselman(6) built a MAP/1 model to study alternative milling machine centre configurations.

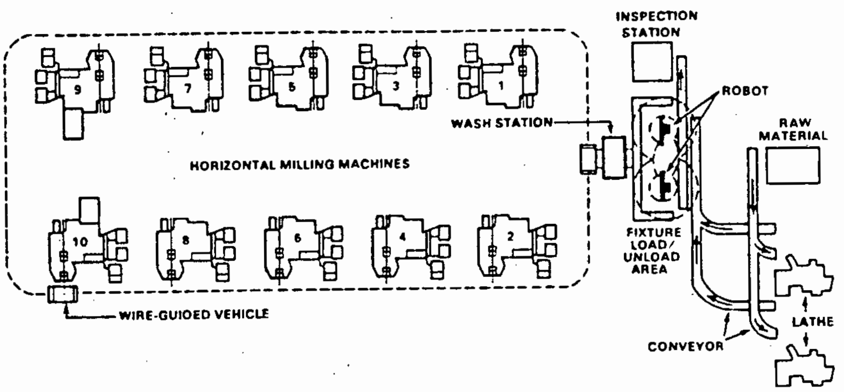


Fig. 1 - Schematic of a Milling Machine Centre

The model allowed the throughput performance to be evaluated under various machine mix conditions. The results are depicted in Figure 2.

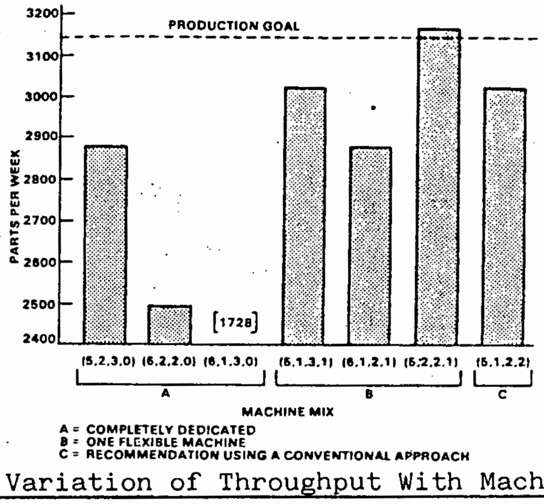


Fig. 2 - Variation of Throughput With Machine Mix

The bar chart shows that machine mix (5,2,2,1), which represents 5 machines dedicated to the first operation, 2 machines to the second operation and 2 machines to the last operation with 1 flexible machine, can produce the required number of parts per week. Moreover, by limiting the route options available in the system (i.e. allowing only 1 flexible machine), the milling machine centre works more efficiently, increasing overall productivity.

The author demonstrates that simulation can be the technique of choice when it comes to designing a FMS automation and forecasting its performance.

Miner et al.[7] developed a GASP IV model of a chemical plant with the objective to establish the best way to improve the throughput. The plant manufactures six products, each going through a series of steps; different products can be in production at the same time. Production must be scheduled to meet demands and to maintain minimum inventories, and it must operate within the constraints of processing space and in-process storage. The model allowed to determine the following:

1. The effect of customer demand patterns on operation requirements of the manufacturing facility.
2. The effect of required lead time for orders on manufacturing costs, inventory levels, and production scheduling.
3. Alternative production scheduling procedures.
4. Alternative system configurations (the number and capacity of storage tanks, filters, reactors and pipelines).

An analysis of the results indicated that an 80 % increase in throughput could be realized by adding a filtration system to the plant. Furthermore, an additional 20 % increase could be achieved by using dual-purpose reactors for handling either Process 1 or Process 2. Simulation showed to be an extremely flexible and powerful tool for the evaluation of alternatives. Management responded enthusiastically and initiated similar projects in other areas of the plant.

In an attempt to increase the productivity of a small parts stamping plant, Hancock et al.[8] developed a GPSS simulation model to determine the relative economic advantages of changing the crewing, increasing the spare tooling, or improving the die preparation. The percent utilization and the cost per 1000 parts produced were chosen as the measures of performance. With a demonstration group of 8 machines, the authors found that die preparation was the most important operation affecting machine utilization. As a result of the modelling experiment, machine utilization was increased from 37 % to 60 %. In addition, the authors showed that if die failure rates were kept under control, and presses were loaded correctly together with proper spare tool inventories, utilization could be increased further to 76 %.

A SLAM II simulation model of a petroleum product distribution system was developed by Pritsker[9] to evaluate the feasibility of actually following a proposed product allocation plan. The representation of the system in the model included product transportation from refineries to terminals via pipelines, tankers, and barges. Thus, given the physical characteristics of the system and the desired product movements, the model evaluated proposed assignments with respect to what can be feasibly scheduled consistent with pipeline flow limits, transportation times, tanker and barge availability, and certain product constraints. The different input and output information for the model is illustrated in Figure 3 below:

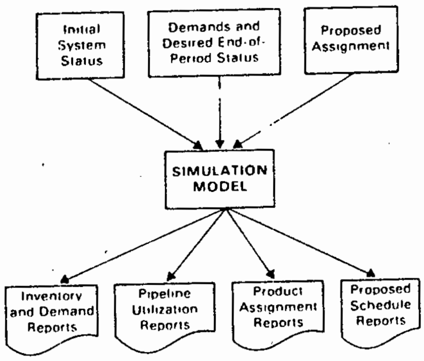


Fig. 3 - Distribution Procedure Inputs and Outputs

The model proved to be a powerful asset to the refinery in that it helped to evaluate the influence of different linear programming and heuristic assignment procedures on the distribution of petroleum. Furthermore, it was proposed as a procedure for performing refinery scheduling, crude supply planning, pipeline scheduling, and tanker scheduling.

Pritsker [9] also built a SLAM II simulation model to compare the current and proposed manufacturing capabilities of a table-products manufacturing facility. A schematic diagram of the process is depicted in Figure 4 below:

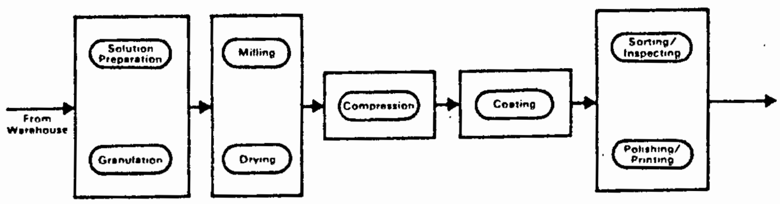


Fig. 4 - Schematic of the Tablet Manufacturing Process

The objective of the modelling effort was to answer the following questions:

1. Can the current manufacturing facility meet the forecasted production requirements?
2. Can the proposed facility meet the forecasted production requirements and, if so, will the large capital cost be justified by the additional capacity?

The model was used to test many alternatives with respect to the impact of operating policies on productivity increases. Six alternatives were developed and tested against forecasted production requirements. The results of the analysis are presented in Table 1 below:

Production alternative	Facility configuration	Production shortfall (%)
1	Current Facility (1 shift)	34
2	Current Facility (2 shifts)	21
3	Proposed Facility (1 shift)	10
4	Proposed Facility (2 shifts)	1
5	Proposed Facility Revised (1 shift)	2
6	Proposed Facility Revised (2 shifts)	0

Table 1 - Computer Model Results for Six Manufacturing Alternatives

The results clearly points out that a proposed facility operating under a 2-shift schedule or with additional capabilities would optimize production. The model was continued and used to assess detailed planning and production procedures for the proposed facility.

Auterio[10] constructed a Q-GERT simulation model to analyse the productive capacity of an aerial port cargo processing. The air terminal is depicted in Figure 5 below:

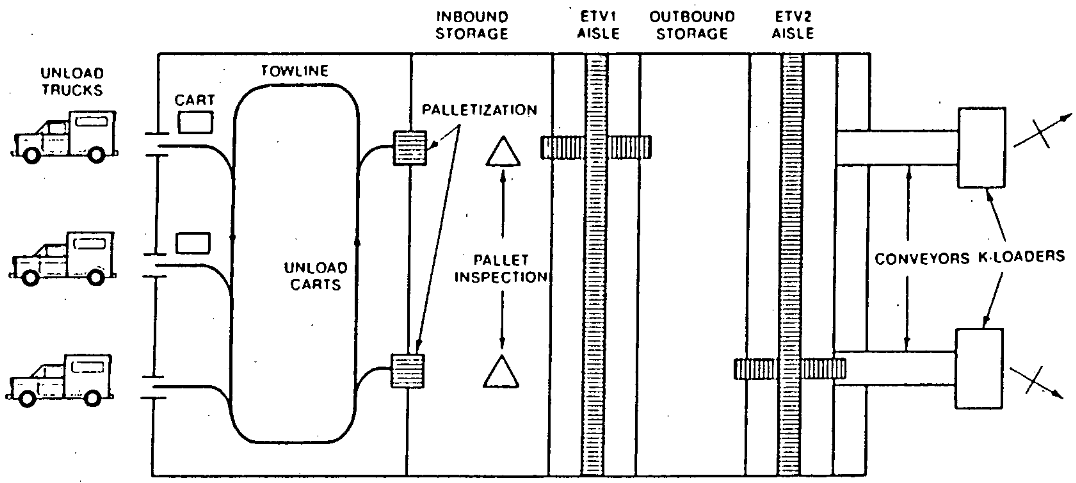


Fig. 5 - Schematic Diagram of Air Terminal

At the terminal, cargo arrives by truck or by aircraft. The cargo is unloaded and sorted according to shipment type, destination and priority. Then, it is moved to various in-process storage areas where it is held until it can be consolidated. Following consolidation, it is weighed, inspected and stored. When the cargo is selected for a mission, it is transferred to a staging area where it is combined with other cargo. The batch is then loaded on to the aircraft.

The model allowed management to answer the following questions:

1. Is it worthwhile to introduce automation equipment in ports to improve processing capacity?
2. Where should new equipment be located?
3. How many aircraft can a port load simultaneously?
4. During contingencies, what additional resources will be required to support an increase in the level of air traffic?

The chapter emphasized the significance of simulation in various industries. Furthermore, a comparison of local with international applications, highlights clearly the existing limitations in the South African field. In conclusion, then, there is an urgent need for modelling and optimizing industrial processes through the simulation technique.

CHAPTER THREE

PROBLEM FORMULATION

3.1 The Situation

3.1.1 Products

Over fifty different kinds of sales products are distributed by AECI to its customers. The products are stored at three main locations on the plant, namely the Acids Despatch, Chemical Despatch, and Plastics Despatch. Within each despatch area, the products are packed and stored in a number of different ways, depending on the product type and the customer requirement. Appendix A summarises the products distributed, together with the type and size and container.

In view of the different packing methods employed, various handling methods may be used during loading/unloading operations. Handling methods may take one of the following forms:

1. Purely manual handling, employed for small packages or container vessels.
2. Forklift truck and manual, used for lifting heavier items onto the vehicle. Manual labour is employed to load the products onto the forks and also to stack the products on the vehicles.
3. Forklift truck only, used for handling large drums and palletised products.
4. Drum trolleys, for medium-sized containers. Loaded, unloaded and pulled manually.
5. Tailgate loaders. The tailgate on the back of a vehicle is used to lift or lower the load. Tailgates are loaded either manually or with the aid of a forklift.
6. Crane trailers. Built-in cranes are used to load and unload large pressure vessels.
7. Bulk filling points. No labour is employed here, except to hook and unhook the supply to and from the trailer tank respectively.

3.1.2 Raw Materials

With the exception of Ammonium Nitrate, all raw materials are usually delivered by rail to the factory, and will not be considered in this project. However, the need to include Ammonium Nitrate in the model arises from the fact that it does interact with the distribution of sales products (i.e. it is delivered to the factory using vehicles that also deliver sales products). Ammonium Nitrate is handled in bulk.

3.1.3 Distribution Resources

Vehicle resources may be broken down into three categories, namely, mechanical horses (6 in all), which are connected to trailers (7 in all), and 6 trucks. Load capacities vary from 11 tonnes to 23 tonnes for the trailers, and 2 to 13 tonnes for the trucks. It is important to mention, at this stage, that these vehicles are not fully flexible, but are dedicated to carry specific types of products. For instance, there are only two trailers that are designed to handle large cylindrical tanks, also known as barrels. Furthermore, for safety reasons, large pressure vessels can only be carried on trucks which can accomodate standard cradles. Each vehicle requires one driver and one assistant. On some occasions, two assistants are needed.

Loading/unloading resources comprises the following:

1. Five forklift trucks of equal load-carrying capacity.
2. One gantry responsible for connecting/disconnecting barrels to/from trailers.
3. Two filling points: Filling point no. 1 delivers Caustic Soda and Sulphuric acid in bulk to the appropriate barrels.
   Filling point no. 2 delivers only Hydrochloric acid.
4. Human resources: a gang or workers is assigned to the despatch areas.
5. Vehicle resources: some of the vehicles are fitted with their own cranes or tailgates.

3.1.4 Customer Service Policy

Upon reception of an order from a customer, AECI will try to its best to satisfy the customer as early as possible. Generally, a customer's order is satisfied within 48 hours after the order has been placed. Other important criteria taken into account include the route schedule of the vehicle and the vehicle load utilization.

3.2 Objectives

Having established the physical requirements and constraints of the problem, the model objectives can now be clearly defined. The end target of simulating the distribution system is to provide a tool that will:

1. Extract information from the real-world situation and convert it into meaningful measures of performance for the company.
2. Enable AECI to investigate alternative strategies, in an attempt to optimize its distribution.

The measures of distribution performance that are chosen are defined as follows:

1. Customer service. This relates to the time that it takes for an order to be satisfied, from the moment it is received at the factory.
2. Vehicle utilization. The percentage time of the day (24 hours), during which the vehicle is assigned a load. Thus, as soon as a load is allocated to a vehicle, the latter is effectively being utilized.
3. Loading resource utilization. The percentage time of the day, during which the loading resource is being utilized.
4. Human resource utilization. The maximum number of human resources used at any time during the day, as compared to the maximum available number of resources.
5. Distribution costs. This is measured in terms of:
   1. Total fuel consumed during a chosen time period.
   2. Number of hours worked under normal time condition during a chosen time period.
   3. Number of hours worked under overtime condition during a chosen time period.

A number of input information are taken into account by the model. Figure 6 illustrates them, and shows the function of the model:

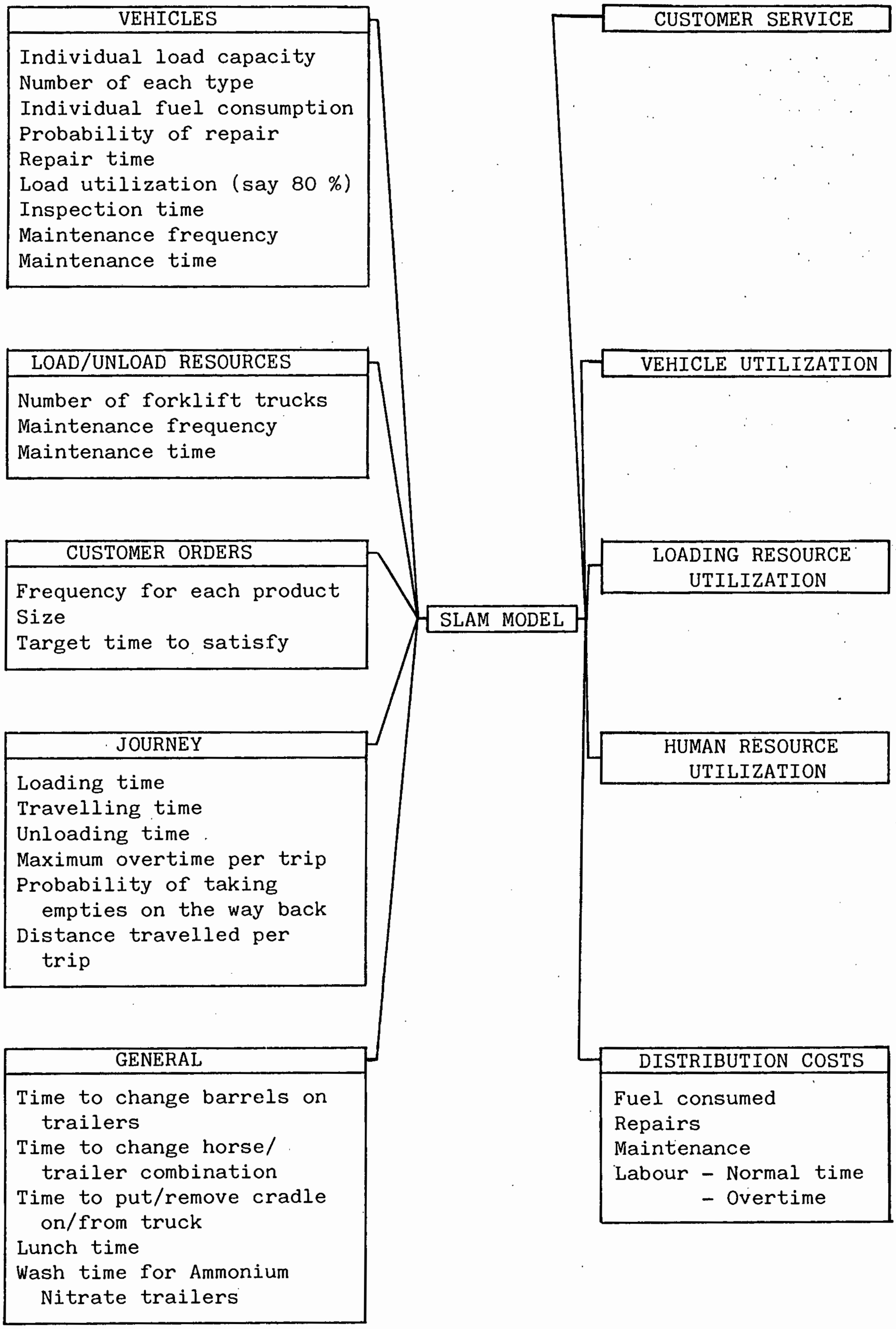


Fig. 6 - Conversion of Input Parameters to Distribution Performance Measures

3.3 Assumptions

3.3.1 Demand and Supply of Products

Demand for products at any time is assumed to be related to two parameters, namely the frequency at which orders are placed everyday and the size of the order. Owing to the large number of different kinds of products and packing types that may be ordered, it would be intricate to treat each product on an individual basis. For the purpose of the model, it is convenient therefore to break down the products into product groups. Five groups can be identified, as detailed below:

1. Product 1 - comprises bags of PLASTICS, independently of the kind of plastic product. All products stored at the Plastics despatch fall under this category. Order size will be treated as the bulk mass (in kilograms) which is equivalent to the cumulative sum of the individual constituents of the order.
2. Product 2 - consists of AMMONIUM NITRATE raw material. Due to the fact that it is handled in bulk loads equivalent to the load-carrying capacity of the trailer, it is suitable to treat an order as one trailer. Hence, the order size is not applicable here.
3. Product 3 - this constitutes all products handled in BARRELS. One barrel represents the volume that can be transported when it is full. In addition, because, the barrels are designed to contain specific types of products, Product 3 is subclassified into three types, namely, BARREL 1 for Caustic Soda, BARREL 2 for Sulphuric acid, and BARREL 3 for Hydrochloric acid. In this case, order size represents the number of each type of barrel.
4. Product 4 - relates to LARGE PRESSURE VESSELS (P.V). The term 'large' applies to standard vessels of 0,8 m diameter and 1,9 m long, with a gross weight exceeding 1,5 tonnes. All P.Vs handled with cranes fall under this category. Order size is equivalent to the number of such P.Vs.
5. Product 5 - All products not falling under the above categories, such as polycans, drums, small pressure vessels, are classified under this group. The definition of order size is identical to that for Product 1.

As far as ordering is concerned, it is further assumed that the above product groups are mutually exclusive (e.g. orders placed for Product 3 are independent of those placed for Product 4).

Regarding the supply of products, it is assumed to be 'infinite'. This is explained in conjunction with Figure 7 below:

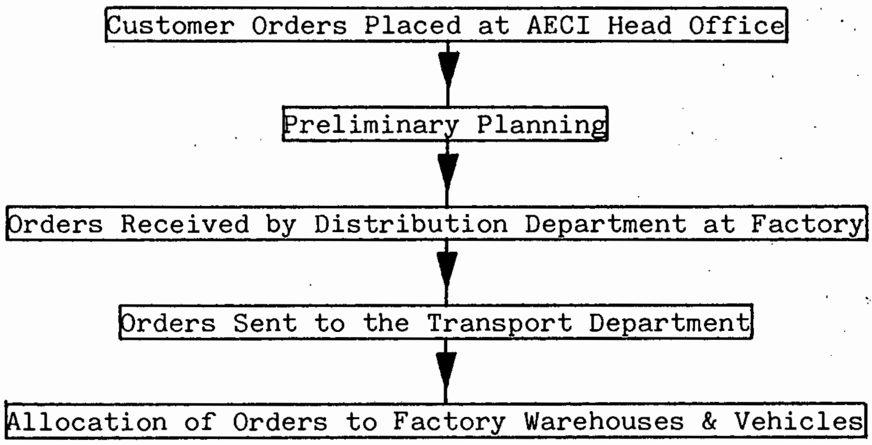


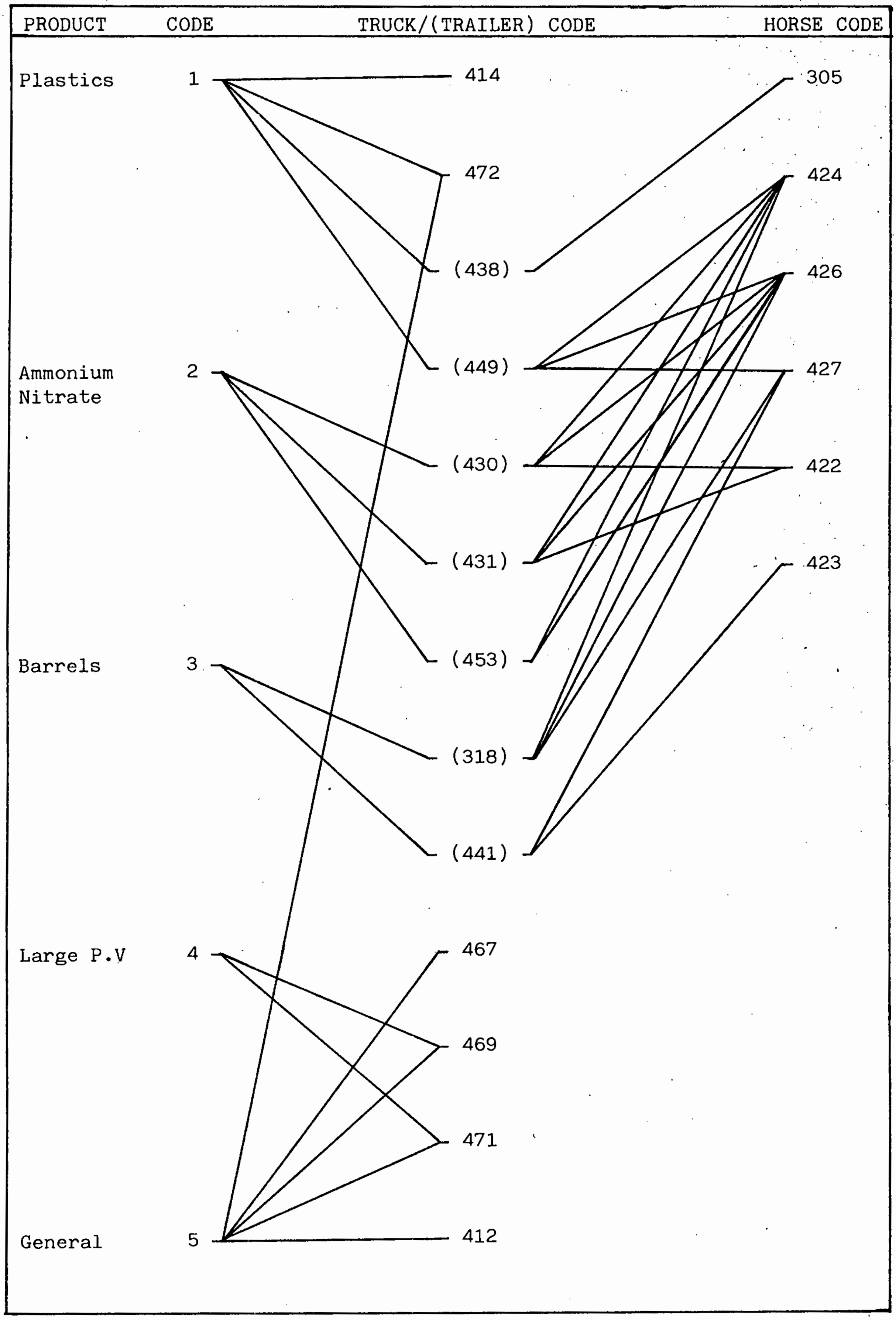
Fig. 7 - Order Route From Customer To Warehouse

Orders are placed at the Head Office in Cape Town. At this stage, a preliminary planning is done to establish the availability of the desired product at the factory. Once it is ensured that the product is available, the order is issued to the distribution department of the plant in Somerset West, which in turn plans with the transport department the vehicle to be used, and the time when delivery will be effected. Thus, under normal conditions, when an order is placed at the factory, there is enough supply to satisfy it. The model is based on this important assumption.

3.3.2 Vehicle Allocation

Vehicles are allocated according to the product type. Moreover, only certain combinations of mechanical horses and trailers are possible. This is depicted in Table 2. The code numbers that appear refer to the 'Item Number' used by the transport department, and will be employed throughout the model for vehicle resources.

TABLE 2 - Possible Allocations of Vehicles to the Products



3.3.3 Maintenance of Resources

Only two kinds of resources are considered within the maintenance context; vehicles and forklift trucks.

With the exception of trailers used for transporting Ammonium Nitrate, all vehicles are maintained on a kilometre basis. Whenever a truck or a mechanical horse has travelled a cumulative distance exceeding 5000 km, it is sent to the maintenance department for a general service. The vehicle then becomes unavailable for a period of 24 hours. This also takes into account the maintenance schedule for each vehicle and the limitations of maintenance resources. In addition, for a mechanical horse, the trailer that was connected to it during the last journey preceeding maintenance also becomes unavailable.

Concerning Ammonium Nitrate, which is classified as an explosive, law regulations state that explosives-handling vehicles must be maintained on a monthly basis, regardless of the vehicle utilization. Hence, all trailers carrying the raw material go through maintenance every 30 days, for a period of 24 hours. This also applies to the mechanical horses connected to these trailers.

Forklift trucks are also serviced every month. Maintenance lasts 5 hours, starting at 7 a.m.

Finally, the maintenance department is assumed to work during weekdays only. Thus, any vehicle that needs to be maintained during a weekend will be delayed to Monday morning.

3.3.4 Specifications of Resources

Table 3 details specific information pertaining to each material resource, as well as the corresponding availability, load capacity, fuel consumption, and required human resources.

Table 3 - Specifications of Resources

TYPE	ITEM NUMBER	MAXIMUM AVAILABLE	LOAD CAPACITY	FUEL CONSUMPTION	DRIVER	ASSISTANT
--	--	--	kg	ℓ/100km	--	--
TRUCK	412	1	2583	15,2	1	1
TRUCK	414	1	2060	17,6	1	2
TRUCK	467	1	6270	28,0	1	2
TRUCK	469	1	6060 (4 P.V)	26,7	1	1
TRUCK	471	1	11512 (6 P.V)	35,3	1	1
TRUCK	472	1	13332	30,0	1	2
HORSE	305	1	N/A	45,0	1	1
HORSE	422	1	N/A	44,7	1	1
HORSE	423	1	N/A	55,6	1	1
HORSE	424	1	N/A	48,3	1	1
HORSE	426	1	N/A	52,4	1	1
HORSE	427	1	N/A	40,4	1	1
TRAILER	318	1	20000 (4 Barrels)	N/A	N/A	N/A
TRAILER	430	1	23000	N/A	N/A	N/A
TRAILER	431	1	20000	N/A	N/A	N/A
TRAILER	438	1	22690	N/A	N/A	N/A
TRAILER	441	1	20000 (4 Barrels)	N/A	N/A	N/A
TRAILER	449	1	11540	N/A	N/A	N/A
TRAILER	453	1	22630	N/A	N/A	N/A
GANTRY	N/A	1	N/A	N/A	N/A	N/A
FILLPT 1	N/A	1	N/A	N/A	N/A	N/A
FILLPT 2	N/A	1	N/A	N/A	N/A	N/A
BARREL 1	N/A	7	N/A	N/A	N/A	N/A
BARREL 2	N/A	6	N/A	N/A	N/A	N/A
BARREL 3	N/A	3	N/A	N/A	N/A	N/A
CRADLE 2	N/A	2	(2 P.V)	N/A	N/A	N/A
CRADLE 3	N/A	2	(3 P.V)	N/A	N/A	N/A

CHAPTER FOUR

MODEL BUILDING

At this point, a frame of reference for building the model has been established. It remains now to examine the fundamental aspects of the model. To arrive at an appropriate solution, this chapter is broken down into five sections. Firstly, the basic transport network is considered, with emphasis on the batching of orders, vehicle states and details on the journey. Section 4.2 follows with some important SLAM concepts used to interpret the transport network, as well as the model infrastructure. Translation of the transport route into the model concepts is then examined in Section 4.3, with specific details on each product group in Section 4.4. To end with, Section 4.5 analyses the real life data in connection with input parameters for the model.

4.1 Basic Transport Network

The network consists of a closed loop of vehicles that interact with customer orders, loading resources and various activities. Figure 8 illustrates the circuit. As soon as an order is placed at the factory, a record is made of the type of product and quantity required, the place where it needs to be delivered, and the time at which it was received. Orders for similar products are grouped together to form a batch. There are however four important rules controlling the grouping of products, as listed in order of priority below:

1. In any batch, the earliest order should be satisfied within 48 hours.
2. Load utilization of the vehicle should be maximized as much as possible.
3. The route network utilized by the vehicle to deliver loads to individual customers should be as short as possible.
4. Any delivery effected after working hours should not exceed a maximum overtime of 6 hours.

The above rules are not applied on a strict basis, as it is not always possible to satisfy all of them at once. Nevertheless, they do constrain the distribution system to a large extent.

Once a batch has been assigned to a particular vehicle, and the latter

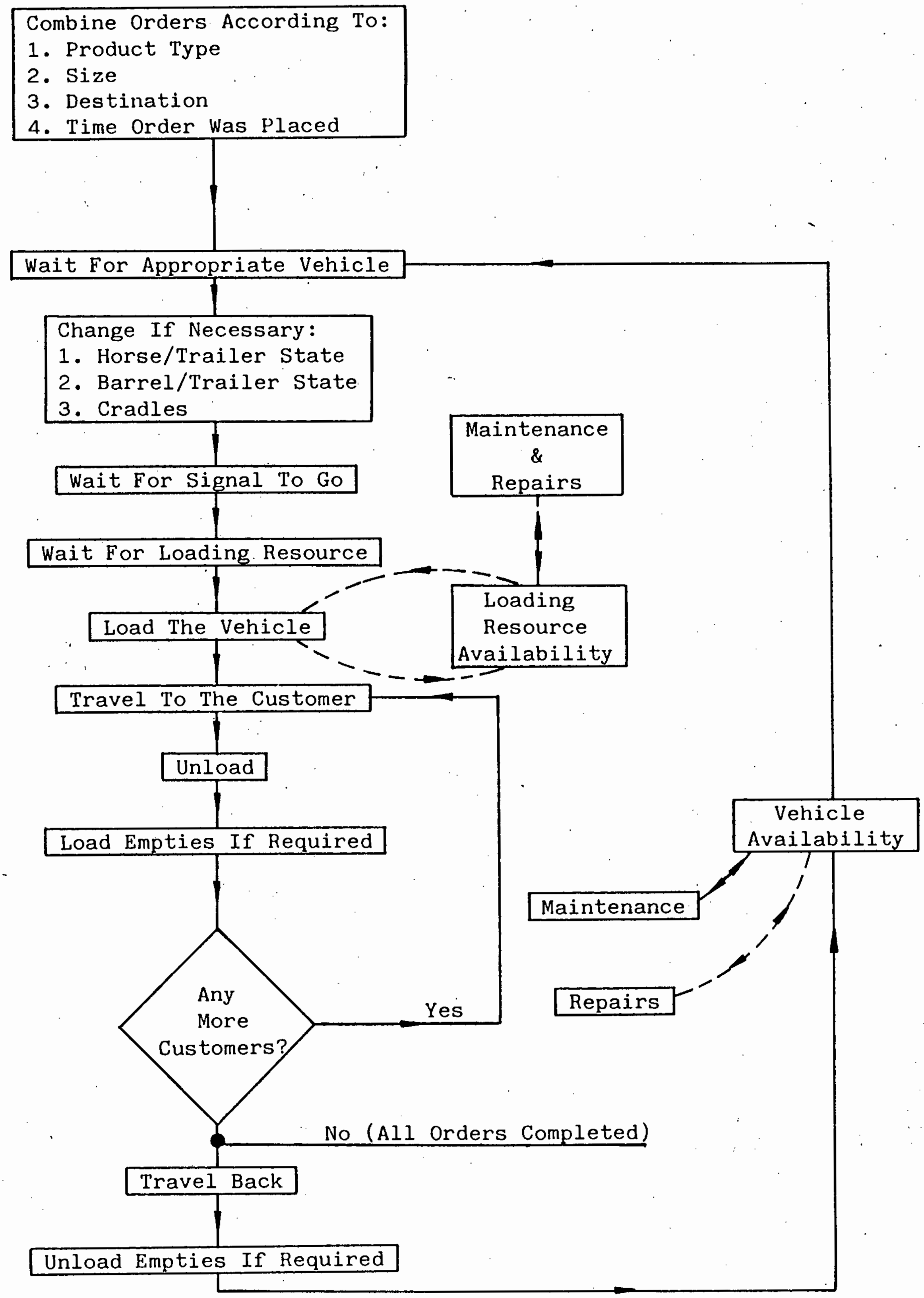


Fig. 8 - Transportation Route: Factory - Customer - Factory

is available for delivery, a check is made to ensure that the vehicle 'state' corresponds exactly to the load requirements. For instance, if the batch consists of 2 barrels of Sulphuric acid, 1 barrel of Hydrochloric acid, and 1 barrel of Caustic Soda, while the available trailer has 4 empty barrels of Caustic Soda connected to it, it will be necessary to change the barrel/trailer state. Similarly, the combination of horses and trailers is checked according to the allocation rules.

When the vehicle is ready to load, another check is necessary to ensure that it is still economical to allow the vehicle to go on the same day (i.e. a customer may not be prepared to receive its load after working hours, or the planned overtime for the trip may be too much). The section 'Wait for Signal to Go' in Figure 8 is concerned with checking such problems.

With the exception of repairs and maintenance, the remainder of the network is self-explanatory. A vehicle may break down or need to be maintained at any moment while it is being used. For modelling purposes, however, it is convenient to concentrate these two activities at one point in the circuit. This is performed when the vehicle becomes available to handle the next orders. Although this approach does not represent the real life situation, it does not introduce any errors in the simulation results on a long term basis. The reason being that, on the long run, delays affect the system to the same extent as the cumulative sum of individual delays. A similar idea is employed with loading resources.

4.2 Model Mechanics

4.2.1 Fundamental Concepts

A number of important concepts are employed to structurs the model. These are:

1. Entities.
2. Resources.
3. Files.
4. Activities.
5. Attributes.
6. Global Variables.
7. Time.

ENTITIES may be visualized as discrete particles flowing through the network. The most important type of entity used in the network is the order entity. In view of the fact that orders are placed at specific points in time, and are satisfied at some later stage, order entities are also introduced into the network at specific times and 'destroyed' later on. Destruction corresponds to the removal of entities from the system. Furthermore, just as individual orders are grouped to form a batch, order entities may be combined to form a batch entity. The concepts of order and batch entities only differ in terms of interpretation.

In the basic transport network, a number of conditions were underlined, with respect to the delivery of loads. One prerequisite was the availability of a vehicle. This is modelled using RESOURCES. Whenever required, resources are allocated to the batch entity. When the resource is no longer required, it is freed and made available to other entities.

Should the batch entity require a resource, which is unavailable, the entity then has to wait in FILES. Files are useful in that they constantly keep track of both the number of entities waiting at any moment and the waiting time of the entity. Hence, the number of customer orders waiting for a particular vehicle may be computed.

As soon as the vehicle resource requirement is met, the batch entity is able to flow through the network. The rate at which it flows is governed by the concept of ACTIVITY. An activity contains information about the duration for which the entity is delayed, as well as conditions or probabilities that control the activity utilization. Thus, the batch entity is delayed through an activity for, say 24 hours, if the vehicle resource allocated to it needs to be maintained at some stage.

An ATTRIBUTE relates to a specific information that the batch entity carries with it throughout the network. For example, to work out the time that it has taken for a specific order to be satisfied, the batch entity carries with it the time at which the earliest order in the batch was placed. Attributes may also be used to distinguish an order entity from another.

Whereas attributes apply to information that can only be used by specific entities, GLOBAL VARIABLES relate to information which is shared by the whole model. This is useful when recording information, and specifying conditions pertaining to all entities. One example is the working hours.

The last concept is TIME. In discrete-event modelling, which applies to the present situation, the model is represented by variables (i.e. attributes and global variables) and by entities. Entities have attributes and belong to files. The state of the model is initiated by specifying initial values to the variables employed in the simulation, by creating the initial entities, and by the initial scheduling of events. During the simulation, the model moves from one state to another as entities go through activities. System status changes only occur at the beginning or at the end of the activity. Thus, time does not advance within an event. The time unit employed in the model is the hour.

4.2.2 Model Infrastructure

The computer program for the model is composed of two parts; one written in SLAM, the other in FORTRAN. Each part is segmented into various sections, as depicted in Figure 9 below:

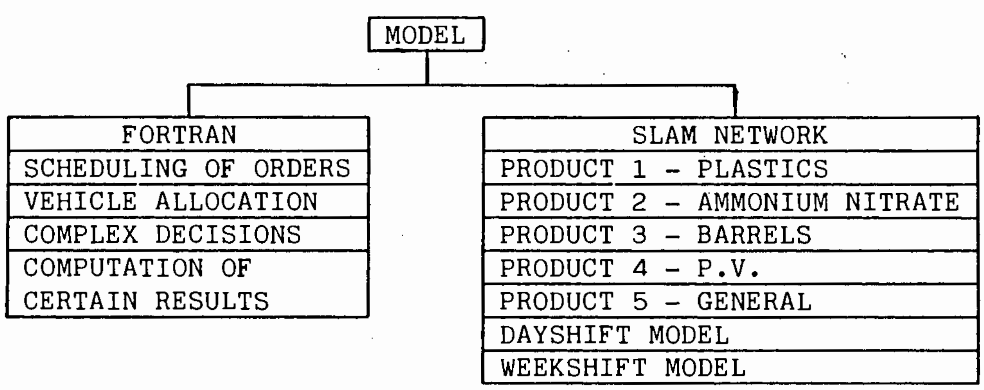


Fig. 9 - Schematic of Model Infrastructure

The product segments are built on the foundations of the basic transport network presented earlier. Evidently, order and batch entities flow through them. Variations from one segment to another arise from the differences between the product definitions and the resources used in each case.

The dayshift model contains one single entity that repeatedly travels through a closed loop during a time period of 24 hours. Two important functions are:

1. Vary some global variables at certain times of the day. These variables are shared by the five product segments.
2. Alter the availability of certain resources for specified durations representing the inspection of vehicles in the morning and the lunch time.

The weekshift model also consists of one entity that goes round a loop, but during a period of 168 hours. Its only function is to vary a global variable representing the state of the week. It enables the rest of the model to differ between a Friday, a Saturday, a Sunday and any other day.

The purpose of the FORTRAN section is to regularly schedule orders, which are then introduced as order entities into the SLAM network. Also, vehicle resources are allocated to the entities. Finally, other important decisions governing the flow of entities are included, as well as the computation of some results (e.g. total fuel consumed for each vehicle).

4.3 Model Concepts

Each of the product segments may be regarded as the combination of eight parts. This section deals with each of them separately.

4.3.1 Creation of Demand

Orders for each of the product groups are created at certain frequencies every day. Due to the fact that in the real life situation, the daily number of orders is not constant, the order frequencies in the model follow some statistical distributions. This is dealt with in Section 4.5.

Once the number of orders has been computed for the day, they are scheduled to arrive at random times. This is represented by a uniform distribution with a range corresponding to 9 working hours. Furthermore, because orders were observed to be placed mostly during weekdays, with rare exceptions during weekends, the model schedules orders only during weekdays.

The last important parameter is the order size. Based upon the product group definitions in Section 3.3.1, the order size is statistically distributed for each product. Order entities are then introduced into the SLAM network by means of ENTER nodes. Following creation, the size of individual entities is added up in either FORTRAN USER FUNCTIONS, or in a FORTRAN EVENT SUBROUTINE, until the required batch size is met. Batch sizing is itself dependent on the available vehicle resources, load utilization and customer service. It is important to note that a batch entity is formed from the last order entity that cooperated to complete the batch. Thus, all the previous entities are destroyed since they are no longer needed.

4.3.2 Allocation of Demand

Following its formation, the batch entity is stored in one of several files, and awaits a vehicle resource to become available. The AWAIT files only differ in the allocation of resources to them. For instance, a batch entity representing 19645 kg of plastic product must not await in a file where a RESOURCE TRUCK 472, with a load capacity of 13332 kg, may be available.

As mentioned in Section 3.1.2 (see Table 2, p. 17), certain vehicle allocations are possible. At this stage, therefore, the entity calls SUBROUTINE ALLOC in FORTRAN, to test which of the possible allocations can be achieved. Should an allocation be possible, the appropriate RESOURCES are SEIZED by the entity. Otherwise, the entity continues to wait. Should there be more than one entity in any one file, the earliest entity (i.e. the earliest batch of orders) is given priority.

4.3.3 Change Vehicle State As Necessary

It is necessary now to check what state the vehicle was in on its last journey. Depending on the product group, some of the following questions must be answered:

1. Is the actual HORSE/TRAILER combination required identical to the previous combination?
2. Does the number and type of BARRELS required on the actual TRAILER correspond exactly to the previous combination?
3. Does the TRUCK require CRADLE resources? If yes, were these CRADLES connected to the TRUCK on the last journey?

The above checks are effected by a call to the appropriate FORTRAN USER FUNCTION. Should the test be negative, the batch entity is delayed in an ACTIVITY for a period representing the time to effect the necessary change.

4.3.4 <u>Hold The Journey As Necessary</u>

Recalling the basic transport network, this section is equivalent to the 'Wait For Signal To Go' (refer Figure 8, p. 21). Again, a call is made to FORTRAN USER FUNCTION (2), where a decision is taken to allow the entity to carry on. The following rules apply:

1. Go if the time is between 7 a.m and 12 p.m, and it is a weekday. This applies to deliveries during normal working hours.
2. Else, wait until the next morning if it is Monday to Thursday, and if the earliest order would then be still satisfied within the maximum target demand time (i.e. 48 hours).
3. Else, wait until Monday morning if it is Friday, and if the earliest order would then still be satisfied within 150 % of the target demand time. In this case, an order placed on Friday morning would wait until Monday for delivery. However, orders placed earlier during the week would still run the chance to be satisfied on Friday.
4. Else, wait until Monday morning if it is a weekend, and if the earliest order would then still be satisfied within the target demand time.
5. Else, wait until the next morning or Monday morning if the maximum overtime condition would be overridden.
6. Else, the vehicle is allowed to go on the same day.

The above rules have been designed with the objective to satisfy two opposing distribution targets, namely to satisfy the customer in time and to minimize overtime. Thus, the chances that delivery will be effected is high in the morning, but decreases gradually as the time advances. This degree of flexibility is illustrated in Figure 10 below:

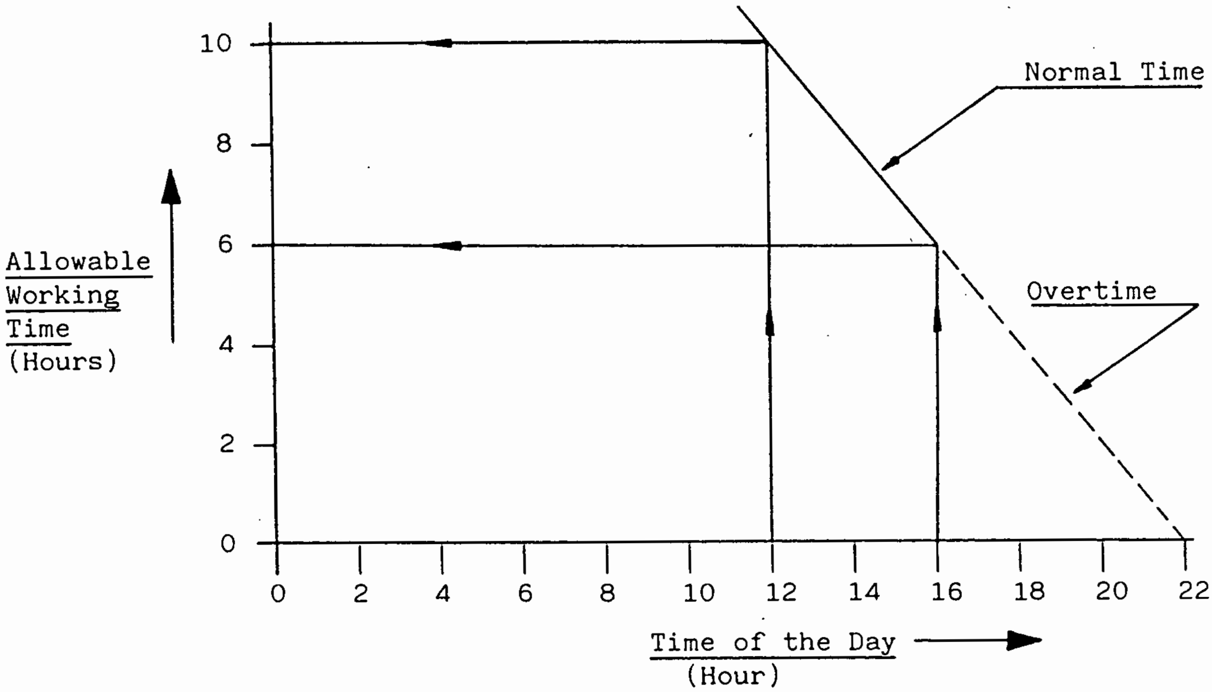


Fig. 10 - Variation of Planned Working Time With Day Time

Should rules no. 2 to 5 be met, the entity is delayed by the appropriate time. Otherwise, it carries on through the network.

4.3.5 Journey

A journey consists of the following sequence of activities:

1. Load the vehicle. Loading time depends on the batch size and the loading time per unit size.
2. Travel to all the customers. Travelling time corresponds to the sum of the travelling time from the factory to the first customer and between customers.
3. Unload completely the vehicle. This depends on the batch size and the unloading time per unit size.
4. Load empties if required. Loading time is expressed as a statistical distribution.
5. Travel back to the factory. Travelling time is equivalent to the time from the last customer to the factory.
6. Unload empties if required. Unloading time is expressed as a statistical distribution.

The durations for the above activities are all statistically distributed, and also depend on the product group. In order to treat entities on an individual basis, most of the activity durations are specified as attributes.

4.3.6 Repair Vehicle As Necessary

After each trip, there is a probability that the batch entity, now effectively representing the vehicle, will be delayed to represent the repair time. The probability and repair time for all vehicles have the same value and statistical distribution respectively. Thus, it is assumed that vehicles are equally likely to break down.

4.3.7 1. Update km Travelled, Fuel Consumed & Overtime. 2. Maintenance

Throughout the network, the entity carries with it an attribute representing the distance travelled (in km) for the trip. By calling FORTRAN USER FUNCTION (5), the total distance travelled and fuel consumed by the particular vehicle since the beginning of the simulation is updated. In addition, a check is made on the actual time. Should it be after 4 p.m on a weekday or after 7 a.m during the weekend, overtime hours worked are computed and updated.

A further call to USER FUNCTION (6) checks whether the vehicle is due for maintenance. Every time the total distance travelled exceeds 5000 km, it is reset to 0, and the entity is delayed for a period corresponding to the maintenance time.

4.3.8 Free Resources and Terminate

At this point, the entity is meaningless to exist any more. Before destruction, the vehicle resources are recorded. This will allow the vehicle state to be compared with the previous state on the next journey. All resources connected to the entity are then FREED and made available to the system.

4.3.9 Collection Of Results From The Network

The following results are collected within the model for each of the five products:

1. Demand Time. This refers to the elapsed time between the moment the first order in a batch is placed and the time when all customers are satisfied. For Product 2, however, the demand time is measured only when the raw material has been unloaded at the factory.
2. Trip Time A. The time taken between starting loading the products at the factory and travelling back to the factory.
3. Trip Time B. Equivalent to the sum of Trip Time A and vehicle repair time.
4. Trip Time C. Equivalent to the sum of Trip Time A, the vehicle repair time, and the vehicle maintenance time.

Records on trip times are accomplished by marking on ATTRIBUTE (2) of the entity the actual time when loading starts (for Product 1, 3, 4, and 5) or when the vehicle leaves the factory to fetch the raw material (for Product 2).

4.4 Specific Details

The model concepts described in the previous section vary slightly from one product group to another. These variations are highlighted for each product in Appendix B, together with details on the following:

1. The dayshift model.
2. The weekshift model.
3. Starting the simulation.
4. Simulation run length.
5. Feeding information to the system.
6. Collecting time-persistent statistics.

Reference is also made to a summary on attributes, global variables, and files in Appendix C, as well as to the computer programs in Appendix E and F, and illustrations of the SLAM network in Appendix D.

4.5 Data Analysis

Having discussed the basic transport network and the different simulation concepts associated with it, the last step is to feed the model with real-life data. This section covers the data collection stage and its conversion into the modelling format.

4.5.1 Collection

All information was gathered from the Transport Department of AECI. Fortunately, vehicle log sheets are available on a daily basis, and provided information on the mechanical horse/trailer combination used, loading, unloading and travelling times, repair times, inspection and lunch times, distance travelled, and the different products and quantities delivered. Data pertaining to orders was collected from relevant records of order forms. Remaining information was obtained from the Transport Manager. All data collected is based on distribution during January and February 1988.

4.5.2 Conversion

For each product group, statistical distributions were obtained for the following variables:

1. Loading time at the factory and unloading time at the customers. For Products 1 and 5, these variables are expressed in [Hour/kg] as they vary continuously with the load size. For Product 3 and 4, the units used are [Hour/Barrel] and [Hour/P.V.] respectively. As Product 2 is handled in bulk, loading and unloading times are expressed in [Hour/Trip].
2. Loading times of empties at the customers and unloading times at the factory. These apply to Products 4 and 5. In the absence of accurate information on the size of empties carried, the times are expressed in [Hour].
3. Number of orders placed per day.
4. The size of orders for the corresponding products. The size is expressed in [kg] for Products 1 and 5, in [Barrel] for Product 3 and in [P.V.] for Product 4. This variable does not apply to Product 2 as it is handled in bulk (i.e. one order represents one trailer of Ammonium Nitrate).

5. Inspection time [Hr] for vehicles and lunch duration [Hr]. These are assumed to be the same in all cases.
6. Repair time [Hr]. It is assumed that the distribution of durations is the same for all vehicles.
7. Distance travelled [km/Trip]. Owing to the fact that deliveries are effected to over 100 locations in the peninsula, it is beyond the scope of this thesis to optimize the transportation route. The distribution represents therefore the total distance travelled per trip, from the factory to the all the customers and back to the factory, regardless of the customer location.
8. Away time [Hr/Trip]. This represents the total travelling time from the factory to the last customer.

The results of statistical distributions for the above variables are presented in Appendix G, together with the criteria used in choosing them. In addition, information is provided on all the other variables employed in the model.

CHAPTER FIVE

SIMULATION RESULTS AND DISCUSSION

As mentioned in Chapter 3, distribution performance is assessed in terms of the customer service, resource utilization and distribution costs. This chapter attempts to analyse in detail these performance measures, using different strategies. Simulation results for the model are first presented and then compared with existing information on the actual situation at AECI, thus allowing the relevance of the model to be established. The impact of various alternative strategies on distribution effectiveness is then studied. It is important to point out that all results discussed in this section are based on distribution during January and February 1988. Consequently, it is not intended to make generalizations, as the effect of seasonality is not taken into account.

5.1 Actual Situation

Appendix H presents sample computer results for the actual situation. These fall under the categories discussed in the following sections.

5.1.1 Statistics for Variables Based on Observation

For each of the five products, some variables may be identified, namely:

1. Demand Time, which represents the time to satisfy the customers, from the moment the orders are placed. With the exception of Ammonium Nitrate (Product 2), this value applies to the earliest order in any batch. Thus, all customers are satisfied within this time.
2. Trip Time A, equivalent to the total journey time (i.e. factory-customers-factory).
3. Trip Time B, the total journey time and repair time combined.
4. Trip Time C, the total journey time, repair time and maintenance time combined.

Mean values for the variables are provided, as well as the corresponding distributions (i.e. standard deviation, the ratio of the standard deviation to the mean, minimum and maximum values observed). Furthermore, the number of observations refers to the number of journeys effected during the simulation period.

Histograms, showing the distributions of demand time and trip times for the different products, appear in Figures 11 to 30 (page 47 to 52), and are illustrated in detail in Appendix H. The following observations are made from a comparison of the different demand times:

1. The time to satisfy orders for Plastics products (Product 1) is normally distributed over a range of 1 to 135 hours, with a mean of 65 hours. In addition, only 47 % of the batches are satisfied within a target demand time of 48 hours.
2. Demand time for Product 5 is also distributed over a relatively large range (1 to 125 hours). However, for approximately the same number of batches as for Product 1, as much as 61 % of them are satisfied within 48 hours.
3. Orders for the remaining products are satisfied within a relatively shorter time. On average, it takes 23,4, 37,2 and 19,5 hours to satisfy orders for Products 2, 3 and 4 respectively. Moreover, the waiting times tend to follow gamma distributions (i.e. there are more batches satisfied in a shorter time). Thus, 92 %, 83 % and 94 % of the batches for Products 2, 3 and 4 respectively are satisfied within the target demand time.
4. Considering all products together, demand time averages 40,4 hours.

Two main factors control the demand time, namely, the trip time and the waiting time for the different distribution resources. Referring to the histograms for the trip times, it is seen that, for each product group, the distributions of Trip Time A, B and C are nearly identical. This indicates that breakdowns and maintenance of vehicles do not significantly affect the journey time. However, delivery of Product 1 to the customers takes approximately 4 times longer than that for the other products. This explains to some extent the observations made with respect to the demand times. The results for the waiting times are studied in Section 5.3.1.

5.1.2 Statistics for Time-Persistent Variables

This applies to:

1. The total distance travelled (km) and fuel consumed (litre) by the

individual vehicle resources (i.e. truck and horse/trailer). Vehicles are classified according to their factory item number. The cumulative values of these two variables are also computed.

2. Information on Product 3; specifically, the corresponding number of trips done with a load of 1, 2, 3 and 4 barrels, the total number of barrels carried and the utilization of barrels at any moment.
3. The number of drivers and assistants utilized at any moment.
4. The number of trucks, mechanical horses and trailers employed at any moment. Results show that horses and trailers are better utilized than trucks.
5. The amount of overtime (hours) worked during weekdays and weekends, together with the total overtime. Overtime amounts to 512 hours during the week and 177 hours during weekends. This averages 3,1 hours per overtime journey.
6. The total number of trips done under normal and overtime conditions, as well as the number of journeys that were ready to start on some day, but were delayed until the next day or week to save on overtime.
7. The simulation period, in terms of the number of days.

In this category, information is provided on the mean, standard deviation, minimum, maximum and current values, as well as the time interval between the start and end of the simulation. However, only the maximum values are noteworthy for the cumulative variables (i.e. km travelled, fuel consumed, overtime, etc.).

Daily utilizations of human resources, vehicle resources, barrel resources and vehicle resources maintained are described in the plots shown in Appendix H. The following pertain to a 62-day distribution period:

1. The results for human resources overestimate the actual utilization, because the model assumes that human resources are utilized whenever vehicle resources are utilized (i.e. even when it is waiting for the next day to start loading). However, the plot provides meaningful information on human resource utilization. It shows that, most often, there are between 4 and 7 drivers utilized, while the utilization of assistants is concentrated within a range of 4 to 9. Furthermore, very rare occasions do occur when more drivers and

assistants are required. Consequently, with better scheduling of deliveries and levelling resources, the number of human resources could be reduced.

2. The number of trucks utilized vary most often from 1 to 3, with rare occasions when 4 trucks are used, and other occasions with zero utilization. This is indeed an important observation in that the model can assist in resource scheduling to improve utilization.
3. The number of mechanical horses and trailers vary most frequently from 2 to 5. Moreover, there is only one day when 6 resources of each are utilized. This implies that, within the present distribution period, vehicle resources could have been reduced by 2 with better resource scheduling.
4. Barrel utilization tends to follow a random pattern with minimum and maximum utilizations of 0 (for 21 days including weekends) and 8 respectively. Nevertheless a comparison of these figures with a total number of 16 barrel resources suggests that barrels are very much underutilized.
5. Referring to the plot for the number of vehicle resources maintained every day, the maintenance department was active on 3 vehicles during the same day for only one day, while for the remainder of the days when it was active, there was only 1 vehicle being maintained. In addition, the time between maintenance varies from 0 to 15 days at a time, with no maintenance during weekends. Such information is noteworthy when planning the requirements of the maintenance department for alternative distribution policies.

5.1.3 File Statistics

Information on the first 17 files is meaningful. A label is associated with each file to describe what the orders are waiting for. Refer to the section on File Statistics in Appendix H for a detailed explanation of labels.

For each of the files the average number of the order batches that have been waiting is presented, together with the maximum and current number, and the average waiting time (in hours). These values are important in that they indicate the relative concentration of order batches at different places. The following observations were made from the results:

1. On average, orders for Products 1 and 5 have been awaiting vehicles significantly longer than those for Products 2, 3 and 4. This identifies an existing imbalance in the vehicle/product allocation. This is further emphasized by the fact that although orders for Products 1 and 5 waited relatively longer than those for Products 3 and 4, there have been less orders for the former products waiting than the latter products.
2. Waiting times for the remainder of the resources are considerably shorter. On average, it takes 0,227 hour (14 minutes) for a barrel resource to become available, while a forklift truck is available within 0,145 hour (9 minutes) when required. Hence, resources other than vehicles do not appear to constrain the distribution.

5.1.4 Regular Activity Statistics

These apply to all activities used in the network to direct or delay the batch or order entities. The most significant result in this category is the entity count, which refers to the number of orders or batches that went through the different activities. For instance, there were 20, 46 and 40 batches that were assigned to the small-sized, medium-sized and large-sized vehicles (Product 1) respectively. This directly indicates the relative utilization of these vehicles. Utilization of larger vehicles is also emphasized for Product 5. Moreover, on the 63 journeys effected by vehicles for Product 4, the vehicles broke down on 6 journeys. Similar results are available for vehicles carrying the other products. Other useful information is tabulated for changing horse/trailer combinations, number of orders for the different barrels, etc.

5.1.5 Resource Statistics

The most important result concerns the average utilization of resources. Each tabulated figure should be divided by the corresponding maximum number of resources to obtain the percentage time of the day during which the resource is unavailable. For vehicles, the results exclude the inspection and lunch-times, whereas for the GANTRY and FILLPT 1 and 2 resources, only the lunch-time is excluded. Thus an average utilization

0,72 for HORSE 472 indicates that during 24 hours, the vehicle was used for 17,2 hours, which includes the waiting time to go, loading and unloading times, total journey time, breakdowns and maintenance. However, an average utilization of 1,2 for BARREL 1 (maximum capacity 7) means that each of the barrels was utilized for

$\frac{1,2}{7}$ * 100 % = 17,1 % of the day.

Truck utilization averages 39 % (9,4 hours), while the mechanical horses and trailers were used 68,7 % (16,5 hours) of the day. These results confirm the fact that larger vehicles are better utilized. Furthermore, this imbalance suggests that the overtime worked (689 hours) is mainly accounted for by the high utilization of trailers.

CRADLE resources have 100 % utilization, indicating that the vehicles for Product 4 were never used for carrying Product 5. Hence, the cradles were always connected to these vehicles. Furthermore, the imbalance between the demand times for Products 4 and 5 suggests that the rule employed to deliver Product 5, using Product 4 vehicles, is not sophisticated enough.

The remaining resources appear to be underutilized. On average, the fillpoints are active during 5,5 % of the day, while total barrel utilization amounts to 2 every day. Concerning the forklift trucks, each of them is employed in loading operations during 7 % of the day.

5.2 Relevance of the Results

It is convenient, at this stage, to compare the simulation results with available information on the actual distribution. Table 4 illustrates the comparison for some important parameters and shows that they correlate relatively well. The results for the actual situation are computed in Appendix J.

TABLE 4 - Comparison of Simulation Results With Actual Distribution

VARIABLE	ACTUAL	MODEL	DISCREPANCY (%)
Average Demand Time (Hour)	48*	40,4*	- 15,8
Load Utilization (%)	69,6	70,0	+ 0,6
Total Overtime (Hour)	676	689	+ 1,9
Number of Trips - P1	137	109	- 20,4**
Number of Trips - P2	156	167	+ 7,1
Number of Trips - P3	147	104	- 29,3**
Number of Trips - P4 & P5	176	179	+ 1,7
Total Number of Trips	616	559	- 9,3
Total Distance Travelled (km)	68985	64246	- 6,9
Number of Barrels Carried	474	397	- 16,2

Note: * - The 'actual' value represents the actual target, whereas the 'model' value is the achieved demand time.

** - These discrepancies arise from the rules utilized in batching orders. The rules do not exactly correspond to the ones used in practice.

5.3 Alternative Strategies

Ten different strategies were simulated to estimate the impact of certain system parameters on distribution effectiveness. The results for each strategy have been summarized in Appendix I, and are discussed under this section. It is important to mention that each strategy is based on the actual prevailing conditions, with the exception of one distribution parameter being varied.

5.3.1 Variation of Load Utilization

This strategy only applies to vehicles delivering Products 1 and 5, as the other products are treated in bulk or discrete quantities. Nevertheless, owing to the existing vehicle allocation rules, all products are affected in the end.

Under this scheme, load utilization is altered in turn from 70 %, which represents the actual utilization achieved, to 50 %, 60 %, 80 % and 90 %. This implies that a vehicle will be allocated a load when enough orders can be combined to fulfill the desired utilization. The following effects are observed when increasing the utilization from 50 % to 90 % :

1. Average demand time constantly increases from 37,8 hours to 40,4 hours at 70 %. A further increase of 10 % in load utilization results in an abrupt rise to 49,4 hours. From 80 % to 90 %, the increase is even more pronounced.
2. Overall vehicle utilization gradually decreases from 57,2 % to 53,1 % (at 80 %), with no significant reduction thereafter. This is associated with an improvement in trailer utilization.
3. Increasing the load utilization to 70 % results in 5 % saving in fuel consumption. However, a further increase to 90 % increases fuel consumption by 3 %. This is explained by the higher fuel consumption of mechanical horses with respect to trucks.
4. Overtime does not follow a specific trend for load utilizations of 50 to 70 %. However, a further increase of 10 % in load utilization increases overtime by 6,5 % whereas from 80 to 90 %, overtime rises by 12,4 %. This is associated with longer loading and unloading times per trip, and the fact that vehicles probably leave later during the day (i.e. more orders have to be received).

In view of reaching the best compromise between customer service, resource utilization and distribution costs, the optimum load utilization should be 80 %. Such a utilization is assumed for the remaining strategies.

5.3.2 Variation of Target Demand Time

Target demand time was altered from 48 hours to 24 and 72 hours. The following observations may be made:

1. Customers can not be satisfied within 24 hours. Thus, with the target demand time set to 24 hours, avarage demand time drops from 49,4 to 40,4 hours only. This indicates that the constraints imposed onto the system by the other parameters (i.e. a load utilization of 80 %, limitations on the different resources, etc.) do not allow the target to be achieved. Furthermore, in an attempt to satisfy the customers earlier, the vehicles tend to work more under overtime condition, and are thus delayed less until the next day or week. Consequently, overtime significantly increases by

23 % , while overall vehicle utilization decreases from 53,1 % to 40,1 %. Average waiting times of the loads for vehicles also decreases, by 5 hours, which confirms that the vehicles go faster through the transport loop, thus becoming available earlier.

2. On the other hand, opposite results are obtained when the target demand time is increased to 72 hours. Quantitatively, average demand time rises to 52,9 hours, with an overall increase to 56,4 % in vehicle utilization and 3 hours in waiting times. Moreover, overtime is reduced by 13,8 %.

5.3.3 Variation of Maintenance Frequency for Vehicles

The actual frequency of 5000 km between maintenance of vehicles for Products 1, 3, 4 and 5 was changed to 4000, 4500, 5500 and 6000 km. With the exception of the average demand time, which steadily increases with more frequent maintenance, most of the remaining distribution performance parameters tend to follow a sinusoidal pattern. For instance, overall vehicle utilization varies as shown in Figure 31 below:

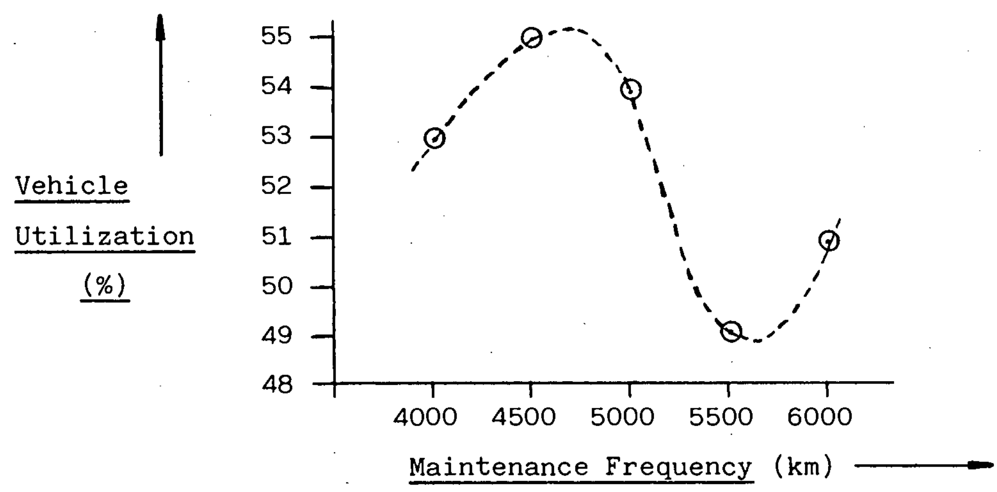


Fig. 31 - Variation of Overall Vehicle Utilization With Maintenance Frequency

The above variation appears doubtful, but may be understood in terms of the maintenance time in each case. The model assumes that the maintenance department does not work during weekends. Consequently, while a vehicle will be delayed for 24 hours if it is maintained during the week, it will be forced to wait until Monday if maintenance were to start on Friday afternoon. This difference in delays could therefore explain the results. For instance, at a frequency of 4500 km, there could have been more vehicles maintained during weekends, while at 5500 km, there could have been less. However, it is believed that the actual maintenance rules utilized could be improved.

5.3.4 Variation of Maintenance Time for Vehicles

Maintenance time was changed from 24 hours to 16 and 36 hours. Similarly to the previous section, the results are inconsistent with logical expectations. They suggest that variations in maintenance time can only be fully analysed with additional knowledge on the period of the week at which vehicles are maintained.

5.3.5 Variation of Maximum Overtime Per Trip

Under this strategy, the effect of altering the desired maximum overtime per trip from 6 hours to 4 and 8 hours is analysed. Results show that:

1. While the average demand time increases by 15 hours for a reduction of 2 hours in maximum overtime, an equivalent increase reduces the demand time by 8 hours. Waiting times of the orders for the vehicles also follow a similar trend.
2. Overall vehicle utilization rises by 3,1 % when more overtime is allowed, but drops by 1,9 % with less overtime. The above observations are consistent in that vehicles are delayed to start a journey until the next day or week more often when maximum overtime is low.
3. With a 4-hour maximum overtime policy, total overtime is reduced by 38 hours. On the other hand, it is increased by 123 hours with a 8-hour policy.
4. A saving of approximately 120 litres of fuel can be achieved with a 4-hour policy, while 350 more litres of fuel are consumed with a 8-hour policy.

5.3.6 Variation of Probability of Repair

Increasing the probability of repair (i.e. the frequency of breakdowns) from 0,10 to 0,125 resulted in a 19,2 % rise in average demand time. However, a further increase to 0,15 did not significantly affect demand time. Furthermore, should the vehicles break down less frequently, the customers would still be satisfied in a longer time. This inconsistency is attributed to the following explanations:

1. When comparing the number of repairs with the number of journeys travelled, the probabilities obtained do not always correlate with the ones implemented. For example, when a 0,125 probability is chosen, results show that 61 repairs were effected on 534 journeys in total. This corresponds to an effective probability of 0,114. At 0,15, the probability obtained is 0,166.
2. A break down of the total number of repairs into the repairs of vehicles for each product group does not provide steady values for the probability of repair.

The above observations were initially believed to be related to background 'noise' in the random number generation process. Nevertheless, tests were made by altering the seed number governing the random number generation and proved negative. It is thought, therefore, that the approach employed to model breakdowns is not sophisticated enough.

5.3.7 Variation of Inspection Time

Presently, all vehicles and forklift trucks are delayed every morning for a period of 0,35 hour (21 minutes) for inspection and fuelling. Alteration of inspection time to 0,45, 0,60 and 0,75 hour had significant impacts on some performance measures. These are as follows:

1. An increase of 0,1 hour raises average demand time by 8,4 hours. The influence of subsequent increments of 0,15 hour on demand time tend to decrease exponentially, as depicted in Figure 32:

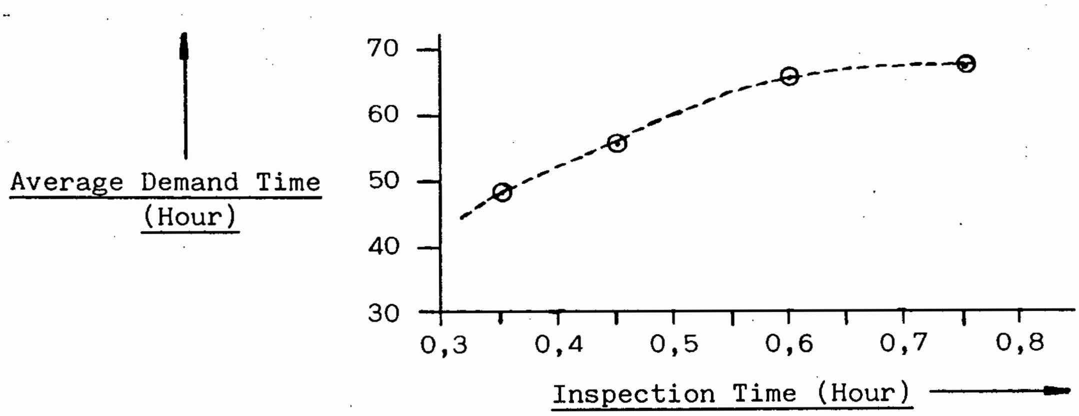


Fig. 32 - Effect of Inspection Time on Average Demand Time

2. Overtime worked follows a trend similar to demand time.
3. Average waiting time of the loads for vehicles increases.
4. Overall vehicle utilization is reduced. This is consistent in that vehicles become less available as inspection time is increased.
5. The influence on the availability of forklift trucks does not significantly affect distribution.

The effect of increasing inspection time is to delay delivery starting time in the morning. As a result, vehicles come back relatively later and run higher chances to have their afternoon trips delayed until the next morning. This increases demand time which, in turn, encourages more deliveries under overtime condition on the long run. Such significant effects on demand time for slight increases in inspection time show however that the rules employed by the model are too strict.

5.3.8 Variation of Time to Change Horse/Trailer Combination

The influence of this strategy on demand time, overtime and waiting time of loads for vehicles is similar to that of inspection time. It is however less pronounced as trucks are not affected. The following occurs when altering the change duration from 0,50 hour to 0,75 and 0,25 hour:

1. Average demand time rises from 49,4 hours to 63,4 hours. A corresponding drop in the change duration improves demand time by 15,5 hours.
2. Overtime varies from 673 hours, for a 0,25-hour change duration, to 808 hours, for a 0,75-hour change duration.
3. Average waiting time steadily increases from 14,4 hours to 35,8 hours when the change duration is varied from 0,25 to 0,75 hour.
4. Truck utilization remains nearly constant while horse/trailer utilization rises from 63,3 % to 70,5 %. This results from the longer periods for which they are delayed.

In this context, the optimal solution would be to suppress the activity of changing the horse/trailer combinations. This could be done by allocating permanently each mechanical horse to a unique trailer. Alternately, the changes should be effected outside delivery hours.

5.3.9 Release of Constraint on Horse/Trailer Allocation

At present, trailers are dedicated to carry specific products. In addition, they only be connected to certain mechanical horses. Thus, situations may arise when a trailer is available for loading, but can not be connected to the available horses because of the allocation rules. This can evidently delay deliveries. Under this strategy, the model was modified to allow any possible horse/trailer allocation. Results are in general positive and are commented upon below:

1. Demand times for most products are improved. Average demand time is reduced by 4,2 hours.
2. The total number of trips is reduced by 21, resulting in a saving of 576 litres of fuel.
3. Horse/trailer utilization is improved with respect to truck utilization.
4. A reduction of 3,3 hours occurs in the average waiting time of loads for vehicles.
5. Average utilization of human resources decreases from 14,1 to 13,4.
6. Overtime is increased by 53 hours. This is due to the number of trips being decreased.

5.3.10 Reduction in Vehicle Resources

Simulation results provided relatively low values for the present overall vehicle utilization. This policy consists of altering in turn one of the vehicle resources from 1 to 0. An examination of the results suggests that one of the following actions should be taken:

1. Discard TRUCK 412 (Product 5). With an 80 % load utilization, this vehicle has an average utilization of 19 %. Under the above policy, average demand time would drop from 49,4 hours to 42,8 hours. This results from all orders for Product 5 being concentrated on larger capacity vehicles (i.e. TRUCK 467 and TRUCK 472). Furthermore, overtime would be reduced by 9 %, fuel consumption by 2600 litres and human resources by 2.
2. Remove TRUCK 469 (Product 4). This would increase the average demand time to 50 hours only, while 43 hours more overtime would be necessary. In addition, 813 litres of fuel would be saved, with a reduction of 2 human resources. Moreover, demand time for Product 4 would average 21 hours (instead of 19 hours).

3. Remove TRAILER 453 for Product 2. Under actual conditions, Ammonium Nitrate is handled mainly by TRAILERS 430 and 431, with a low utilization of TRAILER 453. Under this policy, a 7-hour increase in demand time would occur for Product 2, with a 2-hour rise in the average demand time for all products. Overtime would however increase by 144 hours.

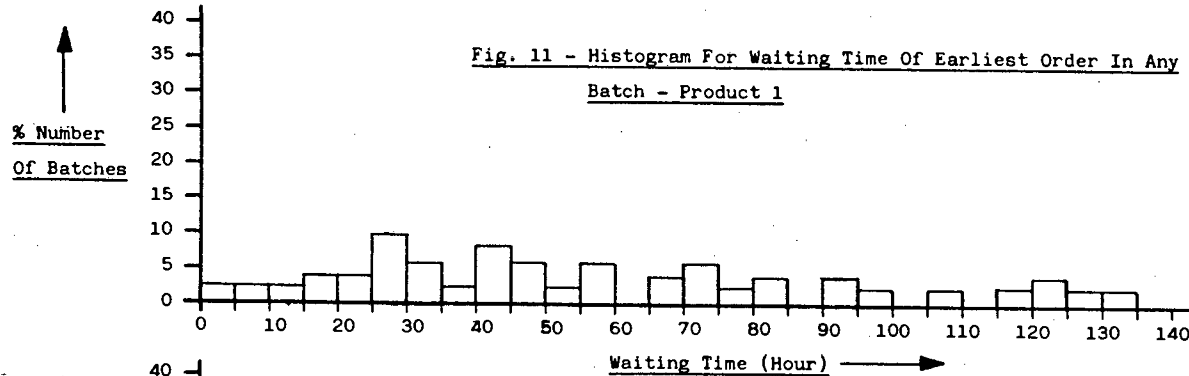


Fig. 11 - Histogram For Waiting Time Of Earliest Order In Any Batch - Product 1

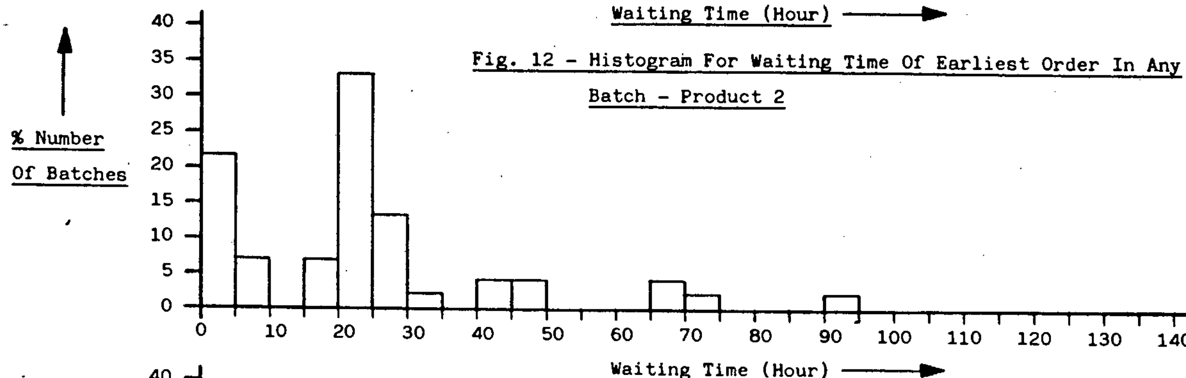


Fig. 12 - Histogram For Waiting Time Of Earliest Order In Any Batch - Product 2

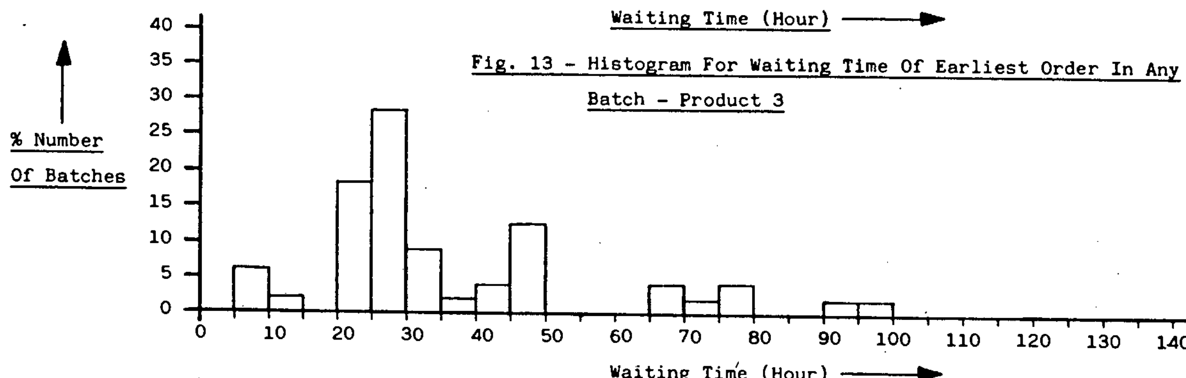


Fig. 13 - Histogram For Waiting Time Of Earliest Order In Any Batch - Product 3

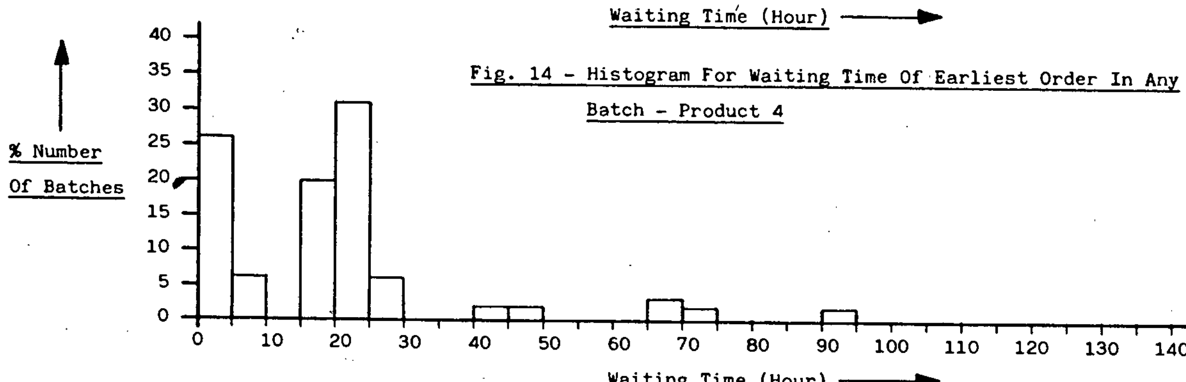


Fig. 14 - Histogram For Waiting Time Of Earliest Order In Any Batch - Product 4

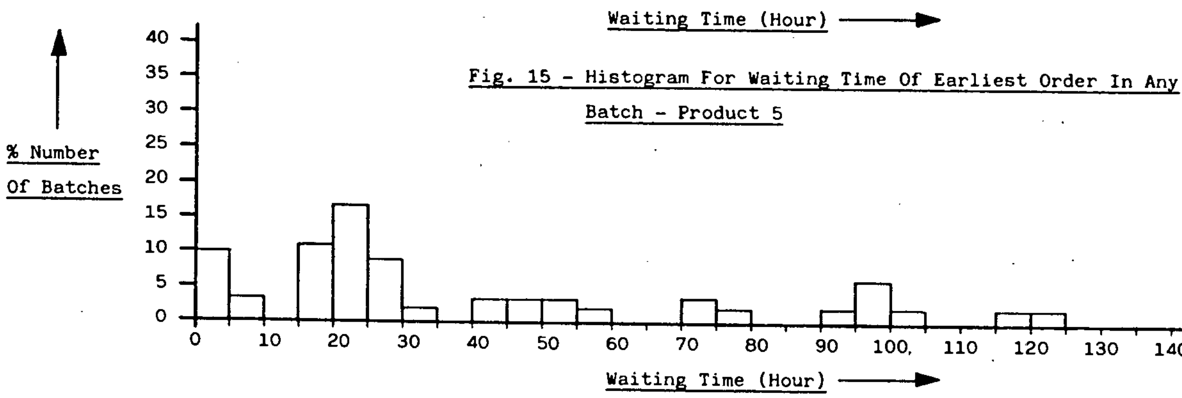


Fig. 15 - Histogram For Waiting Time Of Earliest Order In Any Batch - Product 5

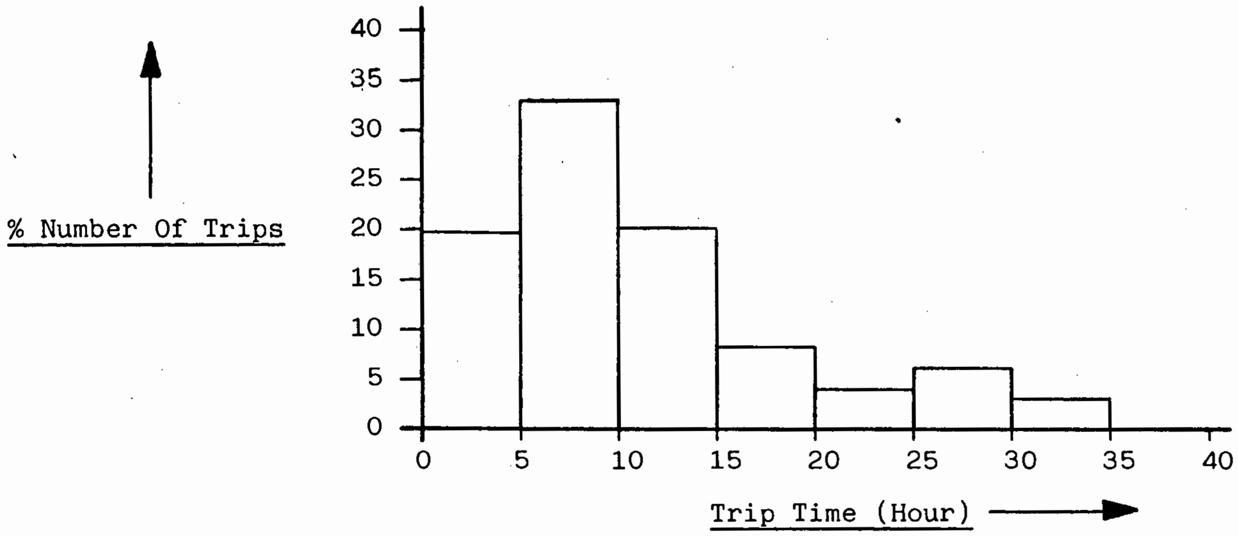


Fig. 16 - Histogram For Trip Time A - Product 1

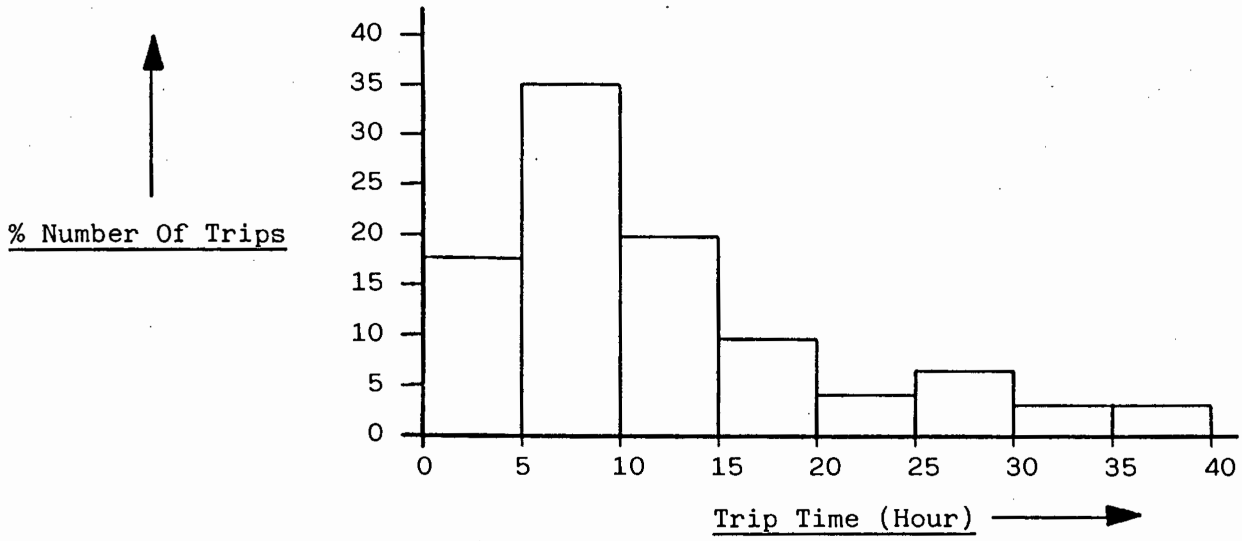


Fig. 17 - Histogram For Trip Time B - Product 1

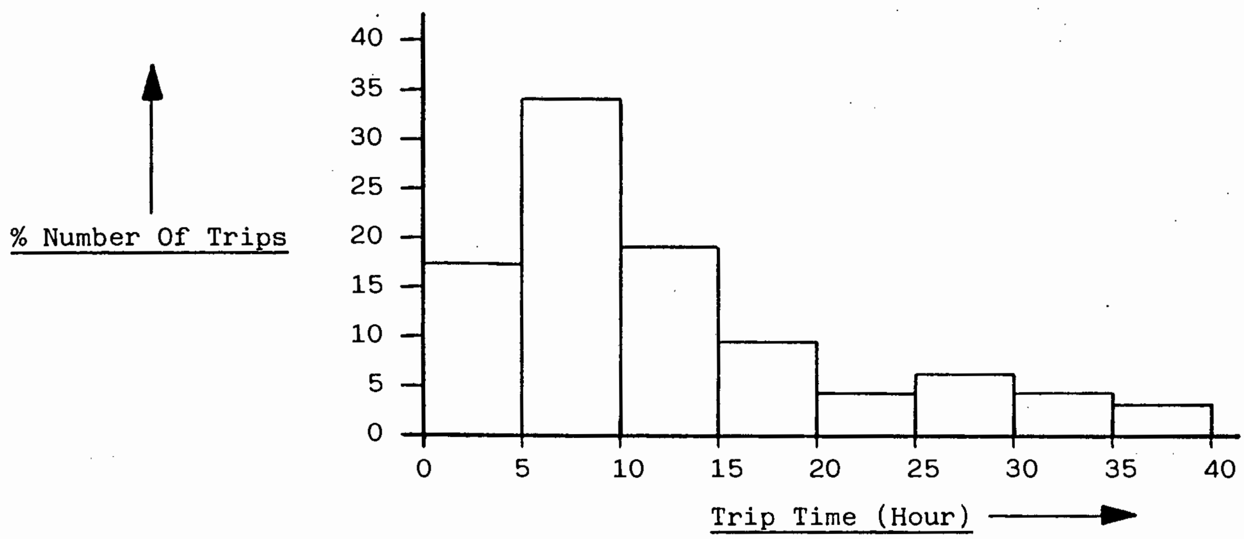


Fig. 18 - Histogram For Trip Time C - Product 1

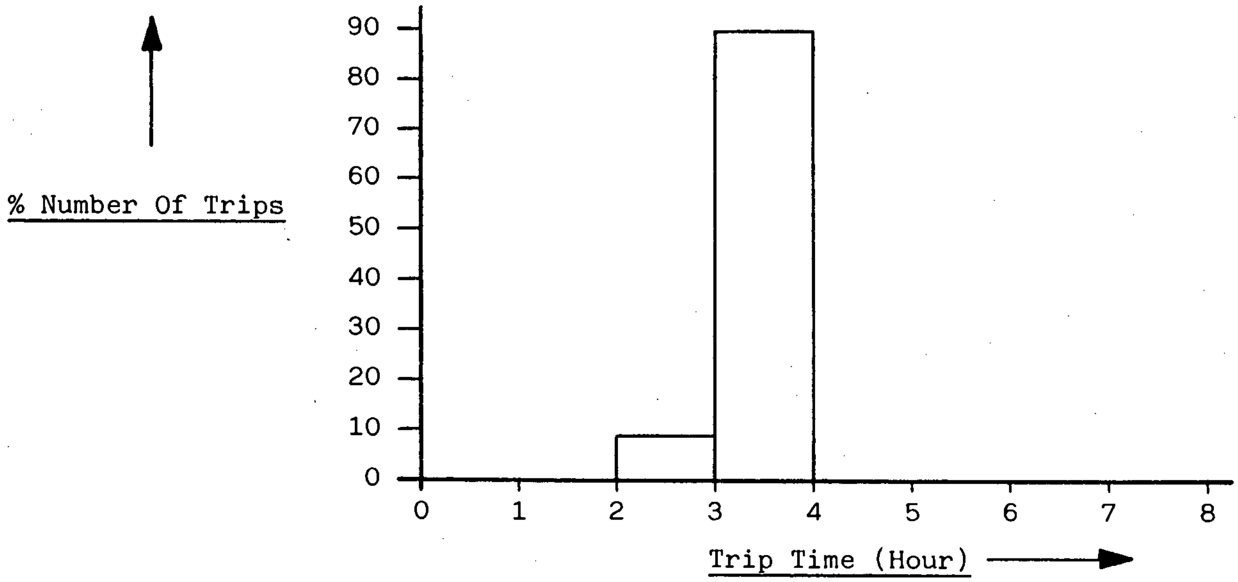


Fig. 19 - Histogram For Trip Time A - Product 2

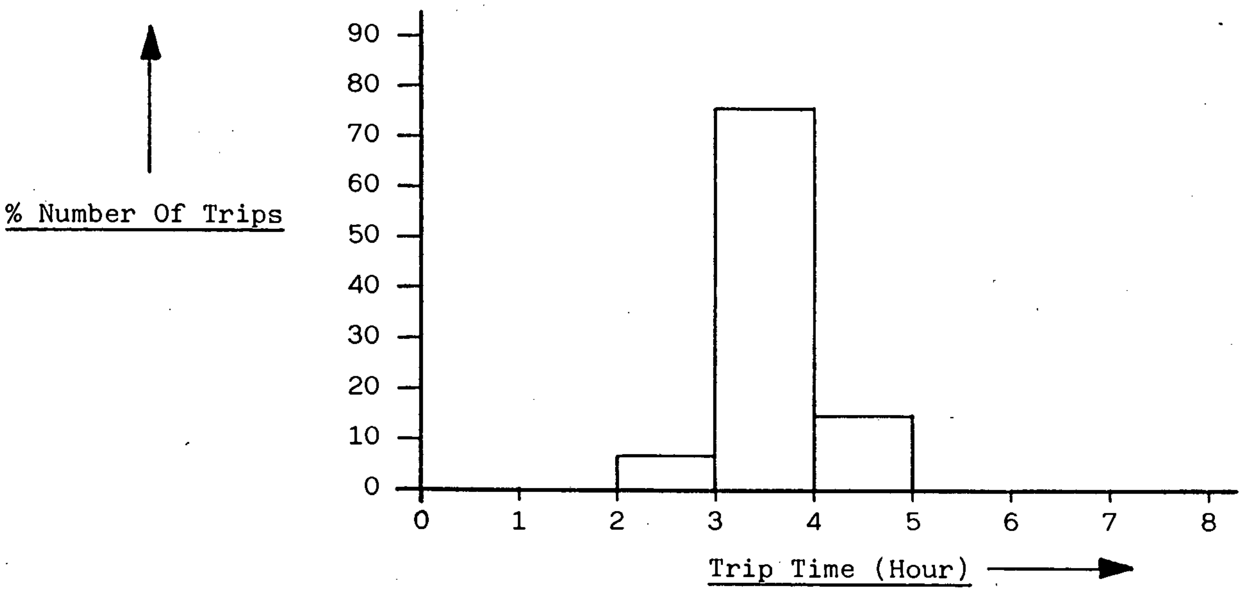


Fig. 20 - Histogram For Trip Time B - Product 2

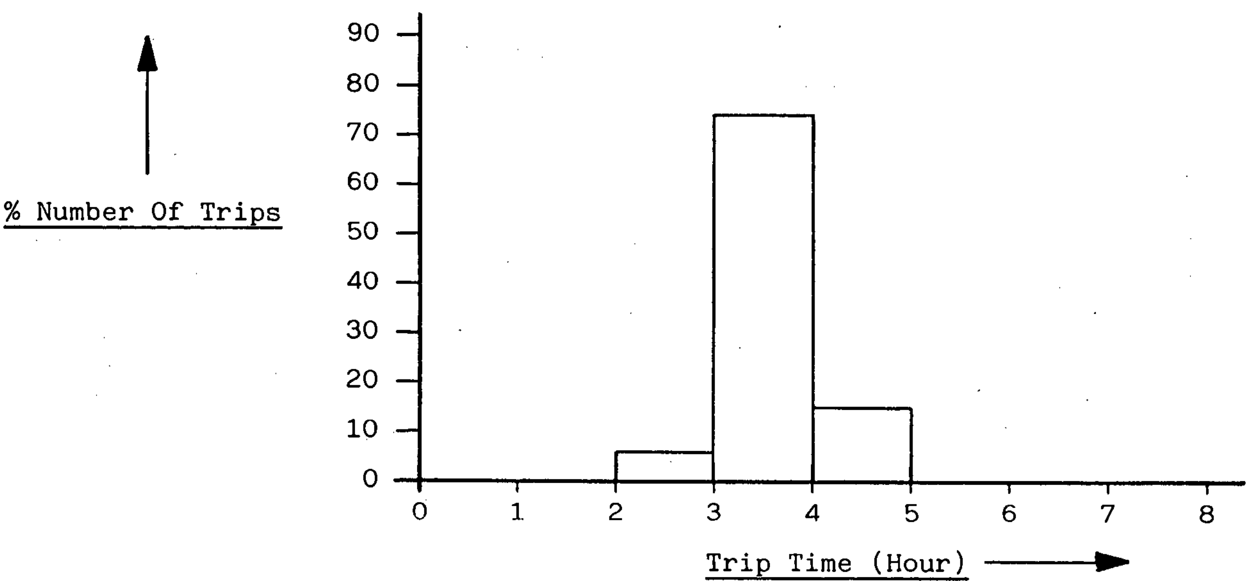


Fig. 21 - Histogram For Trip Time C - Product 2

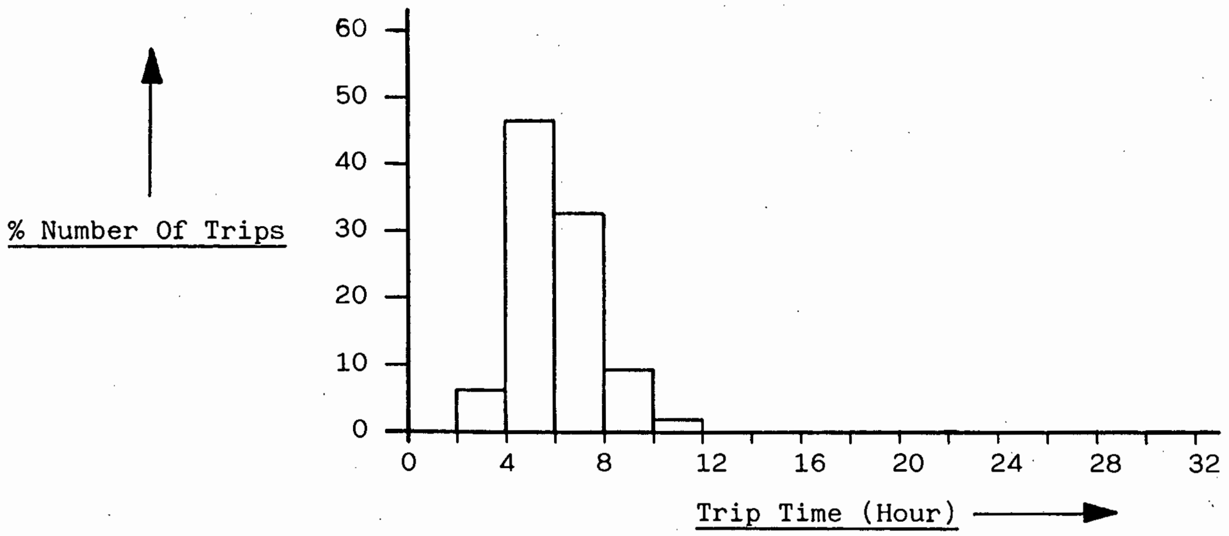


Fig. 22 - Histogram For Trip Time A - Product 3

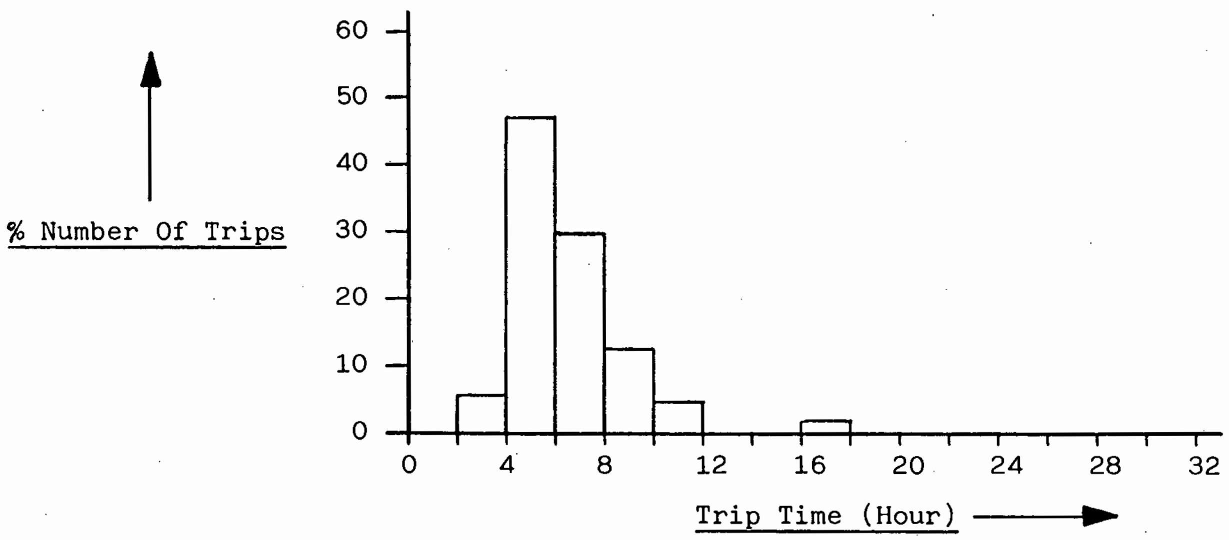


Fig. 23 - Histogram For Trip Time B - Product 3

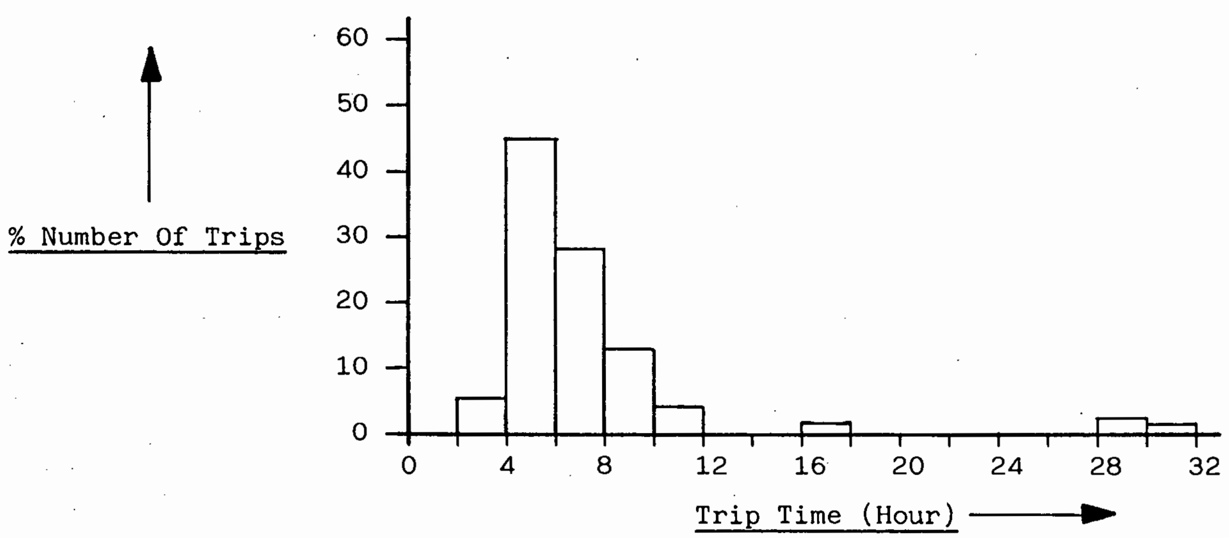


Fig. 24 - Histogram For Trip Time C - Product 3

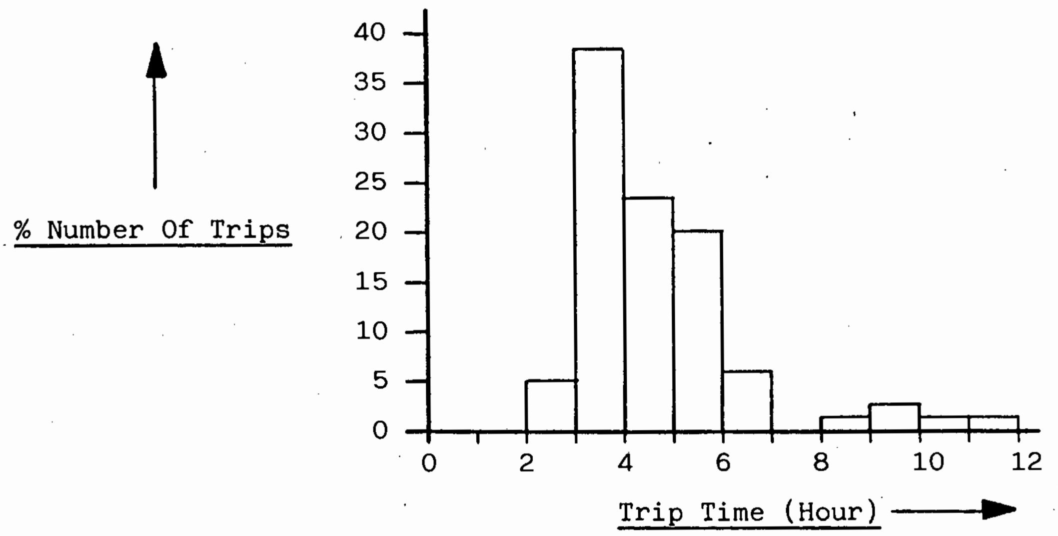


Fig. 25 - Histogram For Trip Time A - Product 4

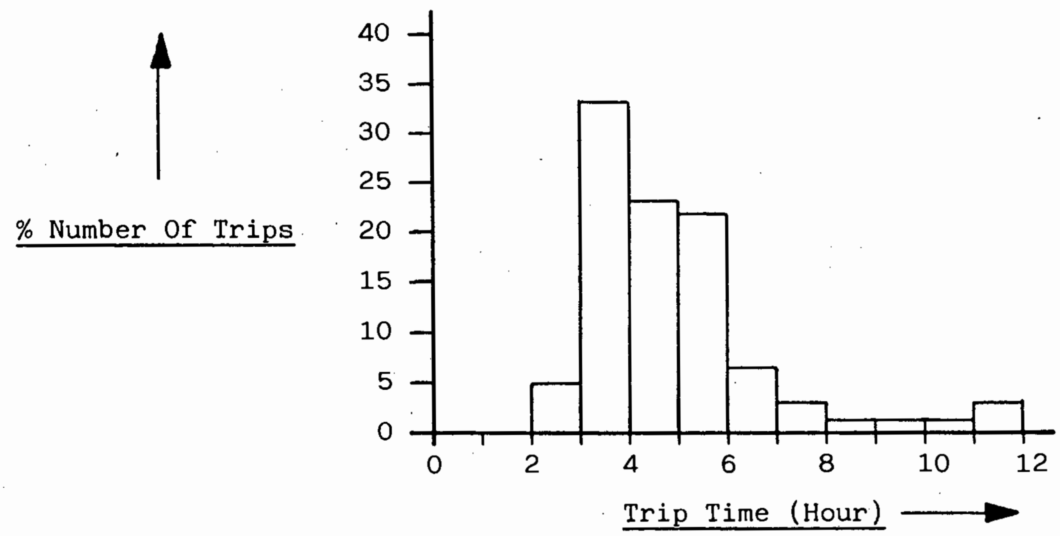


Fig. 26 - Histogram For Trip Time B - Product 4

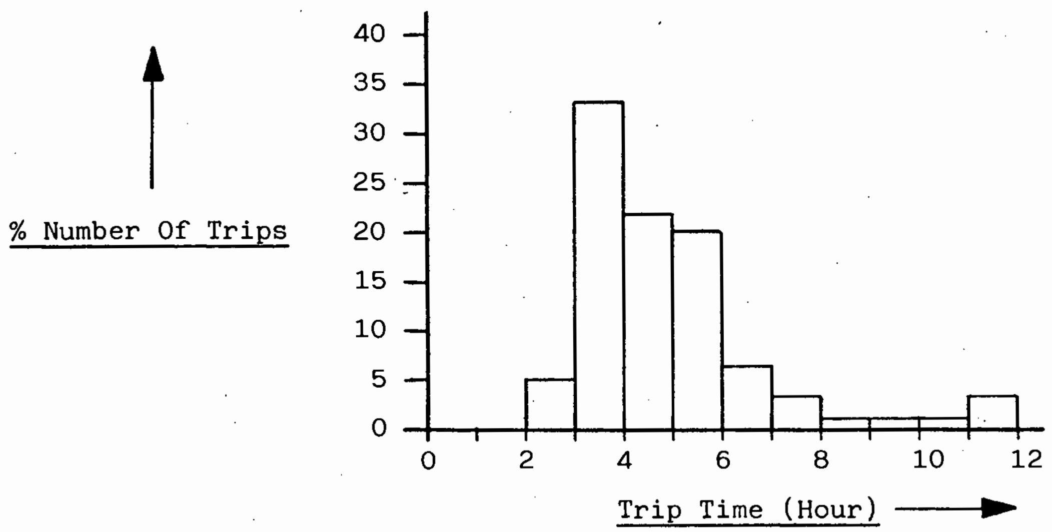


Fig. 27 - Histogram For Trip Time C - Product 4

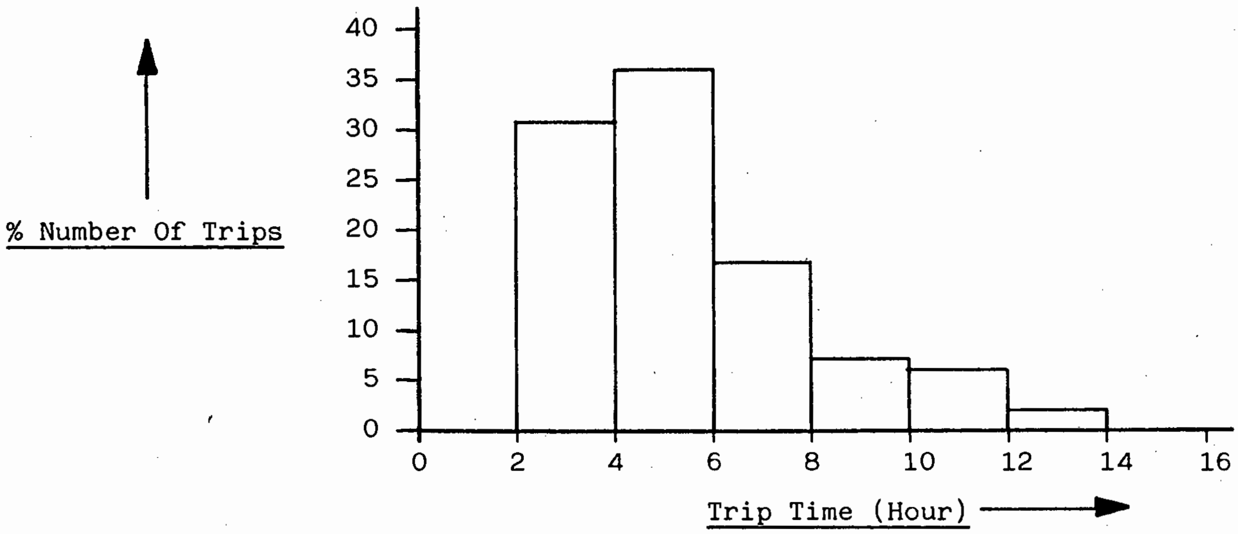


Fig. 28 - Histogram For Trip Time A - Product 5

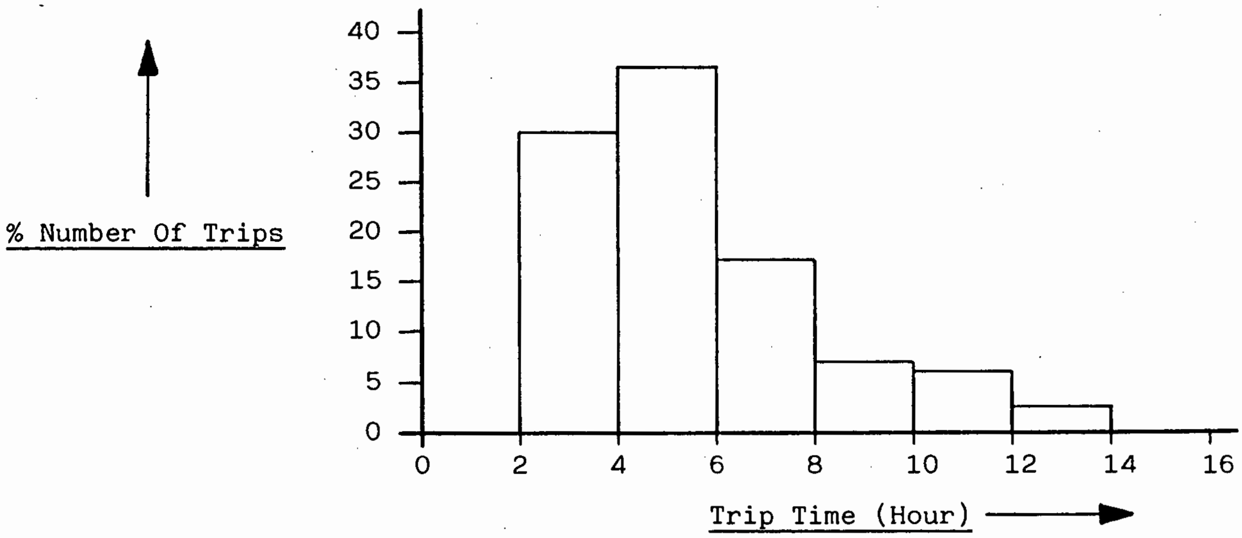


Fig. 29 - Histogram For Trip Time B - Product 5

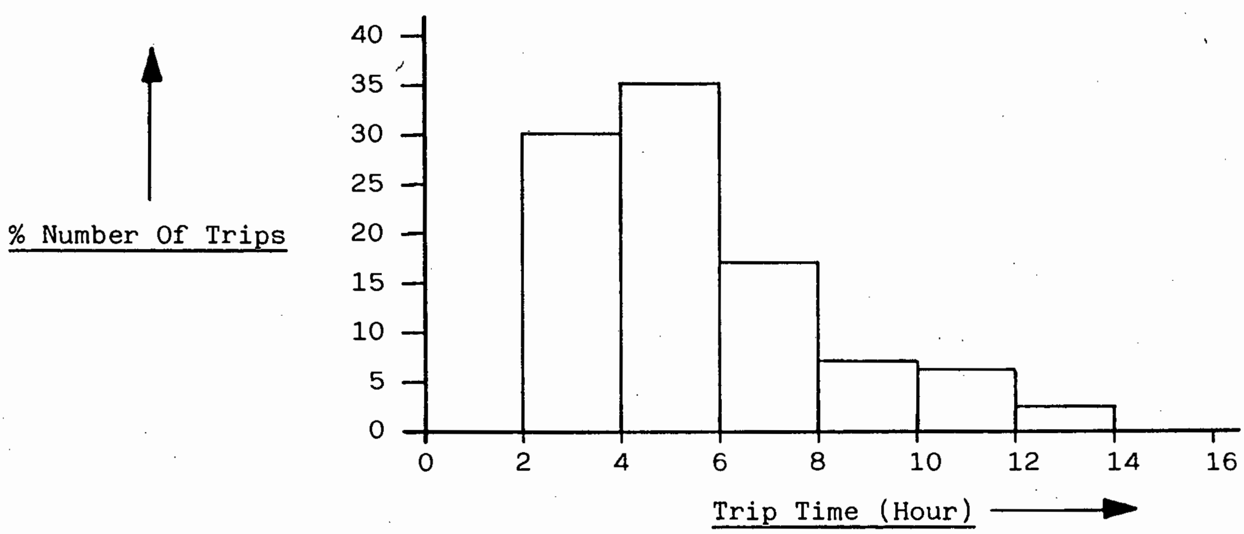


Fig. 30 - Histogram For Trip Time C - Product 5

CHAPTER SIX

SUGGESTIONS FOR FURTHER WORK

In the model-building process, one important target was to incorporate the main facets of the distribution system. Moreover, the rules employed by the model were designed as realistically as possible. On account of the results obtained, some areas for improvement were identified. The following embellishments are suggested:

1. The model assumes that customer orders are placed at random times during working hours. This does not exactly represent the actual situation, as orders are placed more frequently at certain times of the day. In this regard, the model could be improved to take into account the relative chances thta orders are placed withing specific time periods (e.g. 50 % of the orders are placed between 11 a.m. and 1 p.m., 20 % between 1 p.m. and 3 p.m., etc.). This could be achieved using discrete probability distributions.
2. The simulation results obtained provided relatively low values for the utilizations of the forklift trucks, gantry and filling points. One improvement would be to incorporate into the model any additional activities in which these resources are involved. Presently, no accurate information is available on the utilization of these resources.
3. In the actual model, only the effects of vehicle breakdowns and maintenance on the total journey time were studied. The model could be improved to provide information on the influences of the loading time, travelling time and unloading time. This could be achieved by inserting COLCT (Collect) nodes after the relevant ACTIVITIES in the SLAM network.
4. The model could also be refined to take into account any emergency customer requests. One approach would be to mark an ATTRIBUTE on the 'urgent' order entities to distinguish them from normal entities, and assigning them higher priorities in the files. Furthermore, these order entities would be allowed to go as soon as a vehicle resource is available, regardless of any condition that could normally hold the entity back (e.g. maximum overtime exceeded).
5. The present vehicle maintenance rules did not enable the effects of maintenance frequency and duration to be properly analysed. In this regard, the model could be embellished by allowing the vehicles that need to be maintained during weekends (i.e. when the maintenance department is closed) to be available for deliveries until Monday morning.

Consequently, whenever a vehicle resource would need to be serviced, it would always be delayed for the same time period. At present, when the maintenance department is closed, an additional delay of 48 hours is incurred.

6. It was shown that the frequencies of vehicle breakdowns obtained at the end of the simulation period did not correlate with the desired simulation frequencies. The actual model employs only one GLOBAL VARIABLE to represent the probability of repair in the five product segments of the network. It is suggested that a separate GLOBAL VARIABLE should be used in each segment.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

The SLAM II model of the chemical distribution system has proved to be a powerful tool for identifying the key variables of the system. Based on distribution for January and February 1988, an evaluation of the simulation results revealed the following:

1. Trucks were utilized for 39 % of the day, while the utilization of mechanical horses and trailers averaged 69 %. In addition, a maximum number of 4 trucks out of 6 were used at any moment, whereas all mechanical horses and trailers were utilized on only one day.
2. Mean vehicle load utilization was 70 %.
3. Overtime deliveries amounted to 512 hours during weekdays and 177 hours during weekends.
4. Total fuel consumption was 24495 litres.
5. Vehicle breakdowns occurred at a frequency of 1 in every 10 journeys.
6. Customer orders were fulfilled in a mean time of 40,4 hours. Nevertheless, only 47 % of the batches of orders for Plastics products were satisfied within a target satisfaction of demand time* of 48 hours.
7. On average, loads waited 22,2 hours for vehicles to become available. Waiting times of the orders for Plastics and General products were however significantly longer than those for Ammonium Nitrate, Barrels and large Pressure Vessels.
8. Maintenance and repairs of vehicles did not significantly influence the journey time. However, delivery of Plastics products took approximately four times longer than deliveries of the other products.
9. A maximum number of 9 drivers and 11 assistants were utilized at any moment.

In general, simulation results agreed well with existing information on the actual situation. A variety of alternative strategies were simulated to estimate the impact of certain system parameters on distribution effectiveness.

The following conclusions can be drawn from the results:

1. By increasing the vehicle load utilization to 80 %, customers would be

Note: * - The target satisfaction of demand time is referred to as the target demand time in the body of the report.

satisfied in an average time of 49 hours. Load utilization could be increased by batching more orders together. This policy would represent the best compromise between customer service, resource utilization and distribution costs. The remaining policies are based on an 80 % load utilization.

2. By extending the target time to satisfy the demand to 72 hours, overtime would be reduced by 14 %, while the customers would be satisfied in a mean time of 53 hours.
3. The influence of varying the maintenance frequency and duration for vehicles could not be fully investigated. In this regard, the maintenance rules employed by the model need to be improved.
4. No significant improvements were obtained by altering the present 6-hour policy with respect to the maximum overtime per journey.
5. Variation of the frequency of breakdowns for vehicles did not yield consistent results, as the approach employed is not sophisticated enough.
6. Morning inspection of vehicles had a significantly adverse influence on the satisfaction of demand time*. Ideally, it should be effected outside delivery hours.
7. The effect of delaying vehicles during delivery hours for changing the mechanical horse/trailer combination can considerably increase the satisfaction of demand time and overtime. The optimal solution would be to effect these changes outside delivery hours.
8. The present mechanical horse/trailer allocation rules constrain distribution. By allowing all possible combinations, the average satisfaction of demand time would be reduced by 4 hours, together with a reduced number of trips and a saving of 576 litres in fuel consumption.
9. By discarding TRUCK 412 from the system and concentrating loads on larger vehicles, the average satisfaction of demand time would be reduced by 7 hours, with a 9 % saving in overtime. Alternately, removal of TRUCK 469 would increase the mean satisfaction of demand time by 1 hour and overtime by 43 hours. However, 813 litres of fuel would be saved, with a reduction of 2 human resources. The last potential alternative would be to discard TRAILER 453. This would increase the mean satisfaction of demand time by 2 hours and overtime by 144 hours.

Note * - The satisfaction of demand time is referred to as the demand time in the body of the report.

On the basis of the conclusions, the following actions are recommended:

1. Increase the vehicle load utilization by batching more orders together.
2. Increase the target time to satisfy the demand to 72 hours.
3. Inspect vehicles outside delivery hours.
4. Reduce the changes in mechanical horse/trailer combination during delivery hours to a minimum. In addition, when required, allow the trailers to be connected to any mechanical horse. If necessary, modify the design for the horse/trailer linkage mechanism.
5. Discard TRUCK 412.
6. Investigate the existing imbalance in vehicle/product allocation (i.e. some products wait for vehicles significantly longer than others).

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APPENDICES

APPENDIX A

PRODUCTS HANDLED AT AECI

TABLE A1 - Products Handled at the Acid Despatch

CONTAINER TYPE	DIMENSIONS	PRODUCT NAME	WEIGHT GROSS	TARE	NET
-	cm	-	kg	kg	kg
DRUM					
(Mild Steel)	Ø 58 * 58	Persolve	341	15	326
		Sulphuric Acid	242	15	227
		Tetrasolve	339	15	324
		Trichlor	315	15	300
		Arcton 11	300	15	285
	Ø 36 * 56	Arcton 11	74	4	70
(Stainless Steel)	Ø 58 * 85	Nitric Acid	285	15	270
	Ø 28 * 46	Nitric Acid	35	4	31
BLOPAC	Ø 48 * 92	Ammonia Liquor	190	10	180
		Hydrochloric Acid	240	10	230
		Formalin	230	10	220
POLYCAN	27 * 27 * 43	Ammonia Liquor	25	2	23
		Battery Acid	32	2	30
		Hydrochloric Acid	30	2	28
		Peroxides	27	2	25
		Nitric Acid	35	2	33
		Ammonium Thiosulphate	35	2	33
	16 * 16 * 25	Peroxides	20	4	16
PRESSURE VESSELS	Ø 80 * 190	Arcton 12	1650	657	993
		Forane 12	1792	657	1135
		Kaltron 12	1657	657	1000
		Chlorine	1610	657	953
		Sulphur Dioxide	1580	580	1000
		Freon 12	1585	657	928
	Ø 28 * 93	Anhydrous Ammonia	140	70	70
		Chlorine	103	33	70
		Sulphur Dioxide	111	33	78
		Arcton 12	107	31	76
BARRELS	Ø 130 * 220	Caustic Soda	4000	1000	1000
		Hydrochloric Acid	4200	1000	3200
		Ammonia Liquor	3900	1000	2900
		Sulphur Dioxide	4000	1000	3000
		Battery Acid	4100	1000	3100
		Sulphuric Acid	3800	1000	2800
CARBOYS	Ø 46 * 60	Sulphuric Acid	55	12	43

TABLE A2 - Products Handled at the Chemical Despatch

CONTAINER TYPE	DIMENSIONS	PRODUCT NAME	WEIGHT
-	cm	-	kg
POLYCANS (Large)	43 * 30	AECI pol	25
		Arklone	25
		Argal 90	25
		Flavable Sulphur	25
		Flavable Kaptan	25
		Ferritic Sulphate	38
(Small)	33 * 16	Arklone	5
		Argal 90	5
BAGS (Small)	69 * 46 * 16	Bordeaux Mixture	25
		Carbaryl	25
		Copper Sulphate	25
		Folpan Sulphur	25
		Kaptan	25
		Roural Sulphur	25
		Crotothane	25
		Vine Dusting Sulphur	25
(Large)	89 * 46 * 16	Urea	50
		Coopers Sulphur	50
		Crude Sulphur	50
		Kynoch Feed	50
		Vine Dusting Sulphur	50
DRUMS (Small)	Ø 28 * 45	Capsine	25
		Brasikap	30
		Thioflo	20
(Large)	Ø 58 * 100	Arklone	200
		Capsine	200
		Lime Sulphur	200
		Pestridol	200
CARTONS	55 * 29 * 19	Calnitro	20
		Kaptan	12
		Killem Fly Balt	12
		Fumigation Sulphur	25

Five products, of various grades, are handled by the Plastics Despatch. All the products are packed in plastic or paper sacks of overall dimensions 70 * 45 * 15 cm, and which weigh 25 kg each. The products, known by their brand names, are Corvic, Welvic, AECIthene, Alkathene and Alkathene powder.

APPENDIX B

SPECIFIC DETAILS ON THE MODEL

B.1 Product 1 - Plastics

1. In any batch, the arrival time is marked on ATRIB(1) of the first order entity only. This ensures that the demand time takes into account the earliest order. This is accomplished by resetting GLOBAL VARIABLE XX(93) to a large number every time a batch has been formed.

2. USERF(1) (FORTRAN USER FUNCTION). Every time an entity arrives, the batch size is increased by the order size assigned in XX(90). Tests are then made to see if the new batch size falls within the desired load utilization of one of the three possible vehicle resources. Should one of the tests be positive, batch sizing is stopped, and a batch entity is sent to the corresponding AWAIT node. Otherwise, further tests are made to check if the size of the actual order entity can fill one of the vehicle resources. Should it be possible, the actual order entity then becomes a batch entity, and is sent to the appropriate AWAIT node. In this case, the size of the previously existing batch will continue to be increased on arrival of future entities. The same approach is employed if the load capacity of the largest vehicle is exceeded.

3. ALLOC(1), (2), (3) apply to the allocation of small-sized, medium-sized and large-sized vehicle respectively to the batch entity. The truck or trailer type is marked on ATRIB(6) of the entity, and the horse type on ATRIB(7). In all cases, an attempt is made to use the same horse/trailer combination as the one used on the last journey. This is accomplished by recording the product of ATRIB(6) and ATRIB(7) in XX(1) for the last journey and comparing the latter with the actual product. A search is then made to check if the actual and previous states can be matched.

4. USERF(4) compares the actual horse/trailer combination with the previous ones. Table B1 illustrates all the possible combinations in terms of ATRIB(6)*ATRIB(7). Horses and trailers are only used for Product 1, 2, and 3. At the end of the journeys for each of these

TABLE B1 - Identification of Horse/Trailer Combination

RESOURCE NUMBER FOR HORSE ATRIB(7)	RESOURCE NUMBER FOR TRAILER - ATRIB(6)						
	13	14	15	16	17	18	19
7	—	—	—	112	—	—	—
8	—	112	120	—	—	—	—
9	—	—	—	—	153	—	—
10	130	140	150	—	—	180	190
11	143	154	165	—	—	198	209
12	156	—	—	—	204	216	—

products, XX(1), XX(2), and XX(3) are recorded respectively as ATRIB(6)*ATRIB(7).

Consider the following example. Suppose the actual vehicle resources used are a HORSE 424 (Resource Number 10) and a TRAILER 449 (Resource Number 18). The corresponding attribute product is 180. Then, if XX(1), (2), or (3) was equal to 198, 216, 190, 150, 140, or 130, it means that Resources Number 10 and 18 were not connected together on the last journeys. Hence, a request to delay the entity for a change in vehicle state is necessary. Otherwise, the entity carries on normally. Such tests are made in the USER FUNCTION.

5. Loading will only start when a loading resource FORKLIFT is available.

6. Demand time is measured when all customers have been satisfied.

7. No empties are handled.

8. Travelling back time to the factory is computed as follows:

$$\text{Travelling Back Time} = \frac{\text{Total Distance Travelled}}{\text{Average Speed}} - \text{Travelling Away Time}$$

B.2 Product 2 - Ammonium Nitrate

1. In view of the fact that the trailers handling this product have approximately the same load capacity (23000 kg, 20000 kg, 22630 kg), there is only one possible vehicle allocation, ALLOC(4). Similarly to Product 1, the horse/trailer combination used for the journey is recorded as ATRIB(6)*ATRIB(7).

2. USERF(8) performs a function similar to USERF(4), in relation to the horse/trailer state. Refer to Note 4 under Section B.1.

3. Refer to Note 8 under Section B.1 for the travelling back time.

4. No empties are handled.

5. ACTIVITY 22 refers to the washing of trailers on Friday afternoons.

B.3 Product 3 - Barrels

1. Whenever an order is placed, the size is represented by the number of entities introduced at once into the system. For instance, to model an order for 3 barrels, 3 entities are introduced, using the ENTER node. To describe the order in terms of barrels types, the entity is sent to one of three ASSIGN nodes, depending on the probabilities specified in ACTIVITIES 30, 31, 32. In ACTIVITY 30, for example, there is a probability of 0,5830 that the entity will be sent to the ASSIGN node for BARREL 1.

2. The functions of USERF(3) are as follows:
   1. Record the number and type of BARREL associated with any batch.
   2. Decide when to finalize a batch.

The type of BARREL is known from the number that ATRIB(3) of the entity is assigned (i.e. 7 corresponds to BARREL 1, 8, BARREL 2, 9, BARREL 3). The number of BARRELS at any time is worked out from the product of ATRIB(3) of each BARREL. Thus, the product number varies as follows:

1. 1 barrel : product number range = 7 - 9.
2. 2 barrels: product number range = 49 - 81.
3. 3 barrels: product number range = 343 - 729.
4. 4 barrels: product number range = 2401 - 6561.

Once a batch has been formed, the product number is substituted into ATRIB(3) of the batch entity. With the exception of the last order entity cooperating to finalize the batch size, all preceeding entities are destroyed. ATRIB(3) is used at a later stage to identify the types of BARRELS connected to the trailers, in order to initiate any change in barrel/trailer state (refer to Note 4 under this section).

The final size of the batch does not always correspond to 4 BARRELS (i.e. the trailer capacity), but depends on the time for which an order has been waiting. The following rule is employed:

1. If there is only one barrel waiting, the maximum waiting time is set to XX(84) (40 hours).
2. On arrival of subsequent entities, the maximum waiting time for the first entity in the batch is worked out from the relationship shown in Figure B2 below:

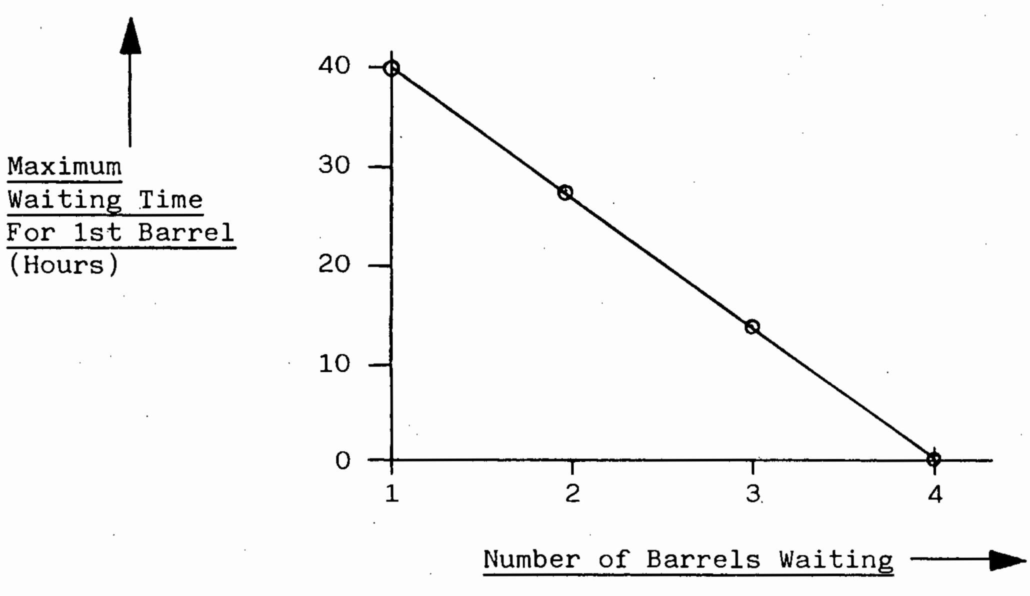


Fig. B1 - Variation of Waiting Time For First Barrel in a Batch

A batch will only be finalized if the maximum waiting time has been reached. Prior to sending a batch entity to the SLAM network, the number of each type of BARREL is marked on ATRIB(8) for BARREL 1, ATRIB(9) for BARREL 2, and ATRIB(10) for BARREL 3 (Note: the BARREL resources will only be assigned to the entity before loading starts).

3. In ALLOC(5), the batch entity awaits either TRAIL 318 or TRAIL 441, as well as one of the horses that may be connected to it, according to the allocation rules presented in Table 2 (p. 17).

4. Barrel/trailer state is checked by comparing the product of ATRIB(3) and ATRIB(6) (i.e. barrel combination code and trailer type), with the previous combination. This is accomplished by USERF(12). Should there be a difference, the batch entity is delayed by a period representing the change in barrel state. However, because there are 2 trailers that handle barrels, a record of ATRIB(3)*ATRIB(6) is done separately for each trailer. Thus, XX(46) records the BARREL/TRAIL 318 state, and XX(47), the BARREL/TRAIL 441 state.

5. USERF(11) performs a function similar to USERF(4) in relation to the horse/trailer state. Refer to Note 4 under Section B.1.

6. BARREL types 1 and 2 are filled at Fillpoint Number 1. BARRELS type 3 are filled at Fillpoint Number 2. Thus, the entity will take one of the following actions:
   1. Go to Fillpoint Number 1 only.
   2. Go to Fillpoint Number 2 only.
   3. Go to both Fillpoints.

   Before awaiting the appropriate FILLPOINT resource, the entity awaits the required number of different BARREL resources.

7. Refer to Note 8 under Section B.1 for the travelling back time.

8. No empties are handled.

9. In addition to freeing the vehicle resources before destroying the batch entity, BARREL resources are also freed and made available to the system.

B.4 Product 4 - Large P.V

1. Whenever an order is placed, the size is represented by the number of entities introduced at once into the network. For example, an order for 2 P.V.s is represented by introducing 2 entities, using the ENTER node.

2. The functions of USERF(7) are:
   1. To record the number of P.V.s associated with any batch.
   2. To decide when to finalize the batch size.

   Every time an entity is introduced into the system, the batch size is incremented by one. Maximum batch size is 6. Intermediate entities cooperating to increase the size are destroyed. A batch is finalized using the same approach as that for barrels. However, it is necessary to take into account the difference in P.V. capacity of the two vehicle resources used (i.e. TRUCK 469 can take 4 P.V.s, whereas TRUCK 471 can take 6 P.V.s). This is done as follows:
   1. If there is 1 P.V waiting, maximum waiting time is set to XX(83) (40 hours).
   2. On arrival of subsequent entities, the maximum waiting time of the first entity in the batch is worked out from the relationship illustrated in Figure B2 below:

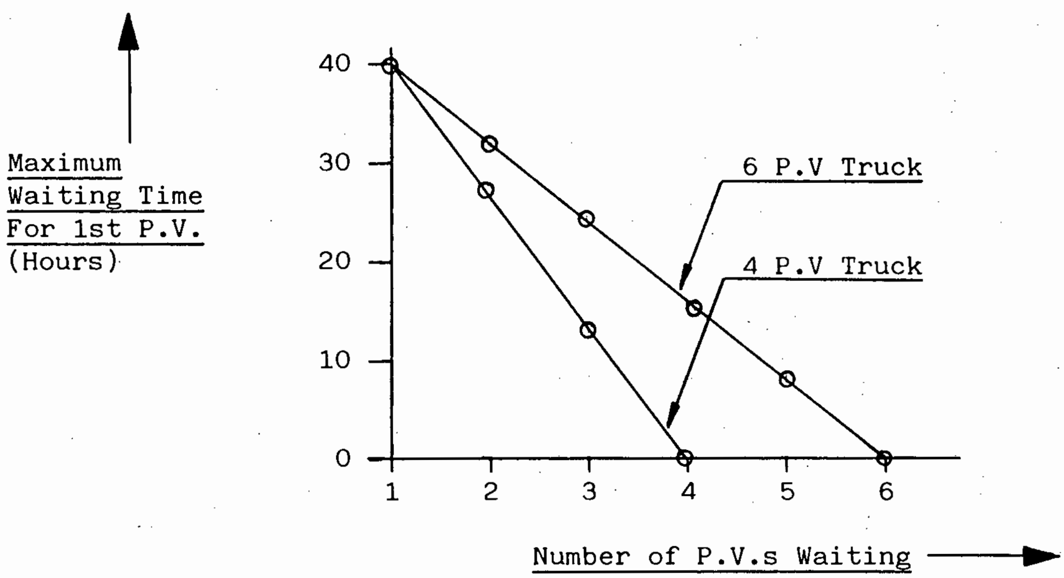


Fig. B2 - Variation of Waiting Time For First P.V. in a Batch

Note that the maximum waiting time is computed for both cases (i.e. where the batch would be allocated to either the small or large capacity truck).

3. Then, if the number of P.V.s waiting is less than the small truck capacity, and the corresponding maximum waiting time (with large truck) is exceeded, and there are more batch entities waiting for the small truck than the big truck, in the corresponding files, finalize the batch size and send a batch entity to the AWAIT node for the big truck.

4. Else, if the number of P.V.s waiting is less than the small truck capacity, and the corresponding maximum waiting time (with small truck) is exceeded, and there are more batch entities waiting for the big truck than the small truck, finalize the batch size and send a batch entity to the AWAIT node for the small truck.

5. Else, if there are 4 P.V.s waiting, and there are more batch entities waiting for the big truck than the small truck, send a batch entity to the AWAIT node for the small truck.

6. Else, a batch entity will be sent to the AWAIT node for the large truck, provided the maximum waiting time (with large truck) has been reached.

3. ALLOC(6), (7) apply to the allocation of TRUCK 469 and TRUCK 471 respectively.

4. Vehicles used to handle Product 4 may also handle Product 5. However, whereas cradles must be installed on the vehicles for Product 4, they are not needed for Product 5. For this reason, cradles are treated as RESOURCES, namely CRADLE 2, each having a capacity for 2 P.V.s, and CRADLE 3, with a capacity of 3 P.V.S. USERF(10) FREES or SEIZES CRADLE resources, depending on which product is being handled.

   The maximum number of available CRADLE 2 and CRADLE 3 corresponds to the number of cradles that can be fitted to the 4 and 6 P.V capacity trucks respectively. Therefore, whenever CRADLES are available, it means that they are not connected to the vehicles. This approach is used to decide whether to SEIZE or FREE the resources, depending on the type of product being handled. Refer to USERF(10) for details.

5. Following delivery to all customers, empties are loaded according to some probability.

6. Refer to Note 8 under Section B.1 for the travelling back time.

B.5 Product 5 - General

1. Refer to Note 1 under Section B.1 for the order arrival time. XX(87) is employed instead of XX(93).

2. EVENT 1 performs a function similar to USERF(1). However, the reason for using an EVENT node is that orders placed for GENERAL products may be delivered using the vehicles for Product 4. Hence, transfer of entities from AWAIT files for Product 5 to those for Product 4 is necessary if the number of batch entities becomes too large. (See explanations in FORTRAN SUBROUTINE TEST 1).

3. ALLOC(8), (9), (10) apply to the allocation of small-sized, medium-sized, and large-sized trucks respectively.

4. Following delivery to all customers, empties are loaded according to some probability.

5. Refer to Note 8 under Section B.1 for the travelling back time.

B.6 Dayshift Model

The following actions are taken on a daily basis:

1. Increment the day number by one (XX(9)).
2. Increment XX(4) by one. When it reaches 30, the variable is reset to 0 and FORKLIFT resources are altered to 0 for 5 hours, from 7 a.m. to 12 p.m. XX(4) is also used for the maintenance of Ammonium Nitrate trailers.
3. Record the time TNOW in XX(8) at 7 a.m. This is used to compute the overtime worked on weekends.
4. Alter the TRUCK and HORSE resources to 0 at 7 a.m. This represents the inspection time.
5. Delay the entity for a period corresponding to the inspection time.
6. Alter back the resources in 4 to their original availability.

7. Delay the entity by a period equivalent to the remaining of the morning.
8. Alter the TRUCK, TRAILER, GANTRY, and FILLPT resources to 0 at 12 p.m.
9. Delay the entity by a period equal to the lunch time.
10. Alter back the resources in 8 to their original availability.
11. Delay the entity by a period corresponding to the rest of the afternoon until 4 p.m.
12. Record the time TNOW in XX(10). This enables the overtime worked during weekdays to be computed.
13. Delay the entity by a period equal to the rest of the day (15 hours).
14. When the FORKLIFTS have been maintained, they are altered back to their original availability.

B.7 Weekshift Model

The following occur in a cycle of one week:

1. Set XX(6) to 1 to represent Monday to Thursday.
2. Delay the entity by 96 hours.
3. Set XX(6) to 2 to represent Friday.
4. Delay the entity by 24 hours.
5. Set XX(6) to 3 to represent Saturday.
6. Delay the entity by 24 hours.
7. Set XX(6) to 4 to represent Sunday.
8. Delay the entity by 24 hours.

B.8 Starting The Simulation

FORTRAN SUBROUTINE INTLC initiates the simulation. At time TNOW = 0, EVENT 7 (ORDERN) is scheduled to occur. In SUBROUTINE ORDERN, the number of daily orders for each product group are computed, and scheduled to arrive at random times during working hours on weekdays.

At each scheduled time, one of the EVENTS (2), (3), (4), (5), and (6) are called, according to the product group. In each of the corresponding subroutines (ORDER 1, 2, 3, 4, and 5), one entity is introduced per order into the SLAM network, by calling SUBROUTINE ENTER. For Product 3 and 4, however, the size of orders is also computed and the corresponding number of entities are introduced into the network.

B.9 Simulation Run Length

At the start of the simulation, all files and statistical arrays are empty. The average file length for the first 15 weeks varies as shown in Figure B3 below:

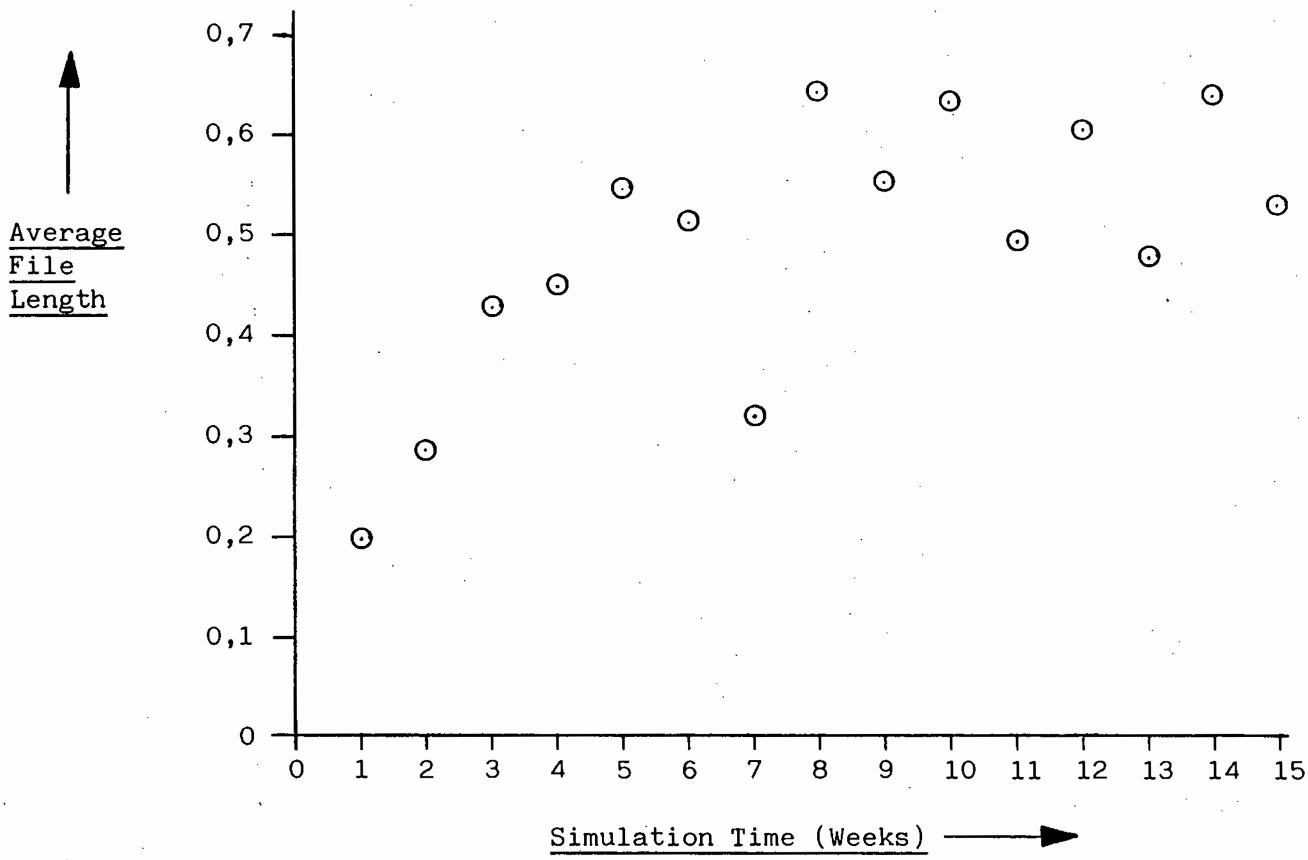


Fig. B3 - Variation of Average File Length With Simulation Run Length

To reduce this initial bias, all statistical arrays, including the file statistics, are cleared at time 2880 (3 months). The model is simulated for a period of 1464 hours thereafter, which corresponds to the time during which all real life data were collected. This is accomplished by means of the MONTR,CLEAR statement appearing at line 7685 of the SLAM network in Appendix E.

B.10 Feeding Information To The System

Information may be altered either in the 'INTLC' statements preceeding the SLAM network (refer to lines 1140 - 1380 in Appendix E), or in the various statistical distributions employed. These have been underlined in the network model (Appendix E) and in the FORTRAN program (Appendix F).

B.11 Collecting Results From The System

In addition to the statistical results collected from the COLCT nodes in the network, time-persistent statistics on certain global variables are gathered using the TIMST statements appearing on lines 1700 - 2130 in Appendix E. Furthermore, RECORD and VAR statements on lines 1580 - 1680 specifies information to be collected on the daily utilization of the following resources:

1. Number of drivers, from USERF(13).
2. Number of assistants, from USERF(14).
3. Number of trucks, from USERF(15).
4. Number of horses, from USERF(16).
5. Number of trailers, from USERF(17).
6. Number of barrels, from USERF(9).
7. Number of vehicles maintained, from USERF(21).

APPENDIX C

SUMMARY OF ATTRIBUTES, GLOBAL VARIABLES & FILES USED IN THE NETWORK

TABLE C1 - Description of the Attributes Carried by the Entities

ATTRIBUTE NUMBER	PRODUCT CODE				
	1	2	3	4	5
1	Time at which the order was placed.				
2	Time at which the vehicle leaves the factory.				
3	1. Loading Time 2. Unloading Time	1. Loading Time 2. Unloading Time	1. Barrel Type 2. Number of Barrels 3. Loading Time 4. Unloading Time	1. Loading Time 2. Unloading Time	1. Loading Time 2. Unloading Time
4	Time that the vehicle goes away to deliver the products to all the customers. Time that the vehicle travels back from the last customer to the factory.				
5	The total km that the vehicle will travel on the journey.				
6	The truck or trailer being used on the journey.				
7	The horse being used on the journey.				
8	Type of product	Type of product	Number of Barrels Type 1 assigned on the journey	Type of product	Type of product
9	--	--	Number of Barrels Type 2 assigned on the journey	Reference to either destroy the load or send the batch to the appropriate file	
10	Size of Load to be transported	--	Number of Barrels Type 3 assigned on the journey	Number of P.V. to be transported	Size of load to be transported

TABLE C2 - Summary of Global Variables Used in the Network

XX( )	DESCRIPTION	DIMENSION
1	Describes which horse was connected to which trailer on the last journey - Product 1.	-
2	Describes which horse was connected to which trailer on the last journey - Product 2.	-
3	Describes which horse was connected to which trailer on the last journey - Product 3.	-
4	Increased every day by 1, reset to 0 at 30 - A signal to maintain vehicles for Product 2 every month.	-
5	Describes the state of the day:= 2 (morning), = 2 (afternoon).	-
6	Describes the state of the week: = 1 (Monday to Thursday), = 2 (Friday), = 3 (Saturday), = 4 (Sunday).	-
7	Alternates between 0 & 1: = 0 (Dayshift) = 1 (Nightshift)	-
8	Records the time TNOW everyday at 7 a.m. Used to compute overtime worked on weekends.	hr
9	Records the number of days ellapsed.	day
10	Records the time TNOW everyday at 4 p.m. Used to compute overtime worked on weekdays.	hr
*11	Load capacity of Resource No. 1	kg
*12	Load capacity of Resource No. 2	kg
13	Records the cumulative overtime worked on weekdays.	hr
14	Records the cumulative overtime worked on weekends.	hr
*15	Load capacity of Resource No. 3	kg
*16	Load capacity of Resource No. 4	kg
*17	Load capacity of Resource No. 5	kg
*18	Load capacity of Resource No. 6	kg
*19	Load capacity of Resource No. 13	kg
*20	Load capacity of Resource No. 14	kg
*21	Load capacity of Resource No. 15	kg
*22	Load capacity of Resource No. 16	kg
*23	Load capacity of Resource No. 17	kg
*24	Load capacity of Resource No. 18	kg
*25	Load capacity of Resource No. 19	kg

*Note - These variables can be modified in "INTLC".

TABLE C2 (CONTD)

XX( )	DESCRIPTION	DIMENSION
*26	Inspection time for vehicles every morning	hr
*27	Duration of lunch time	hr
*28	Required % load utilization on vehicles for Product 1 & 5	-
*29	Fuel consumption of Resource No. 1	ℓ/100km
*30	Fuel consumption of Resource No. 2	ℓ/100km
*31	Fuel consumption of Resource No. 3	ℓ/100km
*32	Fuel consumption of Resource No. 4	ℓ/100km
*33	Fuel consumption of Resource No. 5	ℓ/100km
*34	Fuel consumption of Resource No. 6	ℓ/100km
*35	Fuel consumption of Resource No. 7	ℓ/100km
*36	Fuel consumption of Resource No. 8	ℓ/100km
*37	Fuel consumption of Resource No. 9	ℓ/100km
*38	Fuel consumption of Resource No. 10	ℓ/100km
*39	Fuel consumption of Resource No. 11	ℓ/100km
*40	Fuel consumption of Resource No. 12	ℓ/100km
41	Whenever it is set to 1, the vehicle is sent to a gantry for changing barrels.	-
*42	Washing time for Ammonium Nitrate tankers.	hr
*43	Time to change cradles on vehicles for Product 4.	hr
*44	Maintenance time for vehicles.	hr
*45	Target demand time.	hr
46	Describes which barrels were connected to which trailer on the last journey.	-
47	Describes which barrels were connected to which trailer on the last journey.	-
48	Whenever it is set $>$ 0, the vehicle is delayed by a change of horse/trailer.	-
*49	Time to change barrels on trailers for Product 3.	hr
*50	Time to change horse/trailer.	hr
51	Records the cumulative km travelled by Resource No. 1	km
52	Records the cumulative km travelled by Resource No. 2	km
53	Records the cumulative km travelled by Resource No. 3	km
54	Records the cumulative km travelled by Resource No. 4	km
55	Records the cumulative km travelled by Resource NO. 5	km

*Note - These variables can be modified in "INTLC".

TABLE C2 (CONTD)

XX( )	DESCRIPTION	DIMENSION
56	Records the cumulative km travelled by Resource No. 6	km
57	Records the cumulative km travelled by Resource No. 7	km
58	Records the cumulative km travelled by Resource No. 8	km
59	Records the cumulative km travelled by Resource No. 9	km
60	Records the cumulative km travelled by Resource No. 10	km
61	Records the cumulative km travelled by Resource NO. 11	km
62	Records the cumulative km travelled by Resource No. 12	km
*63	Frequency of km travelled between maintenance	km
64	Records the cumulative fuel consumed by Resource No. 1	ℓ
65	Records the cumulative fuel consumed by Resource No. 2	ℓ
66	Records the cumulative fuel consumed by Resource No. 3	ℓ
67	Records the cumulative fuel consumed by Resource No. 4	ℓ
68	Records the cumulative fuel consumed by Resource No. 5	ℓ
69	Records the cumulative fuel consumed by Resource No. 6	ℓ
70	Records the cumulative fuel consumed by Resource No. 7	ℓ
71	Records the cumulative fuel consumed by Resource No. 8	ℓ
72	Records the cumulative fuel consumed by Resource No. 9	ℓ
73	Records the cumulative fuel consumed by Resource No. 10	ℓ
74	Records the cumulative fuel consumed by Resource No. 11	ℓ
75	Records the cumulative fuel consumed by Resource No. 12	ℓ
76	Records the number of trips with 4 full barrels on vehicles for Product 3.	-
77	Records the number of trips with 3 full barrels on vehicles for Product 3.	-
78	Records the number of trips with 2 full barrels on vehicles for Product 3.	-
79	Records the number of trips with 1 full barrel on vehicles for Product 3.	-
80	Records the cumulative number of full barrels that were transported.	-
81	Whenever it is set >0, the vehicle is delayed by a change of horse/trailer.	-
82	Whenever it is set >0, the vehicle is delayed by a change of horse/trailer.	-
*83	Maximum waiting time if there is a demand for 1 P.V only	-

*Note - These variables can be modified in "INTLC".

TABLE C2 (CONTD)

XX( )	DESCRIPTION	DIMENSION
*84	Maximum waiting time if there is a demand for 1 barrel only.	-
85	Filling time per barrel.	hr
*86	Maintenance time for forklifts.	hr
87	A signal to allow the arrival time of the first demand in any batch for Product 5 to be marked.	-
*88	Probability that vehicles for Product 4 & 5 will take empties on the way back.	-
89	Whenever it is set >0, the vehicle is delayed by a change of cradle.	-
90	Size of order for Product 1.	kg
91	Cumulative size of orders for Product 1 at time TNOW.	kg
92	Size of order for Product 5.	kg
93	A signal to allow the arrival time of the first demand in any batch for Product 1 to be marked.	-
94	Cumulative size of orders for Product 5 at time TNOW.	kg
95	A signal to either allocate a batch of load (Product 1) to a particular vehicle or "destroy" the load.	-
*96	Probability of repair after a trip.	-
*97	Target maximum overtime per trip.	hr
98	Records the total number of journeys done under normal time condition.	-
99	Records the total number of journeys done under waiting time condiiton.	-
100	Records the total number of journeys done under overtime condition.	-

*Note - These variables can be modified in "INTLC".

TABLE C3 - Description of the Entities Kept in the Files

FILE NUMBER	PRODUCT	DESCRIPTION
1	1 - Plastics	Await vehicle allocation number 1.
2	1 - Plastics	Await vehicle allocation number 2.
3	1 - Plastics	Await vehicle allocation number 3.
4	1 - Plastics	Await forklift for loading.
5	2 - Ammonium Nitrate	Await vehicle allocation number 4.
6	3 - Barrels	Await vehicle allocation number 5.
7	3 - Barrels	Await gantry for changing barrels on trailer.
8	3 - Barrels	Await barrels type 1.
9	3 - Barrels	Await barrels type 2.
10	3 - Barrels	Await barrels type 3.
11	3 - Barrels	Await fillpoint number 1 for loading barrels.
12	3 - Barrels	Await fillpoint number 2 for loading barrels.
13	4 - P.V	Await vehicle allocation number 6.
14	4 - P.V	Await vehicle allocation number 7.
15	4 - P.V	Await vehicle allocation number 8.
16	5 - General	Await vehicle allocation number 9.
17	5 - General	Await vehicle allocation number 10.

APPENDIX D

NETWORK ILLUSTRATIONS FOR DISTRIBUTION MODEL

The SLAM network for the model is illustrated in Figures D1 to D7. Each figure is broken down into a number of lines containing the network symbols. The lines should be read in the order described by the labels at the beginning and the end of each line (e.g. a line ending with label ③ continues onto the line with label ③ at the beginning). It should also be noted that the labels only apply to the page where they appear. Thus, whenever a figure continues onto the next page(s), the labels appearing on one page do not apply to the lines on other pages. Furthermore, when a figure carries onto the next page, this is indicated by a ● and/or a ●● sign, depending on whether one or two lines are continuing. To help interpret the network, some codes are included in the different symbols to indicate the variables under consideration. The following codes are used:

1. AW = Travelling time to customers.
2. KM = Total distance travelled (km) for the journey.
3. LT = Loading time per unit size.
4. LTE = Loading time for empties.
5. OT = Offloading time per unit size.
6. OTE = Offloading time for empties.
7. RE = Repair time for vehicles.
8. SP = Average speed of vehicle for journey.
9. SZ = Order size.

Finally, a list of the different files in which the entities await for resources is shown in Table D1. Whenever resources are shared by entities in different files, the files are arranged in order of priority. In addition, the relative order of the files is different for each resource, in view to balance the priorities (i.e. entities in different files are given equal chances, on the whole, to seize the resources).

TABLE D1- Resources Used in the Network

	RESOURCE LABEL	CAPACITY	FILES		
1	TRUCK412	1	15		
2	TRUCK414	1	1		
3	TRUCK467	1	16		
4	TRUCK469	1	13		
5	TRUCK471	1	14		
6	TRUCK472	1	17	2	
7	HORSE305	1	3		
8	HORSE422	1	5		
9	HORSE423	1	6		
10	HORSE424	1	5	2	6
11	HORSE426	1	2	6	5
12	HORSE427	1	6	2	
13	TRAIL318	1	6		
14	TRAIL430	1	5		
15	TRAIL431	1	5		
16	TRAIL438	1	3		
17	TRAIL441	1	6		
18	TRAIL449	1	2		
19	TRAIL453	1	5		
20	GANTRY	1	7		
21	FILLPT1	1	11		
22	FILLPT2	1	12		
23	FORKLIFT	5	4		
24	BARREL1	7	8		
25	BARREL2	6	9		
26	BARREL3	3	10		
27	CRADLE2	2	12		
28	CRADLE3	2	12		

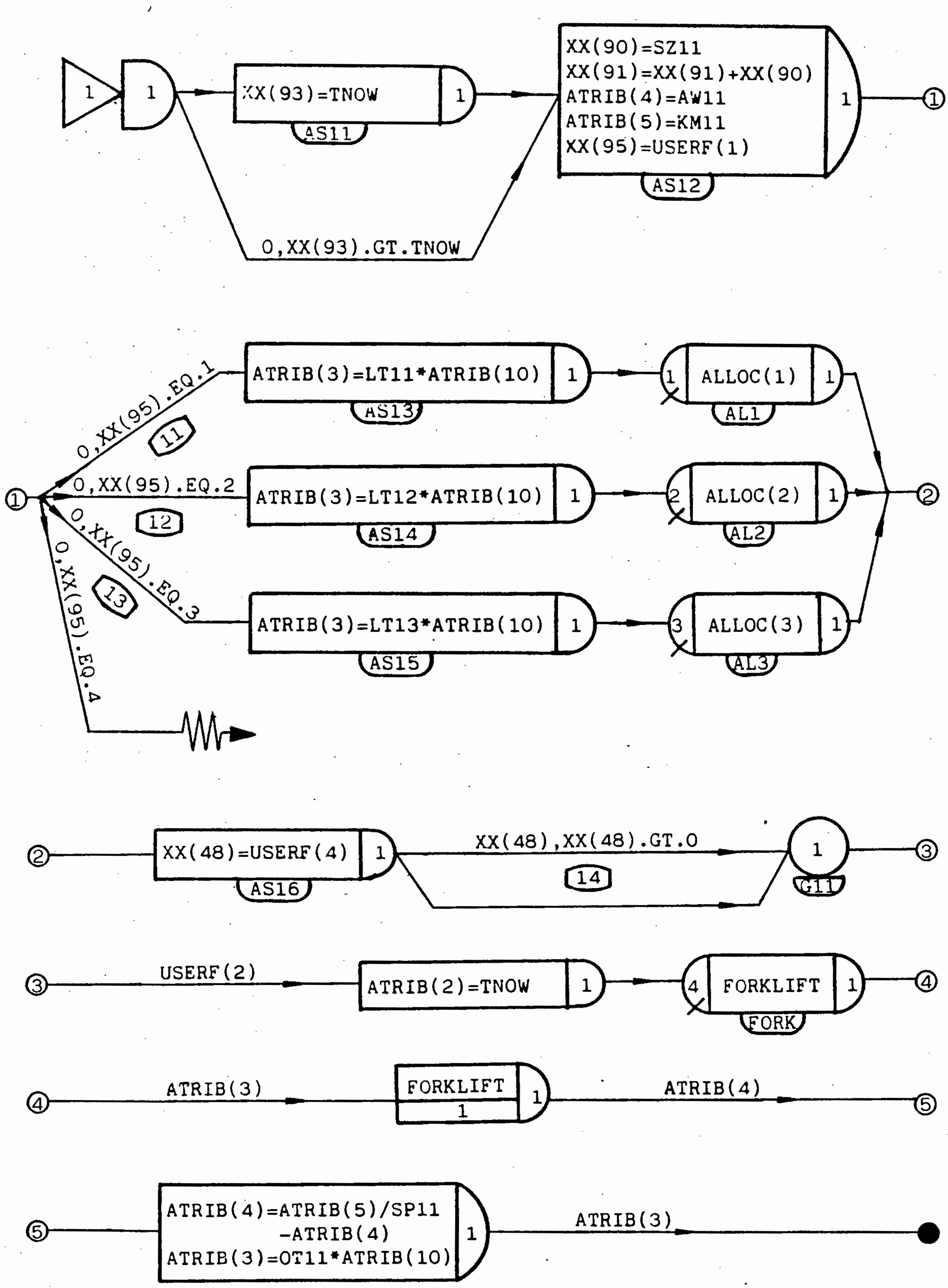


Fig. D1 - Network Model For Product 1 - Plastics

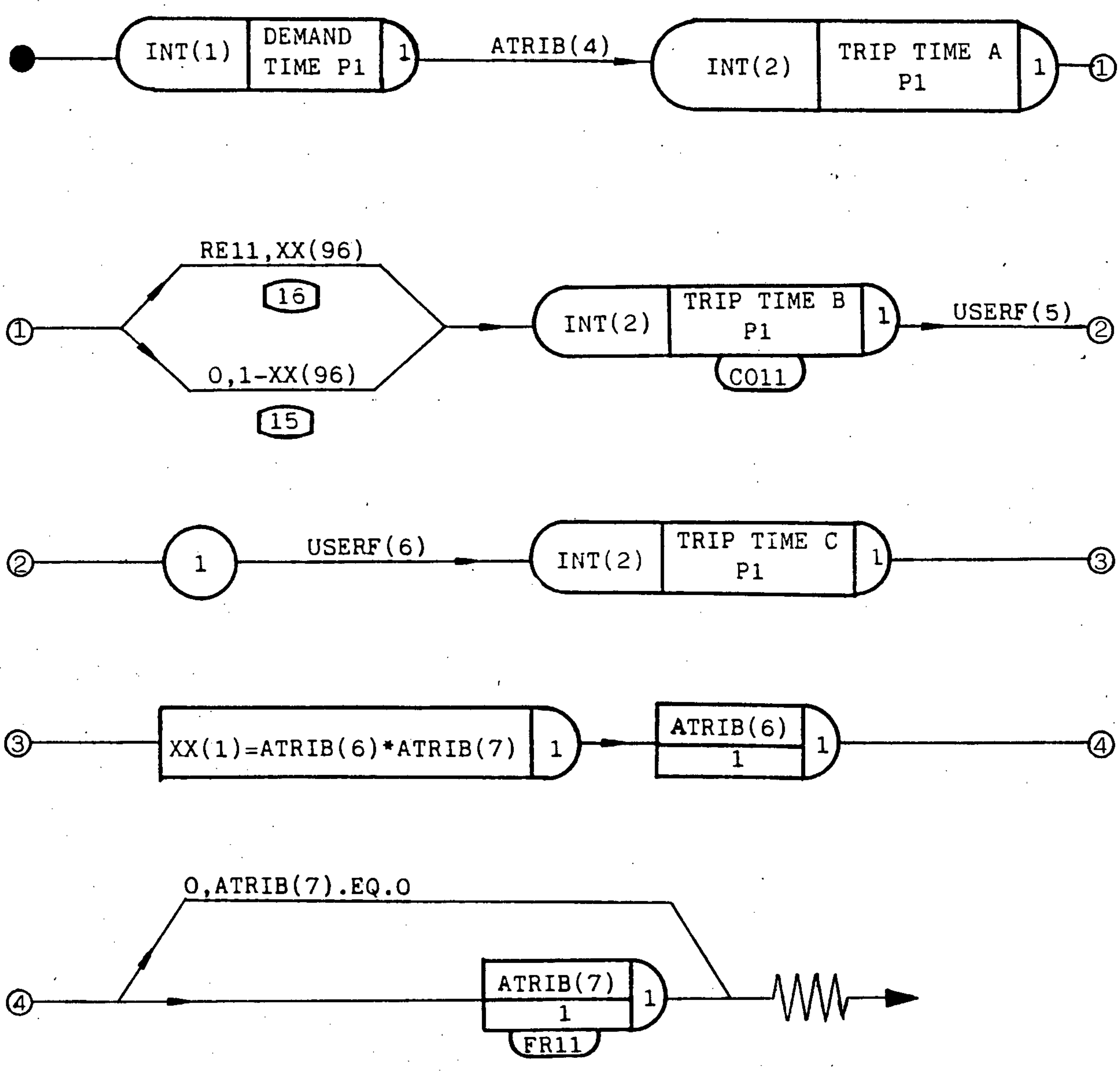

INT(1)
DEMAND TIME P1
1
ATRIB(4)
INT(2)
TRIP TIME A P1
1
RE11,XX(96)
16
0,1-XX(96)
15
INT(2)
TRIP TIME B P1
1
CO11
USERF(5)
1
USERF(6)
INT(2)
TRIP TIME C P1
1
XX(1)=ATRIB(6)*ATRIB(7)
1
ATRIB(6)
1
1
0,ATRIB(7).EQ.0
ATRIB(7)
1
1
FR11

Fig. D1 (CONTD)

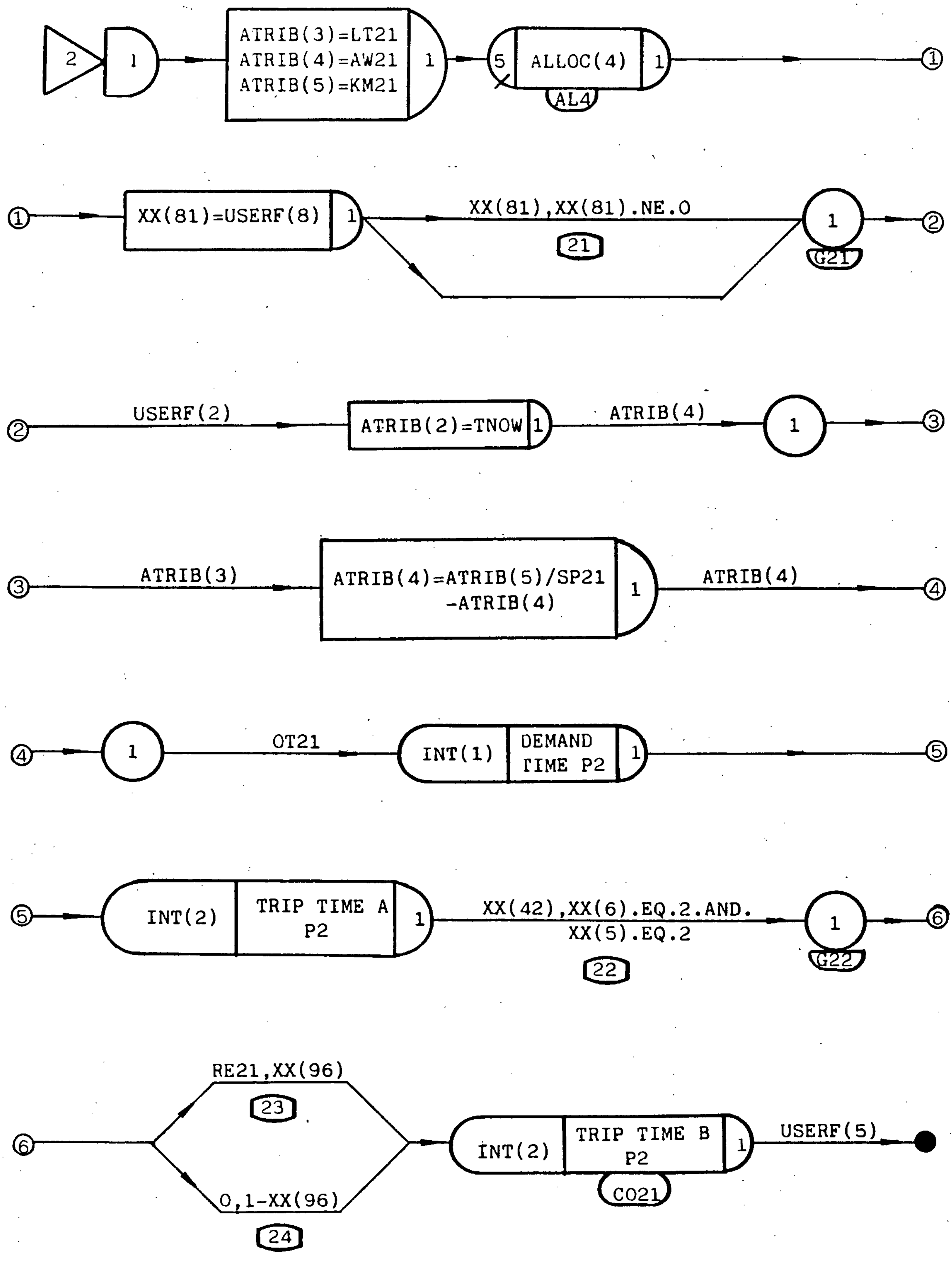
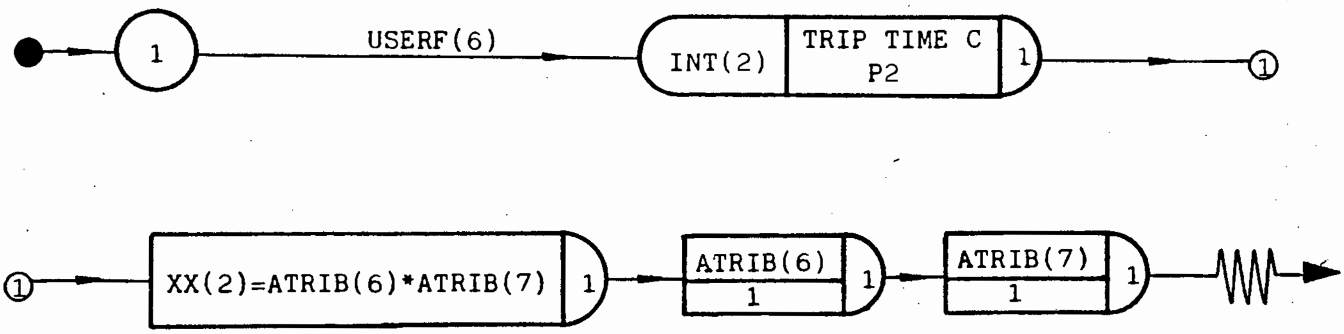


Fig. D2 - Network Model For Product 2 - Ammonium Nitrate



1
USERF(6)
INT(2)
TRIP TIME C
P2
1
1
1
XX(2)=ATRIB(6)*ATRIB(7)
1
ATRIB(6)
1
1
ATRIB(7)
1
1

Fig. D2 (CONTD)

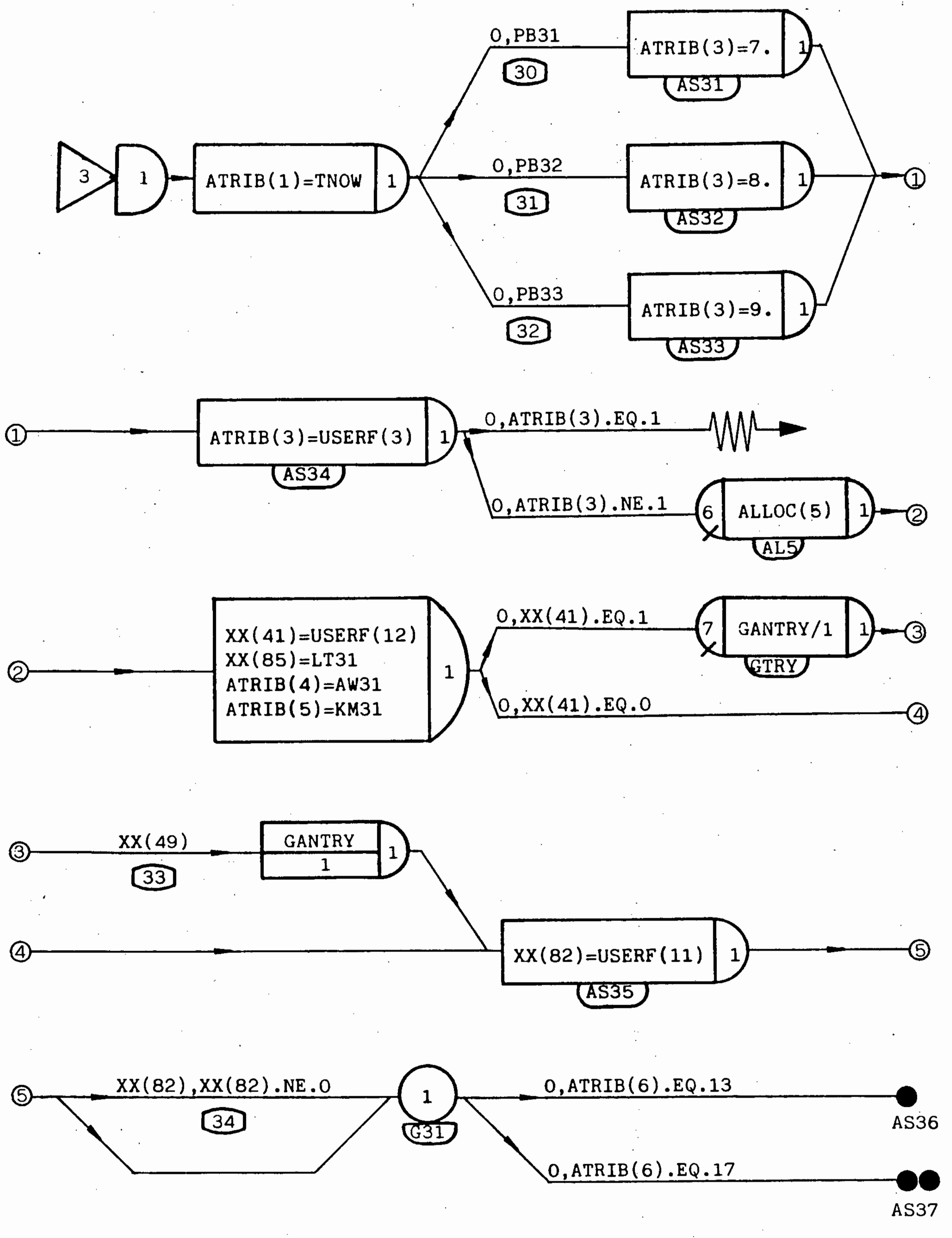
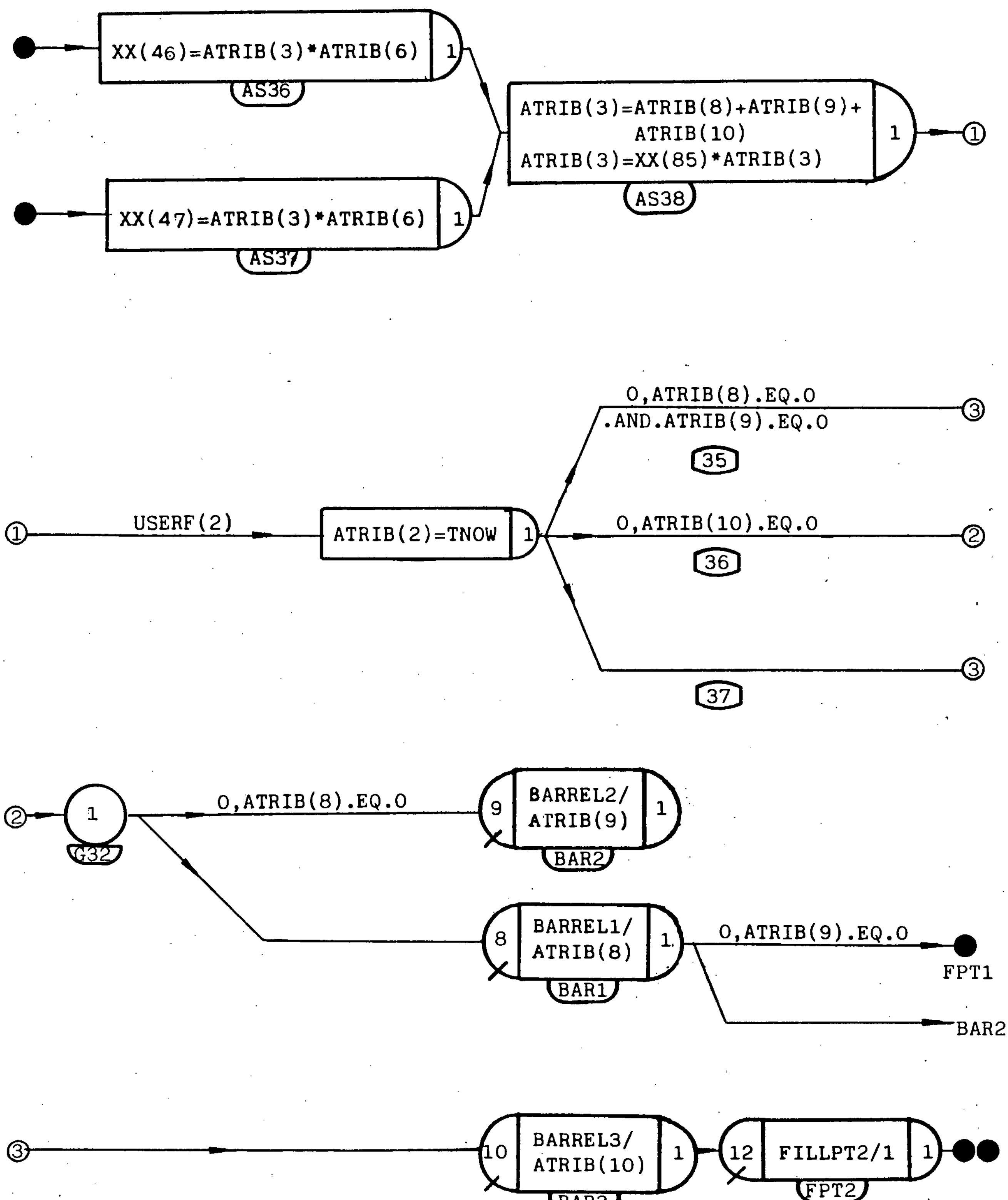


Fig. D3 - Network Model For Product 3 - Barrels



XX(46)=ATRIB(3)*ATRIB(6)
1
AS36
XX(47)=ATRIB(3)*ATRIB(6)
1
AS37
ATRIB(3)=ATRIB(8)+ATRIB(9)+
ATRIB(10)
ATRIB(3)=XX(85)*ATRIB(3)
1
AS38
①
①
USERF(2)
ATRIB(2)=TNOW
1
0,ATRIB(8).EQ.0
.AND.ATRIB(9).EQ.0
35
③
0,ATRIB(10).EQ.0
36
②
37
③
②
1
G32
0,ATRIB(8).EQ.0
9
BARREL2/
ATRIB(9)
1
BAR2
8
BARREL1/
ATRIB(8)
1
BAR1
0,ATRIB(9).EQ.0
FPT1
BAR2
③
10
BARREL3/
ATRIB(10)
1
BAR3
12
FILLPT2/1
1
FPT2

Fig. D3 (CONTD)

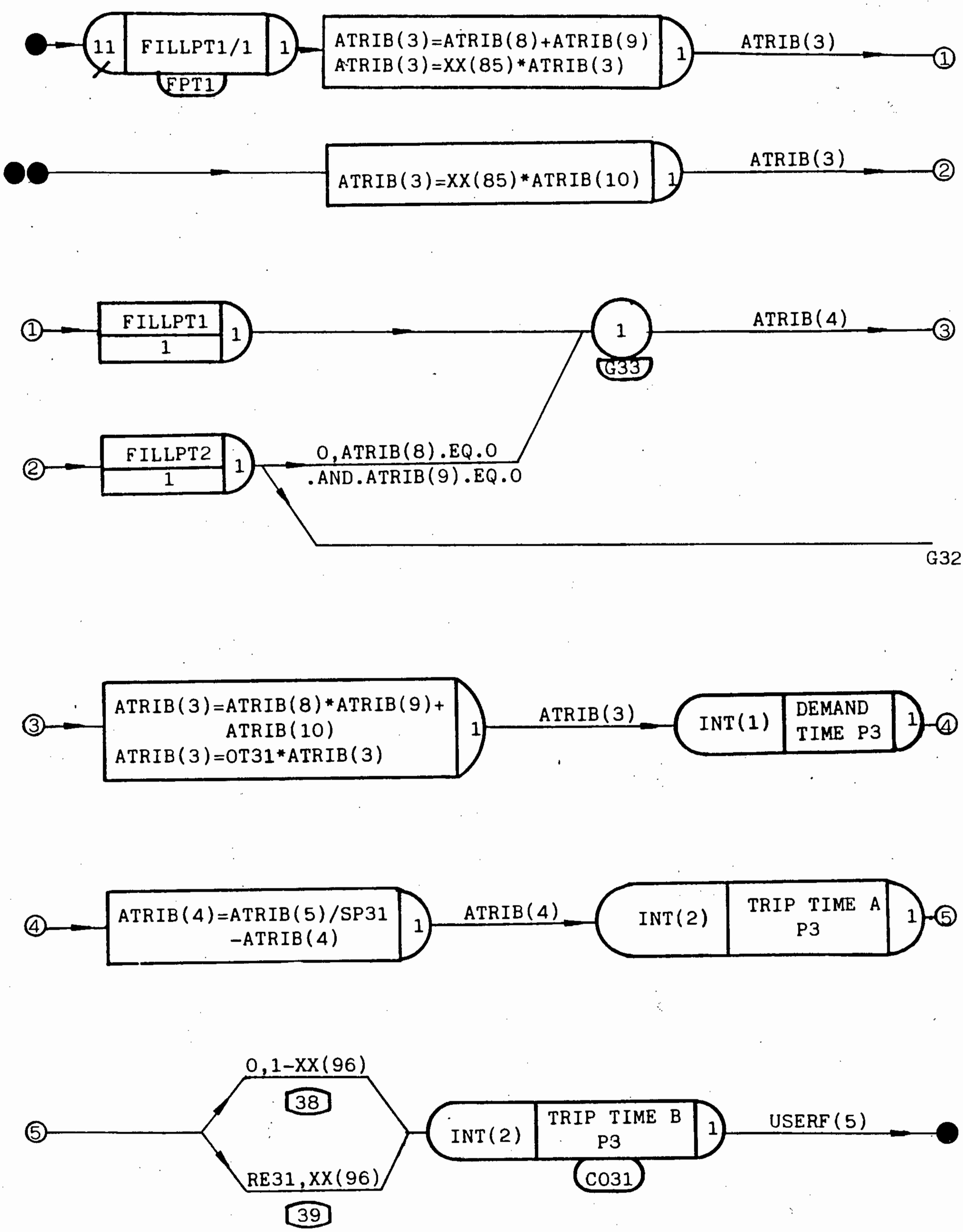

11
FILLPT1/1
1
FPT1
ATRIB(3)=ATRIB(8)+ATRIB(9)
ATRIB(3)=XX(85)*ATRIB(3)
1
ATRIB(3)
ATRIB(3)=XX(85)*ATRIB(10)
1
ATRIB(3)
FILLPT1
1
1
1
G33
ATRIB(4)
FILLPT2
1
1
0,ATRIB(8).EQ.0
.AND.ATRIB(9).EQ.0
G32
ATRIB(3)=ATRIB(8)*ATRIB(9)+
ATRIB(10)
ATRIB(3)=OT31*ATRIB(3)
1
ATRIB(3)
INT(1)
DEMAND
TIME P3
1
ATRIB(4)=ATRIB(5)/SP31
-ATRIB(4)
1
ATRIB(4)
INT(2)
TRIP TIME A
P3
1
0,1-XX(96)
38
RE31,XX(96)
39
INT(2)
TRIP TIME B
P3
1
CO31
USERF(5)

Fig. D3 (CONTD)

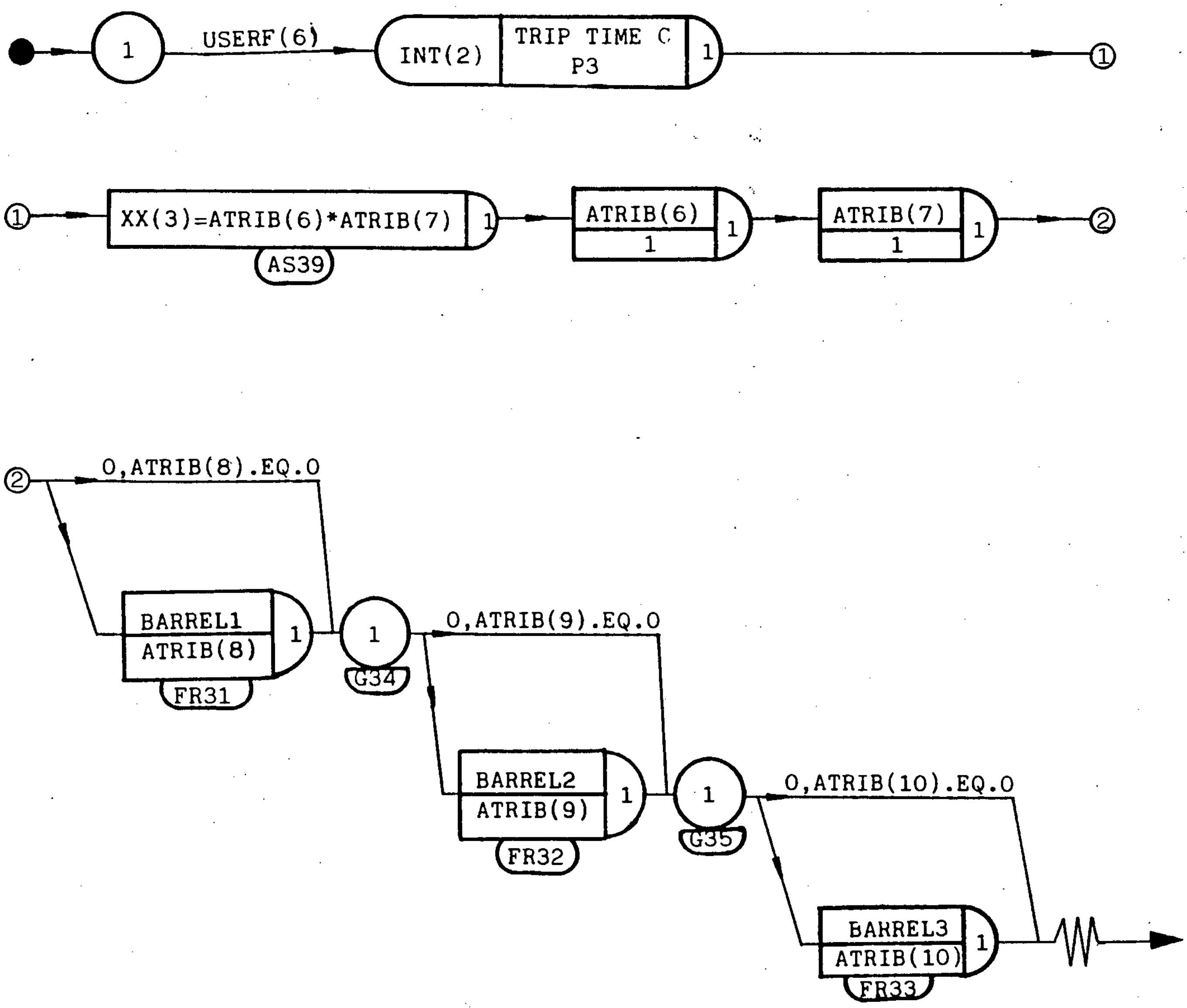

1
USERF(6)
INT(2)
TRIP TIME C
P3
1
①
①
XX(3)=ATRIB(6)*ATRIB(7)
1
AS39
ATRIB(6)
1
1
ATRIB(7)
1
1
②
②
0,ATRIB(8).EQ.0
BARREL1
ATRIB(8)
1
FR31
1
G34
0,ATRIB(9).EQ.0
BARREL2
ATRIB(9)
1
FR32
1
G35
0,ATRIB(10).EQ.0
BARREL3
ATRIB(10)
1
FR33

Fig. D3 (CONTD)

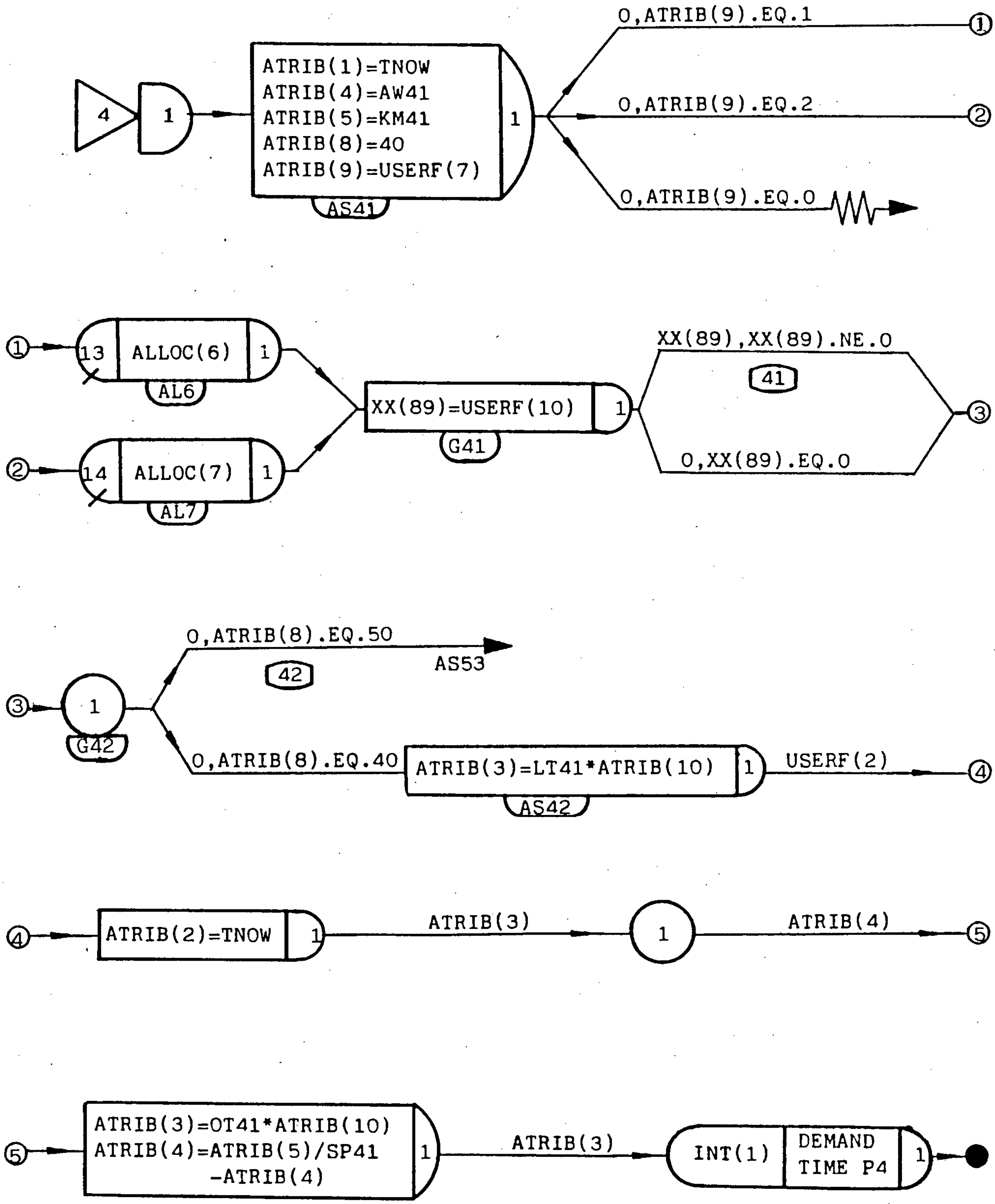


Fig. D4 - Network Model For Product 4 - Large P.V.

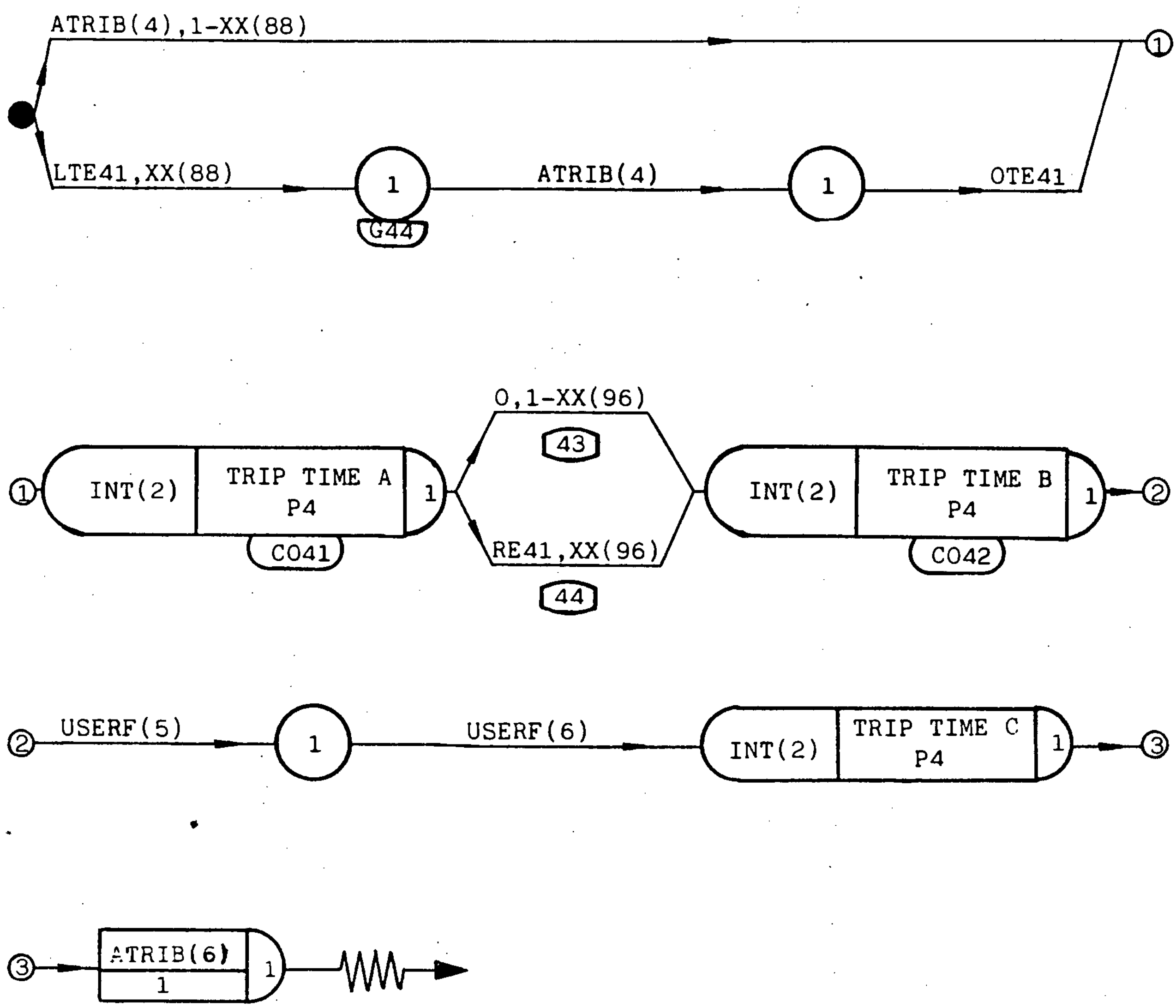

ATRIB(4),1-XX(88)
LTE41,XX(88)
1
G44
ATRIB(4)
1
OTE41
INT(2)
TRIP TIME A
P4
1
CO41
0,1-XX(96)
43
RE41,XX(96)
44
INT(2)
TRIP TIME B
P4
1
CO42
USERF(5)
1
USERF(6)
INT(2)
TRIP TIME C
P4
1
ATRIB(6)
1
1

Fig. D4 (CONTD)

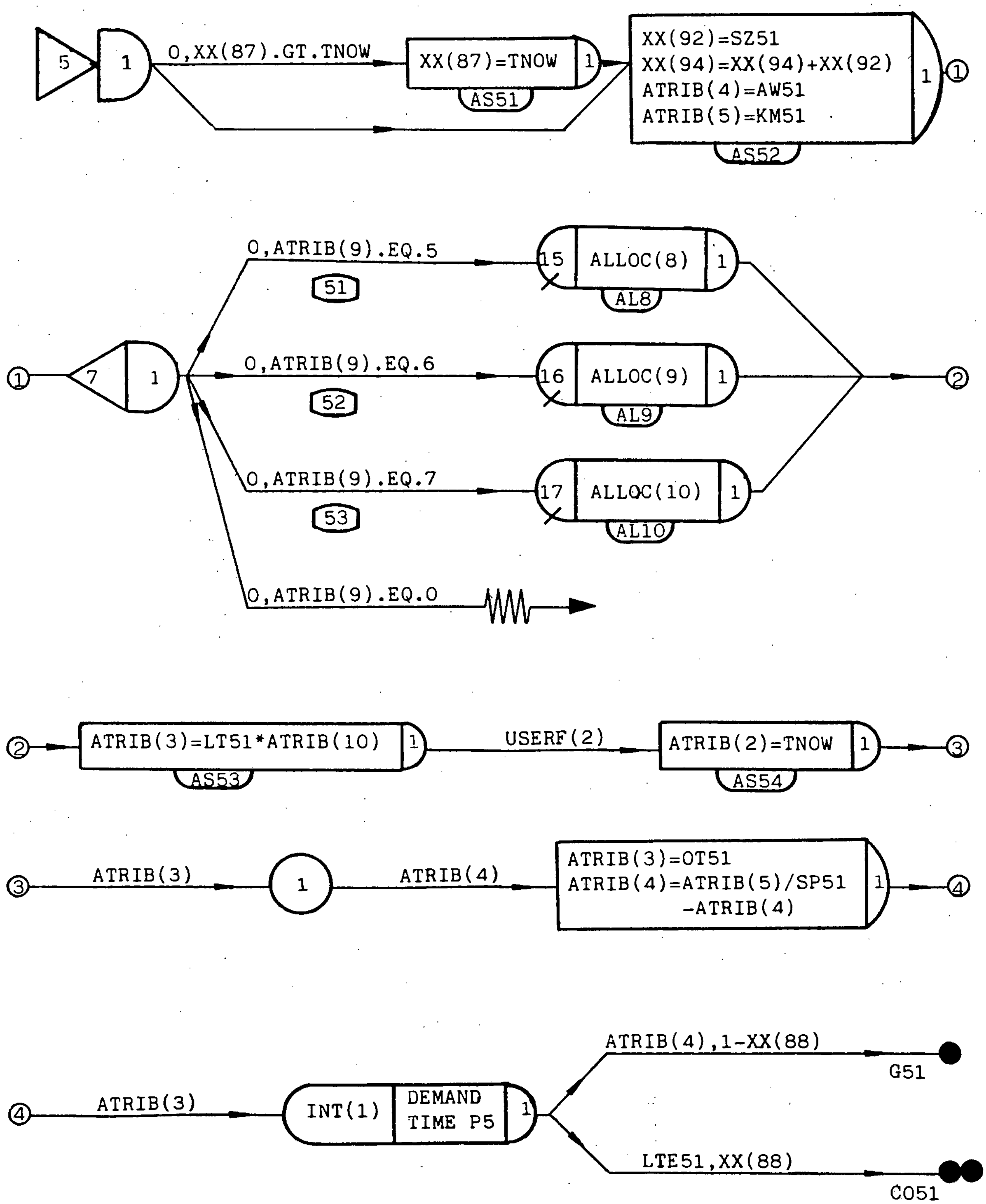


Fig. D5 - Network Model For Product 5 - General

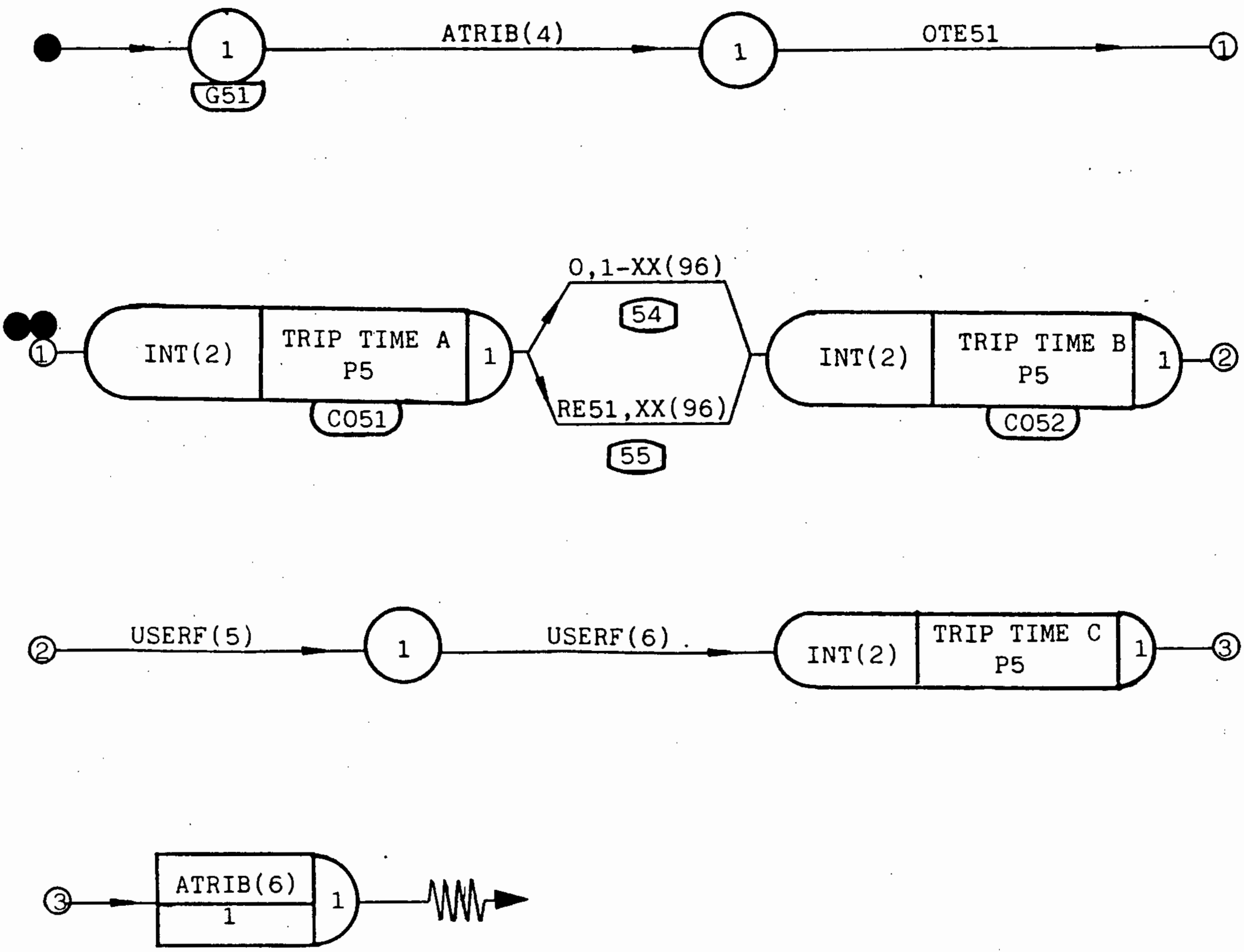

1
G51
ATRIB(4)
1
OTE51
1
1
INT(2)
TRIP TIME A
P5
1
C051
0,1-XX(96)
54
RE51,XX(96)
55
INT(2)
TRIP TIME B
P5
1
2
C052
2
USERF(5)
1
USERF(6)
INT(2)
TRIP TIME C
P5
1
3
3
ATRIB(6)
1
1

Fig. D5 (CONTD)

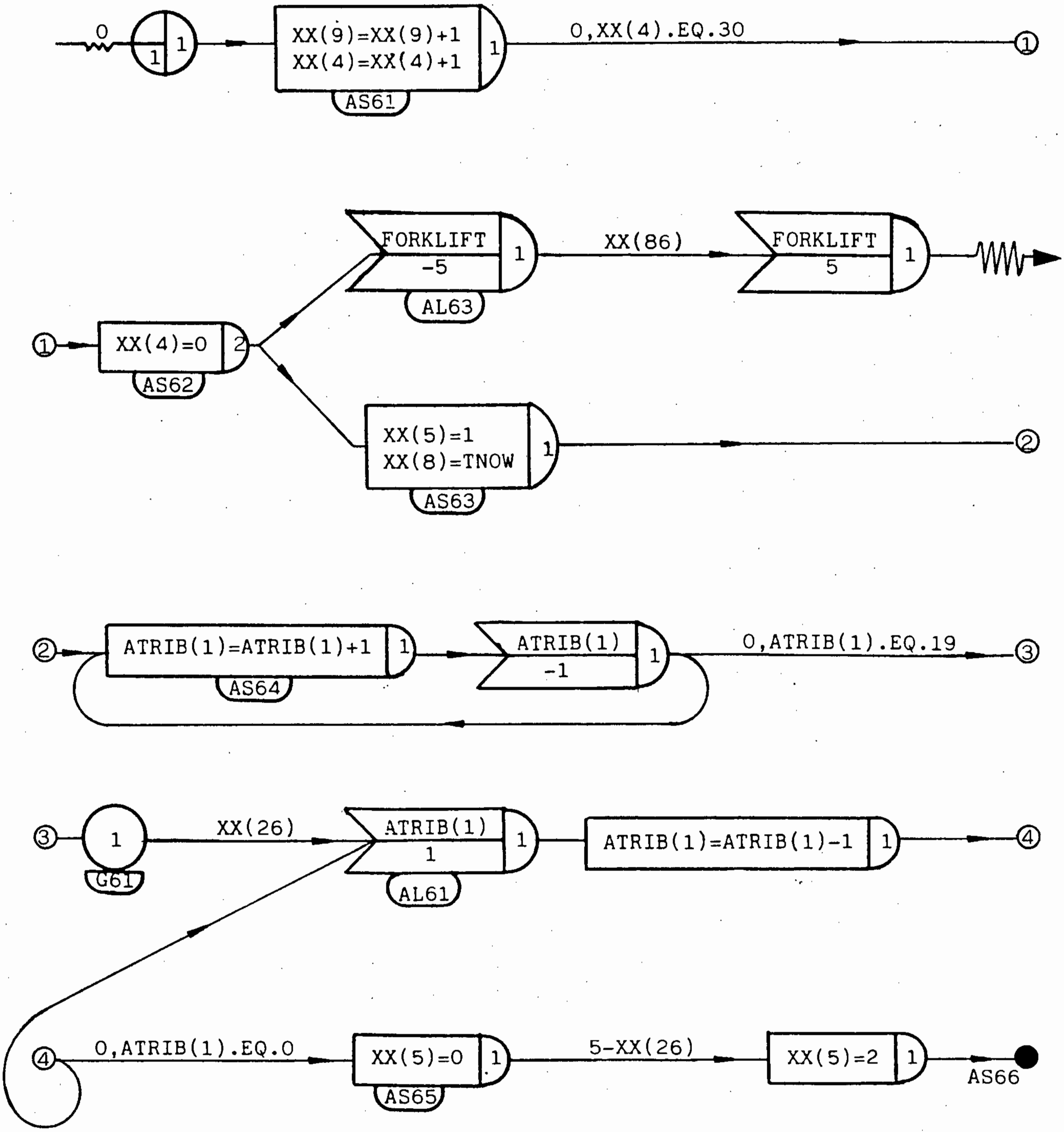


Fig. D6 - Network Model For Dayshift

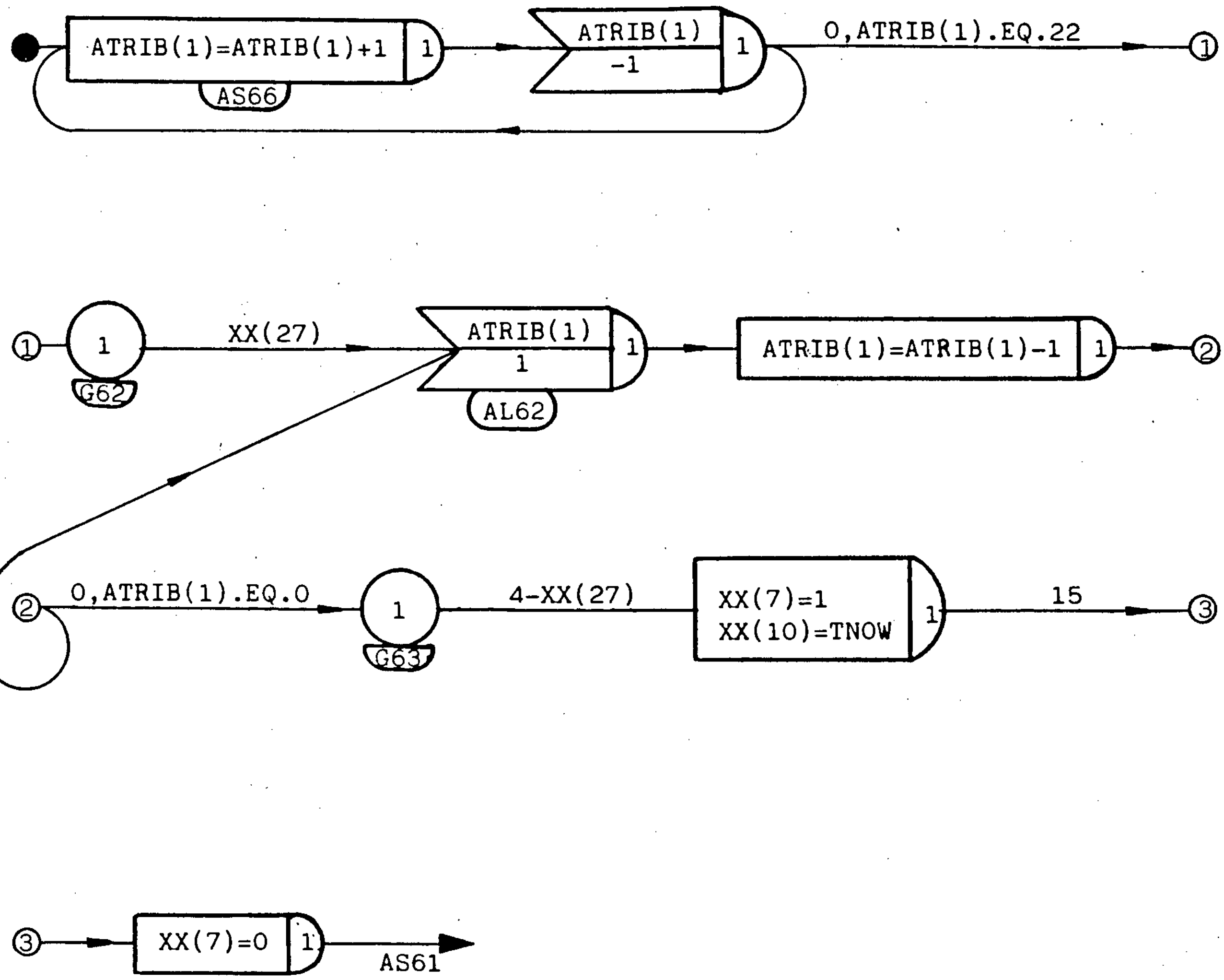

ATRIB(1)=ATRIB(1)+1
1
AS66
ATRIB(1)
-1
1
0,ATRIB(1).EQ.22
1
1
1
G62
XX(27)
ATRIB(1)
1
1
AL62
ATRIB(1)=ATRIB(1)-1
1
2
2
0,ATRIB(1).EQ.0
1
G63
4-XX(27)
XX(7)=1
XX(10)=TNOW
1
15
3
3
XX(7)=0
1
AS61

Fig. D6 (CONTD)

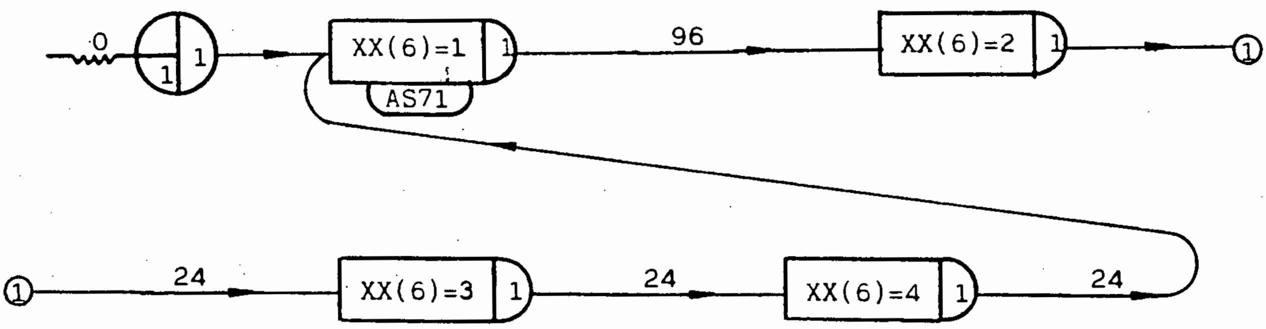


Fig. D7 - Network Model For Weekshift

APPENDIX E

SLAM II STATEMENTS FOR DISTRIBUTION MODEL

```
1000 GEN, N. KOENIG , THESIS ,04/19/88,,Y,Y,,N;
1010 LIMITS,17,10,100;
1020 ;
1030 ;   IN ALL FILES, PRIORITY IS GIVEN TO ENTITIES HAVING THE LOWEST
1040 ;   ATRIB(1) (I.E. THE DEMANDS CREATED THE MOST EARLY)
1050 ;
1060 PRIORITY/1,LVF(1)/2,LVF(1)/3,LVF(1)/4,LVF(1);
1070 PRIORITY/5,LVF(1)/6,LVF(1)/7,LVF(1)/8,LVF(1);
1080 PRIORITY/9,LVF(1)/10,LVF(1)/11,LVF(1),12,LVF(1);
1090 PRIORITY/13,LVF(1)/14,LVF(1)/15,LVF(1)/16,LVF(1);
1100 PRIORITY/17,LVF(1);
1110 ;
1120 ;   INITIALIZE THE LOAD CAPACITIES OF THE VEHICLES
1130 ;
1140 INTLC,XX(11)=2583;            TRUCK 412 - LOAD (KG)
1150 INTLC,XX(29)=15.2;                        FUEL CONSUMPTION (L/100KM)
1160 INTLC,XX(12)=2060;            TRUCK 414 - LOAD (KG)
1170 INTLC,XX(30)=17.6;                        FUEL CONSUMPTION (L/100KM)
1180 INTLC,XX(15)=6270;            TRUCK 467 - LOAD (KG)
1190 INTLC,XX(31)=28.0;                        FUEL CONSUMPTION (L/100KM)
1200 INTLC,XX(16)=6060;            TRUCK 469 - LOAD (KG)
1210 INTLC,XX(32)=26.7;                        FUEL CONSUMPTION (L/100KM)
1220 INTLC,XX(17)=11512;           TRUCK 471 - LOAD (KG)
1230 INTLC,XX(33)=35.3;                        FUEL CONSUMPTION (L/100KM)
1240 INTLC,XX(18)=13332;           TRUCK 472 - LOAD (KG)
1250 INTLC,XX(34)=30.0;                        FUEL CONSUMPTION (L/100KM)
1260 INTLC,XX(35)=45.0;            HORSE 305 - FUEL CONSUMPTION (L/100KM)
1270 INTLC,XX(36)=44.7;            HORSE 422 - FUEL CONSUMPTION (L/100KM)
1280 INTLC,XX(37)=55.6;            HORSE 423 - FUEL CONSUMPTION (L/100KM)
1290 INTLC,XX(38)=48.3;            HORSE 424 - FUEL CONSUMPTION (L/100KM)
1300 INTLC,XX(39)=52.4;            HORSE 426 - FUEL CONSUMPTION (L/100KM)
1310 INTLC,XX(40)=40.4;            HORSE 427 - FUEL CONSUMPTION (L/100KM)
1320 INTLC,XX(19)=20000;           TRAIL 318 - LOAD (KG)
1330 INTLC,XX(20)=23000;           TRAIL 430 - LOAD (KG)
1340 INTLC,XX(21)=20000;           TRAIL 431 - LOAD (KG)
1350 INTLC,XX(22)=22690;           TRAIL 438 - LOAD (KG)
1360 INTLC,XX(23)=20000;           TRAIL 441 - LOAD (KG)
1370 INTLC,XX(24)=11540;           TRAIL 449 - LOAD (KG)
1380 INTLC,XX(25)=22630;           TRAIL 453 - LOAD (KG)
1390 ;
1400 INTLC,XX(84)=40.;           MAXIMUM WAITING TIME FOR 1 BARREL ONLY (HR)
1410 INTLC,XX(83)=40.;           MAXIMUM WAITING TIME FOR I.P.V ONLY (HR)
1420 INTLC,XX(45)=48.;           TARGET DEMAND TIME (HR)
1430 INTLC,XX(44)=24.;           MAINTENANCE TIME FOR VEHICLES (HR)
1440 INTLC,XX(86)=5.;            MAINTENANCE TIME FOR FORKLIFTS (HR)
1450 INTLC,XX(50)=0.5;           TIME TO CHANGE HORSE/TRAILER (HR)
1460 INTLC,XX(49)=1.0;           TIME TO CHANGE BARREL/TRAILER (HR)
1470 INTLC,XX(43)=0.5;           TIME TO CHANGE CRADLE (HR)
1480 INTLC,XX(26)=0.353;         INSPECTION TIME FOR VEHICLES (HR)
1490 INTLC,XX(27)=0.67;          DURATION OF LUNCH TIME (HR)
1500 INTLC,XX(42)=0.5;           WASH TIME FOR AMMONIUM NITRATE TANKERS (HR)
1510 INTLC,XX(28)=80.;           REQUIRED % LOAD UTILIZATION ON VEHICLES
1520 INTLC,XX(63)=5000.;         FREQUENCY OF KM TRAVELLED BETWEEN MAINTENANCE
1530 INTLC,XX(97)=6.;            MAXIMUM OVERTIME PER TRIP (HR)
1540 INTLC,XX(96)=0.09720;       PROBABILITY OF REPAIR AFTER A TRIP
1550 INTLC,XX(88)=0.3241;        PROBABILITY OF TAKING EMPTIES
1560 INTLC,XX(87)=200000.,XX(93)=200000.;
1570 ;
1580 ;RECORD,TNOW,DAY,0,P,24,,,;
1590 ;VAR,USERF(13),D,NO. OF DRIVERS,,;
1600 ;VAR,USERF(14),A,NO. OF ASSISTANT,,;
1610 ;RECORD,TNOW,DAY,0,P,24,,,;
1620 ;VAR,USERF(15),1,NO. OF TRUCKS,,MAX(8);
1630 ;VAR,USERF(16),2,NO. OF HORSES,,MAX(8);
1640 ;VAR,USERF(17),3,NO. OF TRAILERS,,MAX(8);
1650 ;RECORD,TNOW,DAY,0,P,24,,,;
1660 ;VAR,USERF(9),T,NO. OF BARRELS,,MAX(20);
1670 ;RECORD,TNOW,DAY,0,P,24,,,;
1680 ;VAR,USERF(21),M,RES. MAINTAINED,,;
1690 ;
1700 TIMST,XX(51),KM TRAVELLED 412;
1710 TIMST,XX(64),FUEL CONSUMED;
1720 TIMST,XX(52),KM TRAVELLED 414;
1730 TIMST,XX(65),FUEL CONSUMED;
1740 TIMST,XX(53),KM TRAVELLED 467;
1750 TIMST,XX(66),FUEL CONSUMED;
1760 TIMST,XX(54),KM TRAVELLED 469;
1770 TIMST,XX(67),FUEL CONSUMED;
1780 TIMST,XX(55),KM TRAVELLED 471;
1790 TIMST,XX(68),FUEL CONSUMED;
1800 TIMST,XX(56),KM TRAVELLED 472;
1810 TIMST,XX(69),FUEL CONSUMED;
1820 TIMST,XX(57),KM TRAVELLED 305;
1830 TIMST,XX(70),FUEL CONSUMED;
1840 TIMST,XX(58),KM TRAVELLED 422;
1850 TIMST,XX(71),FUEL CONSUMED;
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```
1860 TIMST,XX(59),KM TRAVELLED 423;
1870 TIMST,XX(72),FUEL CONSUMED;
1880 TIMST,XX(60),KM TRAVELLED 424;
1890 TIMST,XX(73),FUEL CONSUMED;
1900 TIMST,XX(61),KM TRAVELLED 426;
1910 TIMST,XX(74),FUEL CONSUMED;
1920 TIMST,XX(62),KM TRAVELLED 427;
1930 TIMST,XX(75),FUEL CONSUMED;
1932 TIMST,USERF(19),TOTAL KM;
1934 TIMST,USERF(20),TOTAL FUEL;
1940 ;
1950 TIMST,XX(76),TRIPS 4 BARRELS;
1960 TIMST,XX(77),TRIPS 3 BARRELS;
1970 TIMST,XX(78),TRIPS 2 BARRELS;
1980 TIMST,XX(79),TRIPS 1 BARREL;
1990 TIMST,XX(80),TOTAL BARRELS;
2000 TIMST,USERF(9),NO. OF BARRELS;
2010 ;
2020 TIMST,USERF(13),NO. OF DRIVERS;
2030 TIMST,USERF(14),NO. OF ASSISTANT;
2040 TIMST,USERF(15),NO. OF TRUCKS;
2050 TIMST,USERF(16),NO. OF HORSES;
2060 TIMST,USERF(17),NO. OF TRAILERS;
2070 ;
2080 TIMST,XX(14),O.TIME WEEK END;
2090 TIMST,XX(13),O.TIME WEEK DAY;
2095 TIMST,USERF(18),TOTAL OVERTIME;
2100 TIMST,XX(98),TRIPS N.TIME;
2110 TIMST,XX(99),TRIPS WAITING;
2120 TIMST,XX(100),TRIPS O.TIME;
2130 TIMST,XX(9),NUMBER OF DAYS;
2140 ;
2150 NETWORK;
2160 ;                                                    SPECIFICATIONS
2170 ;                                         NO. DRIVERS  NO. ASSISTANTS  PRODUCT
2180        RESOURCE/1,TRUCK412(1),15;              1              1           5
2190        RESOURCE/2,TRUCK414(1),1;               1              2           1
2200        RESOURCE/3,TRUCK467(1),16;              1              2           5
2210        RESOURCE/4,TRUCK469(1),13;              1              1           4,5
2220        RESOURCE/5,TRUCK471(1),14;              1              1           4,5
2230        RESOURCE/6,TRUCK472(1),17,2;            1              2           5,2
2240        RESOURCE/7,HORSE305(1),3;               1              1           1
2250        RESOURCE/8,HORSE422(1),5;               1              1           2
2260        RESOURCE/9,HORSE423(1),6;               1              1           3
2270        RESOURCE/10,HORSE424(1),5,2,6;          1              1           2,1,3
2280        RESOURCE/11,HORSE426(1),2,6,5;          1              1           1,3,2
2290        RESOURCE/12,HORSE427(1),6,2;            1              1           3,1
2300        RESOURCE/13,TRAIL318(1),6;                                         3
2310        RESOURCE/14,TRAIL430(1),5;                                         2
2320        RESOURCE/15,TRAIL431(1),5;                                         2
2330        RESOURCE/16,TRAIL438(1),3;                                         1
2340        RESOUREC/17,TRAIL441(1),6;                                         3
2350        RESOURCE/18,TRAIL449(1),2;                                         1
2360        RESOURCE/19,TRAIL453(1),5;                                         2
2370        RESOURCE/20,GANTRY(1),7;       USED TO CHANGE BARRELS ON TRAILERS
2380        RESOURCE/21,FILLPT1(1),11;     LOADS CAUSTIC SODA & SULPHURIC ACID
2390        RESOURCE/22,FILLPT2(1),12;     LOADS HYDROCHLORIC ACID
2400        RESOURCE/23,FORKLIFT(5),4;
2410        RESOURCE/24,BARREL1(7),8;      BARREL1 APPLIES TO CAUSTIC SODA
2420        RESOURCE/25,BARREL2(6),9;      BARREL2 APPLIES TO SULPHURIC ACID
2430        RESOURCE/26,BARREL3(3),10;     BARREL3 APPLIES TO HYDROCHLORIC ACID
2440        RESOURCE/27,CRADLE2(2),12;     2 P.V CAPACITY
2450        RESOURCE/28,CRADLE3(2),12;     3 P.V CAPACITY
2460 ;
2470 ;      ***********************
2480 ;      * PRODUCT 1 - PLASTICS *
2490 ;      ***********************
2500 ;
2510 ;   1. CREATION OF DEMAND
2520 ;
2530        ENTER,1,1;
2540 ;
2550        ACT,,XX(93).GT.TNOW,AS11;
2560        ACT,,,AS12;
2570 ;
2580 AS11   ASSIGN,XX(93)=TNOW,1;
2590 AS12   ASSIGN,XX(90)=GAMA(9303.69,0.4590),
2600                XX(91)=XX(91)+XX(90),
2610                ATRIB(4)=GAMA(0.3418,4.4422),
2620                ATRIB(5)=RLOGN(108.0,30.99),
2630                XX(95)=USERF(1),1;
2640 ;
2650 ;   2. ALLOCATION OF DEMAND
2660 ;
2670        ACT/11,,XX(95).EQ.1.,AS13;                        SMALL D. P1
2680        ACT/12,,XX(95).EQ.2.,AS14;                        MEDIUM D. P1
2690        ACT/13,,XX(95).EQ.3.,AS15;                        LARGE D. P1
2700        ACT,,XX(95).EQ.4.,TE1;
```

```
;
AS13   ASSIGN,ATRIB(3)=GAMA(0.0004,0.7745)*ATRIB(10),1;
AL1    AWAIT(1),ALLOC(1),1;
       ACT,,,AS16 ;
;
AS14   ASSIGN,ATRIB(3)=GAMA(0.0004,0.7745)*ATRIB(10),1;
AL2    AWAIT(2),ALLOC(2),1;
       ACT,,,AS16 ;
;
AS15   ASSIGN,ATRIB(3)=GAMA(0.0004,0.7745)*ATRIB(10),1;
AL3    AWAIT(3),ALLOC(3),1;
;
;   3.  CHANGE HORSE/TRAILER AS NECESSARY
;
AS16   ASSIGN,XX(48)=USERF(4),1;
       ACT/14,XX(48),XX(48).GT.0.,G11;                     CHG HORSE 1
       ACT,,,G11;
;
;   4.  HOLD THE JOURNEY AS NECESSARY
;
G11    GOON,1;
       ACT,USERF(2);                                       TRIP WAIT/GO
       ASSIGN,ATRIB(2)=TNOW,1;
;
;   5.  JOURNEY
;
FORK   AWAIT(4),FORKLIFT/1,1;
       ACT,ATRIB(3);                                       LOAD P1
       FREE,FORKLIFT/1,1;
;
       ACT,ATRIB(4);                                       AWAY P1
;
       ASSIGN,ATRIB(4)=ATRIB(5)/RNORM(43.54,9.614) - ATRIB(4),
               ATRIB(3)=GAMA(0.0006,0.7135)*ATRIB(10),1;
       ACT,ATRIB(3);                                       OFFLOAD P1
       COLCT,INT(1),DEMAND TIME P1,,1;
       ACT,ATRIB(4);                                       BACK P1
       COLCT,INT(2),TRIP TIME A P1,,1;
;
;   6.  REPAIR VEHICLE AS NECESSARY
;
       ACT/15,,1.-XX(96),C011;                             NO REP VEH 1
;
       ACT/16,GAMA(1.1912,1.7682),XX(96),C011;             REP VEH 1
C011   COLCT,INT(2),TRIP TIME B P1,,1;
;
;   7.  UPDATE KM TRAVELLED, FUEL CONSUMED & OVERTIME.     MAINTENANCE
;
       ACT,USERF(5);
       GOON,1;
       ACT,USERF(6);
       COLCT,INT(2),TRIP TIME C P1,,1;
;
;   8.  FREE RESOURCES & TERMINATE
;
       ASSIGN,XX(1)=ATRIB(6)*ATRIB(7),1;
;
       FREE,ATRIB(6)/1,1;
       ACT,,ATRIB(7).EQ.0.,TE1;
       ACT,,,FR11;
FR11   FREE,ATRIB(7)/1,1;
TE1    TERM;
;
;      *********************************
;      * PRODUCT 2 - AMMONIUM NITRATE *
;      *********************************
;
;   1.  CREATION OF DEMAND
;
       ENTER,2,1;
;
AS21   ASSIGN,ATRIB(3)=RNORM(0.6148,0.1045),
               ATRIB(4)=RNORM(0.9905,0.1093),
               ATRIB(5)=RNORM(94.22,5.239),1;
;
;   2.  ALLOCATION OF DEMAND
;
AL4    AWAIT(5),ALLOC(4),1;
;
;   3.  CHANGE HORSE/TRAILER AS NECESSARY
;
       ASSIGN,XX(81)=USERF(8),1;
       ACT/21,XX(81),XX(81).NE.0.,G21;                     CHG HORSE 2
       ACT,,,G21;
;
```

```
;     4.  HOLD THE JOURNEY AS NECESSARY
;
G21       GOON, 1;
          ACT, USERF(2);                                          TRIP WAIT/GO
          ASSIGN, ATRIB(2)=TNOW, 1;
;
;     5.  JOURNEY
;
          ACT, ATRIB(4);                                          AWAY P2
          GOON, 1;
;
          ACT, ATRIB(3);                                          LOAD P2
;
          ASSIGN, ATRIB(4)=ATRIB(5)/RNORM(49.0,5.294) - ATRIB(4), 1;
          ACT, ATRIB(4);                                          BACK P2
          GOON, 1;
;
          ACT, RNORM(0.8190,0.1132);                              OFFLOAD P2
          COLCT, INT(1), DEMAND TIME P2,, 1;
          COLCT, INT(2), TRIP TIME A P2,, 1;
;
;     6.  REPAIR VEHICLE AS NECESSARY
;
          ACT/22, XX(42), XX(6).EQ.2.AND.XX(5).EQ.2., G22;        WASH VEH 2
          ACT,,, G22;
G22       GOON, 1;
          ACT/23, GAMA(1.1912,1.7682), XX(96), CO21;              REP VEH 2
          ACT/24,, 1.-XX(96), CO21;                               NO REP VEH 2
CO21      COLCT, INT(2), TRIP TIME B P2,, 1;
;
;     7.  UPDATE KM TRAVELLED, FUEL CONSUMED & OVERTIME.          MAINTENANCE
;
          ACT, USERF(5);
          GOON, 1;
          ACT, USERF(6);
          COLCT, INT(2), TRIP TIME C P2,, 1;
;
;     8.  FREE RESOURCES & TERMINATE
;
          ASSIGN, XX(2)=ATRIB(6)*ATRIB(7), 1;
          FREE, ATRIB(6)/1, 1;
          FREE, ATRIB(7)/1, 1;
          TERM;
;
;         ***********************
;         * PRODUCT 3 - BARRELS *
;         ***********************
;
;     1.  CREATION OF DEMAND
;
          ENTER, 3, 1;
;
          ASSIGN, ATRIB(1)=TNOW, 1;
;
          ACT/30,, 0.5830, AS31;                                  BARREL 1
          ACT/31,, 0.2676, AS32;                                  BARREL 2
          ACT/32,, 0.1494, AS33;                                  BARREL 3
;
AS31      ASSIGN, ATRIB(3)=7., 1;
          ACT,,, AS34;
;
AS32      ASSIGN, ATRIB(3)=8., 1;
          ACT,,, AS34;
;
AS33      ASSIGN, ATRIB(3)=9., 1;
;
;     2.  ALLOCATION OF DEMAND
;
AS34      ASSIGN, ATRIB(3)=USERF(3), 1;
          ACT,, ATRIB(3).EQ.1., TE1;
          ACT,, ATRIB(3).NE.1., AL5;
AL5       AWAIT(6), ALLOC(5), 1;
;
;     3.  CHANGE BARREL & HORSE/TRAILER AS NECESSARY
;
          ASSIGN, XX(41)=USERF(12),
                  XX(85)=RLOGN(0.3877,0.1073),
                  ATRIB(4)=GAMA(0.3418,4.4422),
                  ATRIB(5)=RLOGN(138.78,74.74), 1;
;
          ACT,, XX(41).EQ.1., GTRY;
          ACT,, XX(41).EQ.0., AS35;
;
GTRY      AWAIT(7), GANTRY/1, 1;
          ACT/33, XX(49);                                         CHG BARREL
```

```
             FREE, GANTRY/1, 1;
;
AS35         ASSIGN, XX(82)=USERF(11), 1;
             ACT/34, XX(82), XX(82). NE. 0. , G31;                CHG HORSE 3
             ACT, , , G31;
;
G31          GOON, 1;
             ACT, , ATRIB(6). EQ. 13, AS36;
             ACT, , ATRIB(6). EQ. 17, AS37;
AS36         ASSIGN, XX(46)=ATRIB(3)*ATRIB(6), 1;
             ACT, , , AS38;
AS37         ASSIGN, XX(47)=ATRIB(3)*ATRIB(6), 1;
;
AS38         ASSIGN, ATRIB(3)=ATRIB(8)+ATRIB(9)+ATRIB(10),
                     ATRIB(3)=XX(85)*ATRIB(3), 1;
;
;     4.     HOLD THE JOURNEY AS NECESSARY
;
             ACT, USERF(2);                                        TRIP WAIT/GO
             ASSIGN, ATRIB(2)=TNOW, 1;
;
;     5.     JOURNEY
;
            . ACT/35, , ATRIB(8). EQ. 0. AND. ATRIB(9). EQ. 0, BAR3;   FILLPT 2 ONLY
             ACT/36, , ATRIB(10). EQ. 0. , G32;                    FILLPT 1 ONLY
             ACT/37, , , BAR3;                                     BOTH FILLPTS
;
G32          GOON, 1;
             ACT, , ATRIB(8). EQ. 0. , BAR2;
             ACT, , , BAR1;
BAR1         AWAIT(8), BARREL1/ATRIB(8), 1;
             ACT, , ATRIB(9). EQ. 0. , FPT1;
             ACT, , , BAR2;
;
BAR2         AWAIT(9), BARREL2/ATRIB(9), 1;
FPT1         AWAIT(11), FILLPT1/1, 1;
             ASSIGN, ATRIB(3)=ATRIB(8)+ATRIB(9),
                     ATRIB(3)=XX(85)*ATRIB(3), 1;
             ACT, ATRIB(3);
             FREE, FILLPT1/1, 1;
             ACT, , , G33;
;
BAR3         AWAIT(10), BARREL3/ATRIB(10), 1;
FPT2         AWAIT(12), FILLPT2/1, 1;
             ASSIGN, ATRIB(3)=XX(85)*ATRIB(10), 1;
             ACT, ATRIB(3);
             FREE, FILLPT2/1, 1;
             ACT, , ATRIB(8). EQ. 0. AND. ATRIB(9). EQ. 0, G33;
             ACT, , , G32;
;
G33          GOON, 1;
             ACT, ATRIB(4);                                        AWAY P3
;
             ASSIGN, ATRIB(3)=ATRIB(8)+ATRIB(9)+ATRIB(10),
                     ATRIB(3)=RLOGN(0.4118, 0.1157)*ATRIB(3), 1;
             ACT, ATRIB(3);                                        OFFLOAD P3
             COLCT, INT(1), DEMAND TIME P3, , 1;
;
             ASSIGN, ATRIB(4)=ATRIB(5)/RNORM(50.24, 5.606) - ATRIB(4), 1;
             ACT, ATRIB(4);                                        BACK P3
             COLCT, INT(2), TRIP TIME A P3, , 1;
;
;     6.     REPAIR VEHICLE AS NECESSARY
;
             ACT/38, , 1. -XX(96), CO31;                           NO REP VEH 3
             ACT/39, GAMA(1.1912, 1.7682), XX(96), CO31;           REP VEH 3
CO31         COLCT, INT(2), TRIP TIME B P3, , 1;
;
;     7.     UPDATE KM TRAVELLED, FUEL CONSUMED & OVERTIME.        MAINTENANCE
;
             ACT, USERF(5);
             GOON, 1;
             ACT, USERF(6);
             COLCT, INT(2), TRIP TIME C P3, , 1;
;
;     8.     FREE RESOURCES & TERMINATE
;
AS39         ASSIGN, XX(3)=ATRIB(6)*ATRIB(7), 1;
             FREE, ATRIB(6)/1, 1;
             FREE, ATRIB(7)/1, 1;
;
             ACT, , ATRIB(8). EQ. 0. , G34;
             ACT, , , FR31;
FR31         FREE, BARREL1/ATRIB(8), 1;
G34          GOON, 1;
```

```
;
           ACT,,ATRIB(9).EQ.0.,G35;
           ACT,,,FR32;
FR32       FREE,BARREL2/ATRIB(9),1;
G35        GOON,1;
;
           ACT,,ATRIB(10).EQ.0.,TE1;
           ACT,,,FR33;
FR33       FREE,BARREL3/ATRIB(10),1;
           TERM;
;
;          *************************
;          * PRODUCT 4 - LARGE P.V *
;          *************************
;
;     1.   CREATION OF DEMAND
;
           ENTER,4,1;
;
AS41       ASSIGN,ATRIB(1)=TNOW,
                  ATRIB(4)=GAMA(0.3418,4.4422),
                  ATRIB(5)=RLOGN(115.8,46.68),
                  ATRIB(8)=40.,
                  ATRIB(9)=USERF(7),1;
;
;     2.   ALLOCATION OF DEMAND
;
           ACT,,ATRIB(9).EQ.1.,AL6;
           ACT,,ATRIB(9).EQ.2.,AL7;
           ACT,,ATRIB(9).EQ.0.,TE1;
;
AL6        AWAIT(13),ALLOC(6),1;
           ACT,,,G41;
AL7        AWAIT(14),ALLOC(7),1;
;
;     3.   CHANGE CRADLE AS NECESSARY
;
G41        ASSIGN,XX(89)=USERF(10),1;
           ACT/41,XX(89),XX(89).NE.0.,G42;                       CHG CRADLE
           ACT,,XX(89).EQ.0.,G42;
G42        GOON,1;
           ACT/42,,ATRIB(8).EQ.50.,AS53;                         P5 WITH VEH 4
           ACT,,ATRIB(8).EQ.40.,G43;
G43        ASSIGN,ATRIB(3)=RLOGN(0.1886,0.04945)*ATRIB(10),1;
;
;     4.   HOLD THE JOURNEY AS NECESSARY
;
           ACT,USERF(2);                                         TRIP WAIT/GO
           ASSIGN,ATRIB(2)=TNOW,1;

;
;     5.   JOURNEY
;
           ACT,ATRIB(3);                                         LOAD P4
           GOON,1;
           ACT,ATRIB(4);                                         AWAY P4
           ASSIGN,ATRIB(3)=RLOGN(0.1421,0.04442)*ATRIB(10),
                  ATRIB(4)=ATRIB(5)/RLOGN(50.3,11.01) - ATRIB(4),1;
           ACT,ATRIB(3);                                         OFFLOAD P4
           COLCT,INT(1),DEMAND TIME P4,,1;
           ACT,ATRIB(4),1.-XX(88),CO41;                          BACK P4
           ACT,GAMA(0.1737,2.8018),XX(88),G44;                   LOAD E  P4
G44        GOON,1;
           ACT,ATRIB(4);                                         BACK E P4
           GOON,1;
           ACT,GAMA(0.1107,3.4167);                              OFFLOAD E P4
CO41       COLCT,INT(2),TRIP TIME A P4,,1;
;
;     6.   REPAIR VEHICLE AS NECESSARY
;
           ACT/43,,1.-XX(96),CO42;                               NO REP VEH 4
           ACT/44,GAMA(1.1912,1.7682),XX(96),CO42;               REP VEH 4
CO42       COLCT,INT(2),TRIP TIME B P4,,1;
;
;     7.   UPDATE KM TRAVELLED, FUEL CONSUMED & OVERTIME.        MAINTENANCE
;
           ACT,USERF(5);
           GOON,1;
           ACT,USERF(6);
           COLCT,INT(2),TRIP TIME C P4,,1;
;
;     8.   FREE RESOURCES & TERMINATE
;
           FREE,ATRIB(6)/1,1;
           TERM;
```

```
;
;        ************************
;        * PRODUCT 5 - GENERAL *
;        ************************
;
;    1.  CREATION OF DEMAND
;
         ENTER,5,1;
;
         ACT,,XX(87).GT.TNOW,AS51;
         ACT,,,AS52;
AS51     ASSIGN,XX(87)=TNOW,1;
AS52     ASSIGN,XX(92)=GAMA(2831.81,0.76234),
                 XX(94)=XX(94)+XX(92),
                 ATRIB(4)=GAMA(0.3418,4.4422),
                 ATRIB(5)=RLOGN(111.3,33.4),1;
;
;    2.  ALLOCATION OF DEMAND
;
         EVENT,7,1;
         ACT/51,,ATRIB(9).EQ.5.,AL8;                          SMALL D. P5
         ACT/52,,ATRIB(9).EQ.6.,AL9;                          MEDIUM D. P5
         ACT/53,,ATRIB(9).EQ.7.,AL10;                         LARGE D. P5
         ACT,,ATRIB(9).EQ.0.,TE1;
;
AL8      AWAIT(15),ALLOC(8),1;
         ACT,,,AS53;
AL9      AWAIT(16),ALLOC(9),1;
         ACT,,,AS53;
AL10     AWAIT(17),ALLOC(10),1;
AS53     ASSIGN,ATRIB(3)=GAMA(0.0003,1.1377)*ATRIB(10),1;
;
;    4.  HOLD JOURNEY AS NECESSARY
;
         ACT,USERF(2);                                        TRIP WAIT GO
AS54     ASSIGN,ATRIB(2)=TNOW,1;
;
;    5.  JOURNEY
;
         ACT,ATRIB(3);                                        LOAD P5
         GOON,1;
;
         ACT,ATRIB(4);                                        AWAY P5
;
         ASSIGN,ATRIB(3)=GAMA(0.0002,1.143),
                 ATRIB(4)=ATRIB(5)/RLOGN(46.86,9.685)  ATRIB(4),1;
         ACT,ATRIB(3);                                        OFFLOAD P5
         COLCT,INT(1),DEMAND TIME P5,,1;
;
         ACT,ATRIB(4),1.-XX(88),CO51;                         BACK P5
         ACT,GAMA(0.2932,2.5868),XX(88),G51;                  LOAD E P5
;
G51      GOON,1;
         ACT,ATRIB(4);                                        BACK E P5
;
         GOON,1;
         ACT,GAMA(0.4390,1.8152);                             OFFLOAD E P5
CO51     COLCT,INT(2),TRIP TIME A P5,,1;
;
;    6.  REPAIR VEHICLE AS NECESSARY
;
         ACT/54,,1.-XX(96),CO52;                              NO REP VEH 5
         ACT/55,GAMA(1.1912,1.7682),XX(96),CO52;              REP VEH 5
CO52     COLCT,INT(2),TRIP TIME B P5,,1;
;
;    7.  UPDATE KM TRAVELLED, FUEL CONSUMED & OVERTIME.       MAINTENANCE
;
         ACT,USERF(5);
         GOON,1;
         ACT,USERF(6);
         COLCT,INT(2),TRIP TIME C P5,,1;
;
;    8.  FREE RESOURCES & TERMINATE
;
FR51     FREE,ATRIB(6)/1,1;
         TERM;
;
;        *************
;        * DAY SHIFT *
;        *************
;
         CREATE,0,0,,1,1;
;
AS61     ASSIGN,XX(7)=XX(7)+1.,
                XX(4)=XX(4)+1.,1;
```

```
        ACT,,XX(4).EQ.30.,AS62;
        ACT,,,AS63;
AS62    ASSIGN,XX(4)=0.,2;
        ACT,,,AL63;
        ACT,,,AS63;
;
;  1.  INSPECTION OF VEHICLES
;
AS63    ASSIGN,XX(5)=1,
               XX(8)=TNOW,1;
AS64    ASSIGN,ATRIB(1)=ATRIB(1)+1.,1;
        ALTER,ATRIB(1)/-1,1;
        ACT,,ATRIB(1).EQ.19,G61;
        ACT,,,AS64;
G61     GOON,1;
        ACT,XX(26),,AL61;                         7.00 A.M - 7.30 A.M
AL61    ALTER,ATRIB(1)/1,1;
        ASSIGN,ATRIB(1)=ATRIB(1)-1.,1;
        ACT,,ATRIB(1).EQ.0.,AS65;
        ACT,,,AL61;
;
AS65    ASSIGN,XX(5)=0.,1;
        ACT,5.-XX(26);                            7.30 A.M - 12.00 P.M
        ASSIGN,XX(5)=2.,1;
;
;  2.  LUNCH TIME
;
AS66    ASSIGN,ATRIB(1)=ATRIB(1)+1.,1;
        ALTER,ATRIB(1)/-1,1;
        ACT,,ATRIB(1).EQ.22.,G62;
        ACT,,,AS66;
G62     GOON,1;
;
        ACT,XX(27),,AL62;                         12.00 P.M - 12.45 P.M
;
AL62    ALTER,ATRIB(1)/1,1;
        ASSIGN,ATRIB(1)=ATRIB(1)-1,1;
        ACT,,ATRIB(1).EQ.0.,G63;
        ACT,,,AL62;
;
G63     GOON,1;
        ACT,4-XX(27);                             12.45 P.M - 4.00 P.M
        ASSIGN,XX(7)=1.,
               XX(10)=TNOW,1;
        ACT,15;                                   4.00 P.M - 7.00 A.M
        ASSIGN,XX(7)=0.,1;
        ACT,,,AS61;
;
;  3.  MAINTENANCE OF FORKLIFTS
;
AL63    ALTER,FORKLIFT/-5,1;
        ACT,XX(86);
        ALTER,FORKLIFT/5,1;
        ACT,,,TE1;
;
;       *************
;       * WEEKSHIFT *
;       *************
;
        CREATE,0,0,,1,1;
;
AS71    ASSIGN,XX(6)=1.,1;
        ACT,96;                                   MONDAY TO THURSDAY
        ASSIGN,XX(6)=2.,1;
        ACT,24;                                   FRIDAY
        ASSIGN,XX(6)=3.,1;
        ACT,24;                                   SATURDAY
        ASSIGN,XX(6)=4.,1;
        ACT,24,,AS71;                             SUNDAY
;
        END;
;
INIT,0,4344;         SPECIFY THE BEGINNING & ENDING OF THE SIMULATION
MONTR,CLEAR,2880;
;
FIN;
```

APPENDIX F

FORTRAN PROGRAM FOR DISTRIBUTION MODEL

```
      DIMENSION NSET(8000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(8000)
      EQUIVALENCE(NSET(1),QSET(1))
      NNSET = 8000
      NCRDR = 5
      NPRNT = 6
      NTAPE = 7
      CALL SLAM
      STOP
      END


*      ****************
       SUBROUTINE INTLC
*      ****************

       CALL SCHDL(1,0.,A)

       RETURN

       END


*     ******************
      SUBROUTINE EVENT(I)
*     ******************

      IF ( I .EQ. 1 ) CALL ORDERN
      IF ( I .EQ. 2 ) CALL ORDER1
      IF ( I .EQ. 3 ) CALL ORDER2
      IF ( I .EQ. 4 ) CALL ORDER3
      IF ( I .EQ. 5 ) CALL ORDER4
      IF ( I .EQ. 6 ) CALL ORDER5
      IF ( I .EQ. 7 ) CALL TEST1

      RETURN

      END


*     ****************
      SUBROUTINE ORDERN
*     ****************

      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)

*  A1 = TIME AT WHICH THE ORDERS ARE PLACED
*  A2 = TIME DURING WHICH ORDERS ARE RECEIVED
*  A3 = NUMBER OF ORDERS PLACED

*  IF IT IS FRIDAY, SCHEDULE THE NEXT ORDERS FOR MONDAY
      IF (XX(6).EQ.2.) CALL SCHDL(1,72.,A)

*  ELSE, SCHEDULE FOR TOMORROW
      IF (XX(6).NE.2.) CALL SCHDL(1,24.,A)

*  ORDERS ARE RECEIVED BETWEEN 7 A.M & 5 P.M
      A2 = 10.

*  GENERATE THE ORDERS FOR PRODUCT 1 & SCHEDULE THEM DURING THE DAY
      A3 = GAMA(1.334,6.3625,1)
      A3 = NINT(A3)

      DO 5 I = 1,A3
      A1 = UNFRM(0.,A2,1)
    5 CALL SCHDL(2,A1,A)

*  GENERATE THE ORDERS FOR PRODUCT 2 & SCHEDULE THEM DURING THE DAY
      A3 = GAMA(0.6549,5.6533,1)
      A3 = NINT(A3)

      DO 6 I = 1,A3
      A1 = UNFRM(0.,A2,1)
    6 CALL SCHDL(3,A1,A)

*  GENERATE THE ORDERS FOR PRODUCT 3 & SCHEDULE THEM DURING THE DAY
      A3 = GAMA(0.7789,5.092,1)
      A3 = NINT(A3)

      DO 7 I = 1,A3
      A1 = UNFRM(0.,A2,1)
    7 CALL SCHDL(4,A1,A)

```

```
*   GENERATE THE ORDERS FOR PRODUCT 4 & SCHEDULE THEM DURING THE DAY
        A3 = GAMA(0.6860,5.0115,1)
        A3 = NINT(A3)

        DO 8 I = 1,A3
        A1 = UNFRM(0.,A2,1)
8       CALL SCHDL(5,A1,A)

*   GENERATE THE ORDERS FOR PRODUCT 5 & SCHEDULE THEM DURING THE DAY
        A3 = GAMA(2.9366,2.6346,1)
        A3 = NINT(A3)

        DO 9 I = 1,A3
        A1 = UNFRM(0.,A2,1)
9       CALL SCHDL(6,A1,A)

        RETURN

        END


*       *****************
        SUBROUTINE ORDER1
*       *****************

        COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
       &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)

        ATRIB(1) = TNOW
        ATRIB(8) = 10.

        CALL ENTER(1,ATRIB)

        RETURN

        END



*       *****************
        SUBROUTINE ORDER2
*       *****************

        COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
       &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)

        ATRIB(1) = TNOW
        ATRIB(8) = 20.

        CALL ENTER(2,ATRIB)

        RETURN

        END


*       *****************
        SUBROUTINE ORDER3
*       *****************

        COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
       &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)

*   A3 = SIZE OF ORDER (NUMBER OF BARRELS)

        A3 = GAMA(0.5398,4.067,1)
        J3 = NINT(A3)
        DO 3 I = 1,J3
3       CALL ENTER(3,ATRIB)

        RETURN

        END


*       *****************
        SUBROUTINE ORDER4
*       *****************

        COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
       &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)

*   A4 = SIZE OF ORDER (NUMBER OF P.V)

        A4 = GAMA(1.1590,2.2499,1)
        J4 = NINT(A4)
```

```
      DO 4 I = 1, J4
4     CALL ENTER(4, ATRIB)

      RETURN

      END


*     ****************
      SUBROUTINE ORDER5
*     ****************

      COMMON/SCOM1/ATRIB(100), DD(100), DDL(100), DTNOW, II, MFA, MSTOP, NCLNR
     &, NCRDR, NPRNT, NNRUN, NNSET, NTAPE, SS(100), SSL(100), TNEXT, TNOW, XX(100)

      ATRIB(1) = TNOW
      ATRIB(8) = 50.

      CALL ENTER(5, ATRIB)

      RETURN

      END



*     *******************************
      SUBROUTINE ALLOC ( IALL , IFLAG )
*     *******************************

      COMMON/SCOM1/ATRIB(100), DD(100), DDL(100), DTNOW, II, MFA, MSTOP, NCLNR
     &, NCRDR, NPRNT, NNRUN, NNSET, NTAPE, SS(100), SSL(100), TNEXT, TNOW, XX(100)

      IFLAG = 0

* NO ALLOCATION TO BE MADE BETWEEN 4 P.M AND 7 A.M

      IF (XX(7).EQ.1.) RETURN

      IF ( IALL .EQ. 1 ) THEN

*       ALLOCATION 1 - VEHICLE FOR VERY SMALL DEMAND : PRODUCT 1-PLASTICS
*       ------------------------------------------------------------------

          IF ( NNRSC(2).GT.0 ) THEN
             CALL SEIZE ( 2 , 1 )
             ATRIB(6) = 2.
             ATRIB(7) = 0
             IFLAG = 1
             RETURN

          ELSE
             IFLAG = 0

          ENDIF
          RETURN


      ELSE IF ( IALL .EQ. 2 ) THEN

*     ALLOCATION 2 - VEHICLE FOR MEDIUM DEMAND : PRODUCT 1-PLASTICS
*     --------------------------------------------------------------

       IF (NNRSC(6).LE.0.AND.NNRSC(18).LE.0) RETURN
       IF (NNRSC(6).GT.0) THEN
          CALL SEIZE (6,1)
          ATRIB(6) = 6
          ATRIB(7) = 0
          IFLAG = 1
          RETURN

       ELSE IF (NNRSC(10).GT.0.AND.XX(1).EQ.180) THEN
               CALL SEIZE ( 18 , 1 )
               CALL SEIZE ( 10 , 1 )
               ATRIB(6) = 18
               ATRIB(7) = 10
               IFLAG = 1
               RETURN

       ELSE IF ( NNRSC(11).GT.0.AND.XX(1).EQ.198 ) THEN
               CALL SEIZE ( 18 , 1 )
               CALL SEIZE ( 11 , 1 )
               ATRIB(6) = 18
               ATRIB(7) = 11
               IFLAG = 1
               RETURN
```

```

      ELSE IF ( NNRSC(12).GT.0.AND.XX(1).EQ.216 ) THEN
               CALL SEIZE ( 18 , 1 )
               CALL SEIZE ( 12 , 1 )
               ATRIB(6) = 18
               ATRIB(7) = 12
               IFLAG = 1
               RETURN

      ELSE IF (NNRSC(10).GT.0) THEN
               CALL SEIZE ( 18 , 1 )
               CALL SEIZE ( 10 , 1 )
               ATRIB(6) = 18
               ATRIB(7) = 10
               IFLAG = 1
               RETURN

      ELSE IF ( NNRSC(11).GT.0 ) THEN
               CALL SEIZE ( 18 , 1 )
               CALL SEIZE ( 11 , 1 )
               ATRIB(6) = 18
               ATRIB(7) = 11
               IFLAG = 1
               RETURN

      ELSE IF ( NNRSC(12).GT.0 ) THEN
               CALL SEIZE ( 18 , 1 )
               CALL SEIZE ( 12 , 1 )
               ATRIB(6) = 18
               ATRIB(7) = 12
               IFLAG = 1
               RETURN

      ELSE
               IFLAG = 0

     ENDIF
     RETURN

     ELSE IF ( IALL .EQ. 3 ) THEN

*    ALLOCATION 3 - VEHICLE FOR LARGE DEMAND - PRODUCT 1-PLASTICS
*    ------------------------------------------------------------

            IF (NNRSC(16).GT.0.AND.NNRSC(7).GT.0) THEN
                CALL SEIZE ( 16 , 1 )
                CALL SEIZE ( 7 , 1 )
                ATRIB(6) = 16
                ATRIB(7) = 7
                IFLAG = 1
                RETURN

            ELSE
                IFLAG = 0

            ENDIF
            RETURN


     ELSE IF ( IALL .EQ. 4 ) THEN

*    ALLOCATION 4 - VEHICLE FOR PRODUCT 2-AMMONIUM NITRATE
*    -----------------------------------------------------

             IF (NNRSC(8).LE.0.AND.NNRSC(10).LE.0.AND.NNRSC(11).LE.0)RE
   &            TURN
             IF (NNRSC(14).LE.0.AND.NNRSC(15).LE.0.AND.NNRSC(19).LE.0)R
   &            ETURN

             IF ( NNRSC(8).GT.0.AND.NNRSC(14).GT.0.AND.XX(2).EQ.112) TH
   &            EN
                CALL SEIZE ( 8 , 1 )
                CALL SEIZE ( 14 , 1 )
                ATRIB(6) = 14
                ATRIB(7) = 8
                IFLAG = 1
                RETURN

             ELSE IF ( NNRSC(8).GT.0.AND.NNRSC(15).GT.0.AND.XX(2).EQ.12
   &                  0) THEN
                      CALL SEIZE ( 8 , 1 )
                      CALL SEIZE ( 15 , 1 )
                      ATRIB(6) = 15
                      ATRIB(7) = 8
```

```
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(10). GT. O. AND. NNRSC(14). GT. O. AND. XX(2). EQ. 1
     &              40) THEN
                    CALL SEIZE ( 10 , 1 )
                    CALL SEIZE ( 14 , 1 )
                    ATRIB(6) = 14
                    ATRIB(7) = 10
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(10). GT. O. AND. NNRSC(15). GT. O. AND. XX(2). EQ. 1
     &              50) THEN
                    CALL SEIZE ( 10 , 1 )
                    CALL SEIZE ( 15 , 1 )
                    ATRIB(6) = 15
                    ATRIB(7) = 10
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(10). GT. O. AND. NNRSC(19). GT. O. AND. XX(2). EQ. 1
     &              90) THEN
                    CALL SEIZE ( 10 , 1 )
                    CALL SEIZE ( 19 , 1 )
                    ATRIB(6) = 19
                    ATRIB(7) = 10
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(14). GT. O. AND. NNRSC(11). GT. O. AND. XX(2). EQ. 1
     &              54) THEN
                    CALL SEIZE ( 11 , 1 )
                    CALL SEIZE ( 14 , 1 )
                    ATRIB(6) = 14
                    ATRIB(7) = 11
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(15). GT. O. AND. NNRSC(11). GT. O. AND. XX(2). EQ. 1
     &                    65) THEN
                    CALL SEIZE ( 11 , 1 )
                    CALL SEIZE ( 15 , 1 )
                    ATRIB(6) = 15
                    ATRIB(7) = 11
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(19). GT. O. AND. NNRSC(11). GT. O. AND. XX(2). EQ. 2
     &              09) THEN
                    CALL SEIZE ( 11 , 1 )
                    CALL SEIZE ( 19 , 1 )
                    ATRIB(6) = 19
                    ATRIB(7) = 11
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(8). GT. O. AND. NNRSC(14). GT. O) THEN
                    CALL SEIZE ( 8 , 1 )
                    CALL SEIZE ( 14 , 1 )
                    ATRIB(6) = 14
                    ATRIB(7) = 8
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(8). GT. O. AND. NNRSC(15). GT. O ) THEN
                    CALL SEIZE ( 8 , 1 )
                    CALL SEIZE ( 15 , 1 )
                    ATRIB(6) = 15
                    ATRIB(7) = 8
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(10). GT. O. AND. NNRSC(14). GT. O ) THEN
                    CALL SEIZE ( 10 , 1 )
                    CALL SEIZE ( 14 , 1 )
                    ATRIB(6) = 14
                    ATRIB(7) = 10
                    IFLAG = 1
                    RETURN

            ELSE IF ( NNRSC(10). GT. O. AND. NNRSC(15). GT. O ) THEN
                    CALL SEIZE ( 10 , 1 )
                    CALL SEIZE ( 15 , 1 )
                    ATRIB(6) = 15
```

```
                          ATRIB(7) = 10
                          IFLAG = 1
                          RETURN

               ELSE IF ( NNRSC(10).GT.0.AND.NNRSC(19).GT.0 ) THEN
                          CALL SEIZE ( 10 , 1 )
                          CALL SEIZE ( 19 , 1 )
                          ATRIB(6) = 19
                          ATRIB(7) = 10
                          IFLAG = 1
                          RETURN

               ELSE IF ( NNRSC(14).GT.0.AND.NNRSC(11).GT.0 ) THEN
                          CALL SEIZE ( 11 , 1 )
                          CALL SEIZE ( 14 , 1 )
                          ATRIB(6) = 14
                          ATRIB(7) = 11
                          IFLAG = 1
                          RETURN

               ELSE IF ( NNRSC(15).GT.0.AND.NNRSC(11).GT.0 ) THEN
                          CALL SEIZE ( 15 , 1 )
                          CALL SEIZE ( 11 , 1 )
                          ATRIB(6) = 15
                          ATRIB(7) = 11
                          IFLAG = 1
                          RETURN

               ELSE IF ( NNRSC(19).GT.0.AND.NNRSC(11).GT.0 ) THEN
                          CALL SEIZE ( 11 , 1 )
                          CALL SEIZE ( 19 , 1 )
                          ATRIB(6) = 19
                          ATRIB(7) = 11
                          IFLAG = 1
                          RETURN

               ELSE
                          IFLAG = 0

               ENDIF
               RETURN

          ELSE IF ( IALL .EQ. 5 ) THEN

 *        ALLOCATION 5 - VEHICLE FOR PRODUCT 3-BARRELS
 *        -------------------------------------------

               IF (NNRSC(17).LE.0.AND.NNRSC(13).LE.0) RETURN
               IF (NNRSC(9).LE.0.AND.NNRSC(10).LE.0.AND.NNRSC(11).LE.0.AN
     &            D.NNRSC(12).LE.0) RETURN
               IF ( NNRSC(17).GT.0.AND.NNRSC(9).GT.0.AND.XX(3).EQ.153) TH
     &            EN
                  CALL SEIZE ( 17 , 1 )
                  CALL SEIZE ( 9 , 1 )
                  ATRIB(6) = 17
                  ATRIB(7) = 9
                  IFLAG = 1
                  RETURN

               ELSE IF ( NNRSC(17).GT.0.AND.NNRSC(12).GT.0.AND.XX(3).EQ.2
     &                   04) THEN
                          CALL SEIZE ( 17 , 1 )
                          CALL SEIZE ( 12 , 1 )
                          ATRIB(6) = 17
                          ATRIB(7) = 12
                          IFLAG = 1
                          RETURN
               ELSE IF ( NNRSC(10).GT.0.AND.NNRSC(13).GT.0.AND.XX(3).EQ.1
     &                   30) THEN
                          CALL SEIZE ( 13 , 1 )
                          CALL SEIZE ( 10 , 1 )
                          ATRIB(6) = 13
                          ATRIB(7) = 10
                          IFLAG = 1
                          RETURN

               ELSE IF ( NNRSC(11).GT.0.AND.NNRSC(13).GT.0.AND.XX(3).EQ.1
     &                   43) THEN
                          CALL SEIZE ( 13 , 1 )
                          CALL SEIZE ( 11 , 1 )
                          ATRIB(6) = 13
                          ATRIB(7) = 11
                          IFLAG = 1
                          RETURN
```

```
                ELSE IF ( NNRSC(12).GT.0.AND.NNRSC(13).GT.0.AND.XX(3).EQ.1
     &                   56) THEN
                         CALL SEIZE ( 13 , 1 )
                         CALL SEIZE ( 12 , 1 )
                         ATRIB(6) = 13
                         ATRIB(7) = 12
                         IFLAG = 1
                         RETURN

                ELSE IF ( NNRSC(17).GT.0.AND.NNRSC(9).GT.0 ) THEN
                   CALL SEIZE ( 17 , 1 )
                   CALL SEIZE ( 9 , 1 )
                   ATRIB(6) = 17
                   ATRIB(7) = 9
                   IFLAG = 1
                   RETURN

                ELSE IF ( NNRSC(17).GT.0.AND.NNRSC(12).GT.0 ) THEN
                         CALL SEIZE ( 17 , 1 )
                         CALL SEIZE ( 12 , 1 )
                         ATRIB(6) = 17
                         ATRIB(7) = 12
                         IFLAG = 1
                         RETURN

                ELSE IF ( NNRSC(10).GT.0.AND.NNRSC(13).GT.0 ) THEN
                         CALL SEIZE ( 13 , 1 )
                         CALL SEIZE ( 10 , 1 )
                         ATRIB(6) = 13
                         ATRIB(7) = 10
                         IFLAG = 1
                         RETURN

                ELSE IF ( NNRSC(11).GT.0.AND.NNRSC(13).GT.0 ) THEN
                         CALL SEIZE ( 13 , 1 )
                         CALL SEIZE ( 11 , 1 )
                         ATRIB(6) = 13
                         ATRIB(7) = 11
                         IFLAG = 1
                         RETURN

                ELSE IF ( NNRSC(12).GT.0.AND.NNRSC(13).GT.0 ) THEN
                         CALL SEIZE ( 13 , 1 )
                         CALL SEIZE ( 12 , 1 )
                         ATRIB(6) = 13
                         ATRIB(7) = 12
                         IFLAG = 1
                         RETURN

                ELSE
                         IFLAG = 0

                ENDIF
                RETURN


           ELSE IF ( IALL .EQ. 6 ) THEN

*          ALLOCATION 6 - VEHICLE FOR SMALL DEMAND - PRODUCT 4-P.V
*          ----------------------------------------------------------

                IF ( NNRSC(4).LE.0 ) RETURN
                IF ( NNRSC(4).GT.0 ) THEN
                   CALL SEIZE ( 4 , 1 )
                   ATRIB(6) = 4
                   ATRIB(7) = 0
                   IFLAG = 1
                   RETURN

                ELSE
                   IFLAG = 0

                ENDIF
                RETURN


           ELSE IF ( IALL .EQ. 7 ) THEN

*          ALLOCATION 7 - VEHICLE FOR LARGE DEMAND - PRODUCT 4-P.V
*          ----------------------------------------------------------

                IF ( NNRSC(5).LE.0 ) RETURN
                IF ( NNRSC(5).GT.0 ) THEN
                   CALL SEIZE ( 5 , 1 )
```

```
                    ATRIB(6) = 5
                    ATRIB(7) = 0
                    IFLAG = 1
                    RETURN

                 ELSE
                    IFLAG = 0

                 ENDIF
                 RETURN


         ELSE IF ( IALL .EQ.  8 ) THEN

 *       ALLOCATION 8 - VEHICLE FOR SMALL DEMAND - PRODUCT 5-GENERAL
 *       -------------------------------------------------------------

                 IF ( NNRSC(1).LE.0 ) RETURN
                 IF ( NNRSC(1).GT.0 ) THEN
                    CALL SEIZE ( 1 , 1 )
                    ATRIB(6) = 1
                    ATRIB(7) = 0
                    IFLAG = 1
                    RETURN

                 ELSE
                    IFLAG = 0

                 ENDIF
                 RETURN


         ELSE IF ( IALL .EQ.  9 ) THEN

 *       ALLOCATION 9 - VEHICLE FOR MEDIUM DEMAND - PRODUCT 5-GENERAL
 *       -------------------------------------------------------------

                 IF ( NNRSC(3).LE.0 ) RETURN
                 IF ( NNRSC(3).GT.0 ) THEN
                    CALL SEIZE ( 3 , 1 )
                    ATRIB(6) = 3
                    ATRIB(7) = 0
                    IFLAG = 1

                    RETURN
                 ELSE
                    IFLAG = 0

                 ENDIF
                 RETURN


         ELSE IF ( IALL .EQ.  10 ) THEN

 *       ALLOCATION 10 - VEHICLE FOR LARGE DEMAND - PRODUCT 5-GENERAL
 *       -------------------------------------------------------------

                 IF ( NNRSC(6).LE.0 ) RETURN
                 IF ( NNRSC(6).GT.0 ) THEN
                 CALL SEIZE ( 6 , 1 )
                 ATRIB(6) = 6
                 ATRIB(7) = 0
                 IFLAG = 1
                 RETURN

                 ELSE
                 IFLAG = 0

                 ENDIF
                 RETURN

         ELSE

         IFLAG = 0
         RETURN

         ENDIF
         RETURN

         END
```

```
*       ****************
        SUBROUTINE TEST1
*       ****************

        COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
       &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)

*        ALLOCATION OF MASS TO VEHICLES FOR PRODUCT 5-GENERAL
*        ----------------------------------------------------

* CAPACITIES OF TRUCKS ASSIGNED IN INTLC ( XX(11), XX(15), XX(18) )

        ICAP1 = XX(11)
        ICAP2 = XX(15)
        ICAP3 = XX(18)

* ASSIGN DESIRED % LOAD UTILIZATION

        A = XX(28) / 100.

* RECTIFY ALLOWABLE CAPACITIES

        IC1 = A * ICAP1
        IC2 = A * ICAP2
        IC3 = A * ICAP3

* ACTUAL SIZE OF THIS ENTITY

        I92 = XX(92)

* ACCUMULATED SIZE INCLUDING THIS ENTITY (ALREADY UPDATED IN SLAM )

        I94 = XX(94)

        M1 = NNQ(15)
        M2 = NNQ(16)
        M3 = NNQ(17)

* IF NUMBER OF ENTITIES WAITING FOR TRUCKS IN FILES FOR PRODUCT 5 IS
* TOO LARGE, REMOVE 1 ENTITY FROM THE FILE(S) AND PLACE IT IN THE
* FILES FOR PRODUCT 4 (TRUCKS FOR PRODUCT 4 WILL, ON CERTAIN OCCASIONS,
* BE USED FOR PRODUCT 5, PROVIDED THE CRADLES ARE FIRST REMOVED).

        IF (M1.GE.15) THEN
           CALL RMOVE(4,15,AT1)
           CALL RMOVE(3,15,AT1)
           CALL RMOVE(2,15,AT1)
           CALL RMOVE(1,15,AT1)
           CALL FILEM(14,AT1)
        ENDIF

        IF (M2.GE.15) THEN
           CALL RMOVE(1,16,AT1)
           CALL FILEM(13,AT1)
        ENDIF

        IF (M3.GE.15) THEN
           CALL RMOVE(1,17,AT1)
           CALL FILEM(14,AT1)
        ENDIF

* CHECK IF ACCUMULATED SIZE CAN BE ALLOCATED TO A TRUCK WITH % LOAD
* UTILIZATION SATISFIED

        IF (I94.GE.IC1.AND.I94.LE.ICAP1.AND.NNRSC(3).EQ.0.AND.NNRSC(6).EQ.
       &    0) THEN
           ATRIB(9) = 5.
           GOTO 35

        ELSE IF (I94.GE.IC2.AND.I94.LE.ICAP2.AND.NNRSC(6).EQ.0) THEN
                ATRIB(9) = 6.
                GOTO 35

        ELSE IF (I94.GE.IC3.AND.I94.LE.ICAP3) THEN
                ATRIB(9) = 7.
                GOTO 35

* CHECK IF ACTUAL SIZE CAN BE ALLOCATED TO A TRUCK WITH % LOAD UTILIZATION
* SATISFIED

        ELSE IF (I92.GE.IC1.AND.I92.LE.ICAP1.AND.NNRSC(3).EQ.0.AND.NNRSC(6
       &        ).EQ.0) THEN
                ATRIB(9) = 5.
                GOTO 45
```

```
        ELSE IF (I92.GE.IC2.AND.I92.LE.ICAP2.AND.NNRSC(6).EQ.0) THEN
                  ATRIB(9) = 6.
                  GOTO 45
        ELSE IF (I92.GE.IC3.AND.I92.LE.ICAP3) THEN
                  ATRIB(9) = 7.
                  GOTO 45
* CHECK IF ACCUMULATED SIZE IS GREATER THAN MAXIMUM TRUCK CAPACITY
        ELSE IF (I94.GT.ICAP3) THEN
                  GOTO 55
        ELSE
* IF ABOVE CONDITIONS ARE NOT MET, ENTITY WILL BE DESTROYED
                  ATRIB(9) = 0.
        RETURN
        ENDIF
        RETURN
* SET ATRIB(1) TO THE ARRIVAL TIME OF EARLIEST ENTITY IN BATCH.  RESET
* XX(87) TO SOME LARGE NUMBER TO ALLOW THE NEXT INCOMING ENTITY TO BE
* MARKED.  RESET ACCUMULATED SIZE TO 0.
 35     ATRIB(1) = XX(87)
        ATRIB(10) = XX(94)
        XX(87) = 200000.
        XX(94) = 0.
        RETURN
* DECREASE ACCUMULATED SIZE BY ACTUAL SIZE AND MARK ARRIVAL TIME
 45     XX(94) = XX(94) - XX(92)
        ATRIB(10) = XX(92)
        ATRIB(1) = TNOW
        RETURN
 55     XX(94) =XX(94) - XX(92)
        ATRIB(1) = TNOW
        ATRIB(10) = XX(92)
* DECIDE WHICH TRUCK THE ACTUAL BATCH WILL BE ALLOCATED TO.
        IF (I92.GT.ICAP1.AND.I92.LE.ICAP2) THEN
           ATRIB(9) = 6.
           RETURN
        ELSE IF (I92.GT.ICAP2.AND.I92.LE.ICAP3) THEN
                  ATRIB(9) = 7.
                  RETURN
        ELSE
                  ATRIB(9) = 5.
                  RETURN
        ENDIF
        RETURN
        END
*       ****************
        FUNCTION USERF(I)
*       ****************
        DIMENSION B(10),C(10),F(20),G(10)
        COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
       &,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
        IF (I.EQ.1) THEN
*         ALLOCATION OF MASS TO VEHICLES FOR PRODUCT 1-PLASTICS
*         -----------------------------------------------------
* THE LOGIC USED HERE IS VERY SIMILAR TO THAT USED UNDER TEST 1.
* HOWEVER, NO FILES ARE MANIPULATED.
        ICAP1 = XX(12)
        ICAP2 = (XX(18)+XX(24))/2.
```

```
      ICAP3 = XX(22)

      A = XX(28)/100.

      IC1 = A * ICAP1
      IC2 = A * ICAP2
      IC3 = A * ICAP3

      I90 = XX(90)
      I91 = XX(91)

      IF (I91.GE.IC1.AND.I91.LE.ICAP1.AND.(NNRSC(6).EQ.0.AND.NNRSC(16).E
     &   Q.0.)) THEN
        USERF = 1.
        GOTO 10

      ELSE IF (I91.GE.IC2.AND.I91.LE.ICAP2.AND.NNRSC(16).EQ.0.) THEN
              USERF = 2.
              GOTO 10

      ELSE IF (I91.GE.IC3.AND.I91.LE.ICAP3) THEN
              USERF = 3.
              GOTO 10

      ELSE IF (I90.GE.IC1.AND.I90.LE.ICAP1.AND.(NNRSC(6).EQ.0.AND.NNRSC(
     &         16).EQ.0.)) THEN
              USERF = 1.
              GOTO 20

      ELSE IF (I90.GE.IC2.AND.I90.LE.ICAP2.AND.NNRSC(16).EQ.0.) THEN
              USERF = 2.
              GOTO 20

      ELSE IF (I90.GE.IC3.AND.I90.LE.ICAP3) THEN
              USERF = 3.
              GOTO 20

      ELSE IF (I91.GT.ICAP3) THEN
              GOTO 30

      ELSE
              USERF = 4.
      RETURN

      ENDIF
      RETURN

10    ATRIB(1) = XX(93)
      ATRIB(10) = XX(91)
      XX(93) = 200000.
       XX(91) = 0.
       RETURN

20     XX(91) = XX(91) - I90
       ATRIB(1) = TNOW
       ATRIB(10) = XX(90)
       RETURN

30     XX(91) = I91 - I90
       ATRIB(1) = TNOW
       ATRIB(10) = XX(90)

       IF (I90.GT.ICAP1.AND.I90.LE.ICAP2) THEN
          USERF = 2.
          RETURN

       ELSE IF (I90.GT.ICAP2.AND.I90.LE.ICAP3) THEN
               USERF = 3.
               RETURN

       ELSE
          USERF = 1.
          RETURN

       ENDIF
       RETURN

       ELSE IF (I.EQ.2) THEN

*        DECISIONS TO ALLOW A VEHICLE TO GO ONTO A JOURNEY
*        ---------------------------------------------

* XX(9) = NUMBER OF DAYS
* B(7) = TIME FROM TNOW TO NEXT MORNING AT 7 A.M.
```

```
* W = WAITING TIME OF ENTITY
* N = TIME TO LOAD, TRAVEL AWAY, UNLOAD (& TRAVEL BACK FOR PRODUCT 2)
* T = TOTAL WAITING TIME IF VEHICLE GOES TODAY
* T1 = TOTAL WAITING TIME IF VEHICLE GOES TOMORROW
* T2 = TOTAL WAITING TIME IF IT IS FRIDAY & VEHICLE WAITS TILL MONDAY
* T3 = TOTAL WAITING TIME IF IT IS SATURDAY & VEHICLE WAITS TILL MONDAY
* T4 = TOTAL WAITING TIME IF IT IS SUNDAY & VEHICLE WAITS TILL MONDAY
* OMAX = MAXIMUM OVERTIME PER TRIP
* A = JOURNEY TIME
* A1 = EFFECTIVE TIME FOR WHICH THE VEHICLE CAN BE OUT WITHOUT
*       OVERIDING THE MAXIMUM OVERTIME CONDITION (WEEKDAYS)
* A2 = EFFECTIVE TIME FOR WHICH THE VEHICLE CAN BE OUT WITHOUT
*       OVERIDING THE MAXIMUM OVERTIME CONDITION (WEEKENDS)

      B(7) = 24.*XX(9) - TNOW
      W = TNOW - ATRIB(1)

      IF (ATRIB(8).NE.20.) THEN
         N = 2*ATRIB(3) + ATRIB(4)
         A = 2*ATRIB(3) + ATRIB(5)/RNORM(43.54,9.614,1)

      ELSE
         N = 2*ATRIB(3) + ATRIB(5)/RNORM(43.54,9.614,1)
         A = N
      ENDIF

      T = W + A
      T1= T + B(7)
      T2 = T1+ 48.
      T3 = T1+ 24.
      T4 = T1

      OMAX = XX(97)

      A1 = 24.*XX(9) - TNOW + OMAX - 15.
      A2 = 24.*XX(9) - TNOW + OMAX - 24.

* DO NOT WAIT IF 7 A.M - 12 P.M ON WEEKDAYS
      IF (XX(5).LE.1.AND.XX(6).LE.2.) THEN
         USERF = 0.
         XX(98) = XX(98) + 1.
         RETURN

* WAIT IF IT IS MONDAY TO THURSDAY & THE MAXIMUM PRESCRIBED WAITING
* TIME HAS NOT BEEN REACHED
      ELSE IF (XX(6).EQ.1.AND.T1.LE.XX(45)) THEN
                  USERF = 24.*XX(9) - TNOW
                  XX(99) = XX(99) + 1.
                  RETURN

* WAIT IF IT IS FRIDAY & THE MAXIMUM PRESCRIBED WAITING TIME HAS
* NOT BEEN REACHED
      ELSE IF (XX(6).EQ.2.AND.T2.LE.(XX(45)*1.5)) THEN
                  USERF = 24.*XX(9) - TNOW + 48.
                  XX(99) = XX(99) + 1.
                  RETURN

* WAIT IF IT IS SATURDAY & THE MAXIMUM PRESCRIBED WAITING TIME HAS
* NOT BEEN REACHED
      ELSE IF (XX(6).EQ.3.AND.T3.LE.XX(45)) THEN
                  USERF = 24.*XX(9) - TNOW + 24.
                  XX(99) = XX(99) + 1.
                  RETURN

* WAIT IF IT IS SUNDAY & THE MAXIMUM PRESCRIBED WAITING TIME HAS
* NOT BEEN REACHED
      ELSE IF (XX(6).EQ.4.AND.T4.LE.(XX(45)/2.)) THEN
                  USERF = 24.*XX(9) - TNOW
                  XX(99) = XX(99) + 1.
                  RETURN

* WAIT IF IT IS MONDAY TO THURSDAY & THE MAXIMUM OVERTIME IS EXCEEDED
      ELSE IF (A.GT.A1.AND.XX(6).EQ.1.) THEN
                  USERF = 24.*XX(9) - TNOW
                  XX(99) = XX(99) + 1.
                  RETURN

* WAIT IF IT IS FRIDAY & THE MAXIMUM OVERTIME IS EXCEEDED
      ELSE IF (A.GT.A1.AND.XX(6).EQ.2.) THEN
                  USERF = 24.*XX(9) - TNOW + 48.
                  XX(99) = XX(99) + 1.
                  RETURN

* WAIT IF IT IS SATURDAY & THE MAXIMUM OVERTIME IS EXCEEDED
      ELSE IF (A.GT.A2.AND.XX(6).EQ.3.) THEN
                  USERF = 24.*XX(9) - TNOW + 24.
                  XX(99) = XX(99) + 1.
```

```
                    RETURN
* WAIT IF IT IS SUNDAY & THE MAXIMUM OVERTIME IS EXCEEDED
          ELSE IF (A.GT.A2.AND.XX(6).EQ.4.) THEN
                    USERF = 24.*XX(9) - TNOW
                    XX(99) = XX(99) + 1.
                    RETURN
* OTHERWISE, DO NOT WAIT
          ELSE
                    USERF = 0.
                    XX(100) = XX(100) + 1.
                    RETURN
          ENDIF
          RETURN
      ELSE IF (I.EQ.3) THEN
*    ALLOCATION OF BARRELS FOR PRODUCT 3-BARRELS
*    -----------------------------------------
* C(1) = SIGNAL TO ALLOW THE ARRIVAL TIME OF THE FIRST ORDER IN THE
*        BATCH TO BE MARKED
* C(2) = A CODE TO DETERMINE THE NUMBER OF BARRELS WAITING
* C(3) = ARRIVAL TIME OF FIRST ORDER IN A BATCH
* C(4) = NUMBER OF BARREL1 WAITING
* C(5) = NUMBER OF BARREL2 WAITING
* C(6) = NUMBER OF BARREL3 WAITING
* C(7) = WAITING TIME OF FIRST ORDER IN A BATCH AT TIME TNOW
* C(8) = A SIGNAL TO RESET C(2) TO 1 WHENEVER THE FIRST ORDER IS PLACED
      IF (C(8).EQ.0) C(2) = 1.
      IF (C(1).EQ.0) C(3) = ATRIB(1)
      IF (ATRIB(3).EQ.7.) C(4) = C(4) + 1.
      IF (ATRIB(3).EQ.8.) C(5) = C(5) + 1.
      IF (ATRIB(3).EQ.9.) C(6) = C(6) + 1.
      C(1) = ATRIB(3)
      C(2) = C(2)*C(1)
      C(7) = TNOW - C(3)
      C(8) = 10
* IF THERE ARE 4 BARRELS WAITING
      IF (C(2).GE.2400.) THEN
         XX (76) = XX(76) + 1.
         XX(80) = XX(80) + 4.
         GOTO 25
* IF 3 BARRELS ARE WAITING & THEY HAVE BEEN WAITING MORE THAN THE
* MAXIMUM ALLOCATED WAITING TIME
      ELSE IF (C(2).GT.300.AND.C(2).LT.1000.AND.C(7).GE.(XX(84)/3.))THEN
               XX(77) = XX(77) + 1.
               XX(80) = XX(80) + 3.
               GOTO 25
* IF 2 BARRELS ARE WAITING & THEY HAVE BEEN WAITING MORE THAN THE
* MAXIMUM ALLOCATED WAITING TIME
      ELSE IF (C(2).GT.40.AND.C(2).LT.100.AND.C(7).GE.(XX(84)*2/3.))THEN
               XX(78) = XX(78) + 1.
               XX(80) = XX(80) + 2.
               GOTO 25
* IF 1 BARREL IS WAITING & IT HAS BEEN WAITING MORE THAN THE MAXIMUM
* ALLOCATED WAITING TIME
      ELSE IF (C(2).GT.0.AND.C(2).LT.10.AND.C(7).GE.XX(84)) THEN
               XX(79) = XX(79) + 1.
               XX(80) = XX(80) + 1.
               GOTO 25
* OTHERWISE, DESTROY THE ENTITY (I.E. WAIT FOR THE NEXT ORDER)
      ELSE
               USERF = 1.
               RETURN
      ENDIF
      RETURN
25    USERF = C(2)
* RECORD THE NUMBER OF EACH TYPE OF BARREL FOR THE JOURNEY
      ATRIB(8) = C(4)
      ATRIB(10) = C(6)
```

```
        ATRIB(9) = C(5)

* RESET THE INITIAL CONDITIONS
        C(1) = 0.
        C(2) = 1.
        C(3) = 0.
        C(4) = 0.
        C(5) = 0.
        C(6) = 0.
        C(8) = 0.

        RETURN


        ELSE IF (I.EQ.4) THEN

*     DECISIONS TO CHANGE HORSE/TRAILER FOR PRODUCT 1-PLASTICS
*     --------------------------------------------------------

* M = ACTUAL HORSE/TRAILER STATE
* J = PREVIOUS HORSE/TRAILER STATE - PRODUCT 1
* K = PREVIOUS HORSE/TRAILER STATE - PRODUCT 2
* L = PREVIOUS HORSE/TRAILER STATE - PRODUCT 3

        M = ATRIB(6) * ATRIB(7)
        J = XX(1)
        K = XX(2)
        L = XX(3)

* EACH OF THE 'IF' STATEMENTS COMPARES THE ACTUAL WITH THE PREVIOUS
* HORSE/TRAILER STATES.  SHOULD THERE BE A DIFFERENCE IN ALL CASES,
* THE VEHICLE WILL BE DELAYED BY A CHANGE OF HORSE/TRAILER

        IF (J.EQ.180.AND.(M.EQ.198.OR.M.EQ.216)) GOTO 12
        IF (J.EQ.198.AND.(M.EQ.180.OR.M.EQ.216)) GOTO 12
        IF (J.EQ.216.AND.(M.EQ.180.OR.M.EQ.198)) GOTO 12
        IF (M.EQ.180.AND.L.EQ.130) GOTO 12
        IF (M.EQ.180.AND.(K.EQ.140.OR.K.EQ.150.OR.K.EQ.190)) GOTO 12
        IF (M.EQ.198.AND.L.EQ.143) GOTO 12
        IF (M.EQ.198.AND.(K.EQ.154.OR.K.EQ.165.OR.K.EQ.209)) GOTO 12
        IF (M.EQ.216.AND.(L.EQ.156.OR.L.EQ.204)) GOTO 12

        USERF = 0.
        RETURN

 12     USERF = XX(50)
        RETURN

        ELSE IF (I.EQ.5) THEN


*     UPDATE OVERTIME HOURS FOR WEEKDAYS AND WEEKENDS
*     -----------------------------------------------

* IF THE VEHICLE COMES BACK AFTER 4 P.M & IT IS A WEEKDAY
        IF (XX(7).EQ.1.AND.XX(6).LT.3.) THEN
           XX(13) = XX(13) + TNOW - XX(10)
           USERF = 0.
           RETURN

* IF IT IS SATURDAY
        ELSE IF (XX(6).GE.3.) THEN
                XX(14) = XX(14) + TNOW - XX(8)
                USERF = 0.
                RETURN

* OTHERWISE, DO NOT RECORD THE OVERTIME
        ELSE
                USERF = 0.
        RETURN

        ENDIF
        RETURN


        ELSE IF (I.EQ.6) THEN

*     MAINTENANCE OF TRUCKS AND HORSES
*     --------------------------------

* XX(J) = CUMULATIVE KM TRAVELLED
* XX(L) = CUMULATIVE FUEL CONSUMED
* XX(M) = FUEL CONSUMPTION (SEE 'INTLC' IN SLAM)

        IF (ATRIB(7).EQ.0) K = ATRIB(6)
        IF (ATRIB(7).NE.0) K = ATRIB(7)
```

```
        J = K + 50
        XX(J) = XX(J) + ATRIB(5)
        F(K) = F(K) + ATRIB(5)
        L = K + 63
        M = K + 28
        XX(L) = XX(L) + ATRIB(5)*XX(M)/100.
* VEHICLES FOR PRODUCT 2 ARE MAINTAINED ON A MONTHLY BASIS
        IF (ATRIB(8).EQ.20.AND.XX(4).LT.29.) RETURN
        IF (ATRIB(8).EQ.20.AND.XX(4).GE.29.) GOTO 17
* RESET THE KM TO 0 IF THE VEHICLE HAS TRAVELLED THE PRESCRIBED KM
* BETWEEN MAINTENANCE
        IF ( F(K) .GE. XX(63) ) THEN
           F(K) = 0.
* IF IT IS A WEEKDAY, SET THE MAINTENANCE TIME TO XX(44) FROM TNOW
17      IF (XX(6).LE.2) THEN
           USERF = XX(44)
           RETURN
* IF IT IS SATURDAY, DELAY THE VEHICLE UNTIL MONDAY MORNING + THE
* PRESCRIBED MAINTENANCE TIME
        ELSE IF (XX(6).EQ.3) THEN
              USERF = 24.*XX(9) - TNOW + 24. + XX(44)
              RETURN
* ELSE (SUNDAY), DELAY THE VEHICLE UNTIL MONDAY MORNING + THE PRESCRIBED
* MAINTENANCE TIME
        ELSE
              USERF = 24.*XX(9) - TNOW + XX(44)
              RETURN
        ENDIF
* OTHERWISE, DO NOT DELAY THE VEHICLE
        ELSE
              USERF = 0.
        RETURN
        ENDIF
        RETURN
        ELSE IF (I.EQ.7) THEN
*         ALLOCATION OF P.V TO VEHICLES FOR PRODUCT 4-P.V
*         ---------------------------------------------
* N1 = NUMBER OF BATCHES THAT ARE WAITING FOR THE 4 P.V CAPACITY TRUCK
* N2 = NUMBER OF BATCHES THAT ARE WAITING FOR THE 6 P.V CAPACITY TRUCK
* VCAP1 = CAPACITY OF SMALL TRUCK (4 P.V)
* VCAP2 = CAPACITY OF BIG TRUCK (6 P.V)
* T = ACTUAL TIME
* G(1) = NUMBER OF P.V THAT HAVE ALREADY BEEN COMBINED TOGETHER
* G(2) = WAITING TIME OF FIRST P.V IN THE ACTUAL BATCH
* W1 = MAXIMUM WAITING TIME OF FIRST P.V IF THE BATCH WAS ALLOCATED TO
*         THE 4 P.V TRUCK
* W2 = MAXIMUM WAITING TIME OF FIRST P.V IF THE BATCH WAS ALLOCATED TO
*         THE 6 P.V TRUCK
        N1 = NNQ(13)
        N2 = NNQ(14)
        VCAP1 = 4.
        VCAP2 = 6.
        T = TNOW
        IF (G(1).EQ.0.) ATRIB(1) = TNOW
        G(1) = G(1) + 1.
        G(2) = T - ATRIB(1)
        W1 = (VCAP1 - G(1))*XX(83)/3.
        W2 = (VCAP2 - G(1))*XX(83)/5.
* IF THE CAPACITY OF THE BIG TRUCK HAS BEEN FULFILLED
        IF (G(1).EQ.VCAP2) THEN
           USERF = 2.
           ATRIB(10) = G(1)
           G(1) = 0.
           RETURN
```

```
* IF THE NUMBER OF P.V IS BETWEEN THE 2 TRUCK CAPACITIES & THEIR WAITING
* TIME HAS REACHED/EXCEEDED THE MAXIMUM WAITING TIME
       ELSE IF (G(1).GT.VCAP1.AND.G(2).GE.W2) THEN
               USERF = 2.
               ATRIB(10) = G(1)
               G(1) = 0.
               RETURN

* IF THE CAPACITY OF THE SMALL TRUCK HAS BEEN REACHED& THE NUMBER OF
* BATCHES WAITING FOR THE BIG TRUCK IS G.T THAT FOR THE SMALL TRUCK
       ELSE IF (G(1).EQ.VCAP1.AND.N2.GT.N1) THEN
               USERF = 1.
               ATRIB(10) = G(1)
               G(1) = 0.
               RETURN

* IF THE NUMBER OF P.V IS L.T THE SMALL TRUCK CAPACITY & THE MAXIMUM
* WAITING TIME HAS BEEN REACHED/EXCEEDED & THERE ARE MORE BATCHES
* WAITING FOR THE BIG TRUCK
       ELSE IF (G(1).LT.VCAP1.AND.G(2).GE.W1.AND.N2.GT.N1) THEN
               USERF = 1.
               ATRIB(10) = G(1)
               G(1) = 0.
               RETURN

* IF THE NUMBER OF P.V IS L.T THE SMALL TRUCK CAPACITY & THE MAXIMUM
* WAITING TIME HAS BEEN REACHED/EXCEEDED & THERE ARE MORE BATCHES
* WAITING FOR THE SMALL TRUCK
       ELSE IF (G(1).LT.VCAP1.AND.G(2).GE.W2.AND.N1.GT.N2) THEN
               USERF = 2.
               ATRIB(10) = G(1)
               G(1) = 0.
               RETURN

       ELSE
* OTHERWISE, DESTROY THE ENTITY BUT DO NOT RESET G(1) TO 0
         USERF = 0.
         RETURN

       ENDIF.
       RETURN

       ELSE IF (I.EQ.8) THEN

*      DECISIONS TO CHANGE HORSE/TRAILER FOR PRODUCT 2-AMMONIUM NITRATE
*      ----------------------------------------------------------------

* SEE NOTE UNDER USERF(4)

       M = ATRIB(6)*ATRIB(7)
       J = XX(1)
       K = XX(2)
       L = XX(3)

       IF (J.EQ.180.AND.(M.EQ.140.OR.M.EQ.150.OR.M.EQ.190)) GOTO 14
       IF (J.EQ.198.AND.(M.EQ.154.OR.M.EQ.165.OR.M.EQ.209)) GOTO 14
       IF (L.EQ.130.AND.(M.EQ.140.OR.M.EQ.150.OR.M.EQ.190)) GOTO 14
       IF (L.EQ.143.AND.(M.EQ.154.OR.M.EQ.165.OR.M.EQ.209)) GOTO 14
       IF (K.EQ.112.AND.M.EQ.120) GOTO 14
       IF (K.EQ.120.AND.M.EQ.112) GOTO 14
       IF (K.EQ.140.AND.(M.EQ.150.OR.M.EQ.190)) GOTO 14
       IF (K.EQ.150.AND.(M.EQ.140.OR.M.EQ.190)) GOTO 14
       IF (K.EQ.190.AND.(M.EQ.140.OR.M.EQ.150)) GOTO 14
       IF (K.EQ.154.AND.(M.EQ.165.OR.M.EQ.209)) GOTO 14
       IF (K.EQ.165.AND.(M.EQ.154.OR.M.EQ.209)) GOTO 14
       IF (K.EQ.209.AND.(M.EQ.154.OR.M.EQ.165)) GOTO 14
       IF (K.EQ.140.AND.M.EQ.154) GOTO 14
       IF (K.EQ.154.AND.M.EQ.140) GOTO 14
       IF (K.EQ.150.AND.M.EQ.165) GOTO 14
       IF (K.EQ.165.AND.M.EQ.150) GOTO 14
       IF (K.EQ.190.AND.M.EQ.209) GOTO 14
       IF (K.EQ.209.AND.M.EQ.190) GOTO 14

       USERF = 0.
       RETURN

14     USERF = XX(50)
       RETURN
```

```
        ELSE IF (I.EQ.9) THEN

*       COMPUTE THE NUMBER OF BARRELS CURRENTLY IN USE
*       ---------------------------------------------


        USERF = NRUSE(24) + NRUSE(25) + NRUSE(26)

        RETURN


        ELSE IF (I.EQ.10) THEN

*        DECISIONS TO CHANGE CRADLES ON VEHICLES FOR PRODUCT 4-P.V
*        ---------------------------------------------------------

* ATRIB(9) = 1 --- 4 P.V TRUCK IS IN USE WITH PRODUCT 4
*            2 --- 6 P.V TRUCK IS IN USE WITH PRODUCT 4
*          G.T 3 --- 4 OR 6 P.V TRUCK IS IN USE WITH PRODUCT 5

* SEIZE THE RESOURCES CRADLE2 FOR PRODUCT 4 IF THEY ARE AVAILABLE
        IF (ATRIB(9).EQ.1.AND.NNRSC(27).NE.0) THEN
           CALL SEIZE(27,2)
           USERF = XX(43)
           RETURN

* SEIZE THE RESOURCES CRADLE3 FOR PRODUCT 4 IF THEY ARE AVAILABLE
        ELSE IF (ATRIB(9).EQ.2.AND.NNRSC(28).NE.0) THEN
                CALL SEIZE(28,2)
                USERF = XX(43)
                RETURN

* FREE THE RESOURCES CRADLE2 FOR PRODUCT 5 IF THEY ARE NOT AVAILABLE
        ELSE IF (ATRIB(9).GT.3.AND.ATRIB(6).EQ.4.AND.NNRSC(27).EQ.0) THEN
                CALL FREE(27,2)
                USERF = XX(43)
                RETURN

        ELSE IF (ATRIB(9).GT.3.AND.ATRIB(6).EQ.5.AND.NNRSC(28).EQ.0) THEN
* FREE THE RESOURCES CRADLE3 FOR PRODUCT 5 IF THEY ARE NOT AVAILABLE
                CALL FREE(28,2)
                USERF = XX(43)
                RETURN

* OTHERWISE, DO NOT CHANGE CRADLES
        ELSE
                USERF = 0
                RETURN

        ENDIF
        RETURN


         ELSE IF (I.EQ.11) THEN

*        DECISIONS TO CHANGE HORSE/TRAILER FOR PRODUCT 3-BARRELS
*        -------------------------------------------------------

* SEE NOTE UNDER USERF(4)

         I1 = ATRIB(6)*ATRIB(7)
         J = XX(1)
         K =XX(2)
         L = XX(3)

         IF (J.EQ.216.AND.(I1.EQ.156.OR.I1.EQ.204)) GOTO 40
         IF (J.EQ.198.AND.I1.EQ.143) GOTO 40
         IF (J.EQ.180.AND.I1.EQ.130) GOTO 40
         IF (I1.EQ.130.AND.(K.EQ.140.OR.K.EQ.150.OR.K.EQ.190)) GOTO 40
         IF (I1.EQ.143.AND.(K.EQ.154.OR.K.EQ.165.OR.K.EQ.209)) GOTO 40
         IF (L.EQ.204.AND.I1.EQ.156) GOTO 40
         IF (L.EQ.156.AND.I1.EQ.204) GOTO 40
         IF (L.EQ.130.AND.(I1.EQ.143.OR.I1.EQ.156)) GOTO 40
         IF (L.EQ.143.AND.(I1.EQ.130.OR.I1.EQ.156)) GOTO 40
         IF (L.EQ.156.AND.(I1.EQ.130.OR.I1.EQ.143)) GOTO 40
         IF (L.EQ.153.AND.I1.EQ.204) GOTO 40
      IF (L.EQ.204.AND.I1.EQ.153) GOTO40

         USERF = 0.
         RETURN


40       USERF = XX(50)
         RETURN
```

```
          ELSE IF (I.EQ.12) THEN

*         DECISIONS FOR CHANGING BARRELS ON TRAILERS FOR PRODUCT 3-BARRELS
*         -----------------------------------------------------------------

* XX(46) = PREVIOUS NUMBER & TYPE OF BARRELS ON RESOURCE NO. 13
* XX(47) = PREVIOUS NUMBER & TYPE OF BARRELS ON RESOURCE NO. 17
* I1 = ACTUAL NUMBER & TYPE OF BARRELS ON RESOURCE NO. 13 OR 17

          I1 = ATRIB(3)*ATRIB(6)

* A CHANGE IN BARREL IS NECESSARY IF THE ACTUAL STATE DOES NOT
* CORRESPOND TO THE PREVIOUS STATE
          IF (I1.NE.XX(46).OR.I1.NE.XX(47)) THEN
             USERF = 1.
             RETURN

          ELSE
             USERF = 0.
             RETURN

          ENDIF
          RETURN


        ELSE IF (I.EQ.13) THEN

*      COMPUTE THE NUMBER OF DRIVERS CURRENTLY BUSY
*      -----------------------------------------

        USERF = NRUSE(1)+NRUSE(2)+NRUSE(3)+NRUSE(4)+NRUSE(5)+NRUSE(6)+NRUS
      &E(7)+NRUSE(8)+NRUSE(9)+NRUSE(10)+NRUSE(11)+NRUSE(12)

        RETURN


        ELSE IF (I.EQ.14) THEN

*      COMPUTE THE NUMBER OF ASSISTANTS CURRENTLY BUSY
*      ---------------------------------------------

        USERF = NRUSE(1)+2*NRUSE(2)+2*NRUSE(3)+NRUSE(4)+NRUSE(5)+NRUSE(7)+
      &NRUSE(8)+2*NRUSE(6)+NRUSE(9)+NRUSE(10)+NRUSE(11)+NRUSE(12)

        RETURN


        ELSE IF (I.EQ.15) THEN

* COMPUTE THE NUMBER OF TRUCKS CURRENTLY IN USE
* -----------------------------------------

        USERF = NRUSE(1)+NRUSE(2)+NRUSE(3)+NRUSE(4)+NRUSE(5)+NRUSE(6)

        RETURN


        ELSE IF (I.EQ.16) THEN

* COMPUTE THE NUMBER OF HORSES CURRENTLY IN USE
* -----------------------------------------

        USERF = NRUSE(7)+NRUSE(8)+NRUSE(9)+NRUSE(10)+NRUSE(11)+NRUSE(12)

        RETURN


        ELSE IF (I.EQ.17) THEN

* COMPUTE THE NUMBER OF TRAILERS CURRENTLY IN USE
* -------------------------------------------

        USERF = NRUSE(13)+NRUSE(14)+NRUSE(15)+NRUSE(16)+NRUSE(17)
      &          +NRUSE(18)+NRUSE(19)

        RETURN


        ELSE IF (I.EQ.18) THEN

* COMPUTE THE TOTAL OVERTIME WORKED
* -------------------------------

        USERF = XX(13) + XX(14)

        RETURN
```

```
      ELSE IF (I.EQ.19) THEN

* COMPUTE THE TOTAL KM TRAVELLED
* ----------------------------

      USERF = XX(51)+XX(52)+XX(53)+XX(54)+XX(55)+XX(56)+XX(57)+XX(58)+XX
     &        (59)+XX(60)+XX(61)+XX(62)

      RETURN


      ELSE IF (I.EQ.20) THEN

* COMPUTE THE TOTAL FUEL CONSUMED
* -----------------------------

      USERF = XX(64)+XX(65)+XX(66)+XX(67)+XX(68)+XX(69)+XX(70)+XX(71)+XX
     &        (72)+XX(73)+XX(74)+XX(75)

      RETURN


      ELSE IF (I.EQ.21) THEN

* COMPUTE THE NUMBER OF VEHICLES CURRENTLY BEING MAINTAINED
* --------------------------------------------------------

      USERF = NNACT(18)+NNACT(25)+NNACT(40)+NNACT(45)+NNACT(56)

      RETURN

      ELSE
      RETURN

      ENDIF
      RETURN

      END
```

APPENDIX G

SUMMARY OF DATA USED IN THE MODEL

Table G1 describes all the statistical distributions employed for each product group. Only standard distribution functions were considered. The following formulae were used to compute the different distributions:

For Normal distributions,

1. Mean $= \bar{x} = \dfrac{\sum x_i}{N}$, where x_i is the ith variable in the population, and N is the number of samples used.

2. Standard Deviation $= \sigma = \sqrt{\dfrac{\sum (x_i - \bar{x})^2}{N}}$

For Gamma distributions,

3. Mean $= \beta = \dfrac{\sigma^2}{\bar{x}}$

4. Standard Deviation $= \alpha = \dfrac{\bar{x}}{\beta}$

In addition, two dimensionless coefficients were evaluated to describe the distribution shape. These are the coefficients of skewness (C.O.S) and Kurtosis (C.O.K). The C.O.S indicates how asymetric the distribution is, whereas the C.O.K shows how concentrated the sample population is about the mean. The formulae used to compute these coefficients are as follows:

1. Coefficient of Skewness $= \dfrac{\sum (x_i - \bar{x})^3}{N * \sigma^3}$

2. Coefficient of Kurtosis $= \dfrac{\sum (x_i - \bar{x})^4}{N * \sigma^4}$

In view to decide which distribution function best fits each variable, the following criteria were used:

1. For the purpose of the model, it is convenient to represent the sample populations by distributions which are spread over a relatively small range (i.e. a low standard deviation). This criterion attempts to reduce the degree of uncertainty about the minimum and maximum limits of the variables. For example, a Normal distribution with mean 139 and standard deviation 75 for the distance travelled by vehicles for Product 3 would indicate a

relatively large spectrum, whereas in practice, the maximum distance travelled is known to be within 400 km. Effectively, the end regions of the distribution curve would be cut off to a large extent. In this regard, a better function would be desired.

2. A Normal distribution is chosen when the standard deviation is small as compared to the mean. Specifically, the choice is made when α is greater than 20.
3. If α is smaller than 5, a Gamma distribution is selected.
4. Should neither a Normal nor a Gamma distribution be suitable, the mean and standard deviation for the logarithmic values of the samples are computed. In general, when this test was applied, low values were obtained for σ as compared to $\bar{x}$.

The remaining variables used in the model are listed in Table G2. (Note: The variables pertaining to the vehicle resources are presented in Table 3).

TABLE G1 - Statistical Distributions Used in the Model

N = Number of samples used in computing the distribution.

$\bar{x}$ = Mean of the Normal distribution.

σ = Standard Deviation of the Normal distribution.

C.O.S = Coefficient of Skew.

C.O.K = Coefficient of Kurtosis.

β = Mean of the Gamma distribution.

α = Standard Deviation of the Gamma distribution.

VARIABLE		PRODUCT CODE				
		1	2	3	4	5
			*	**	***	
Loading Time (Hr/kg)	N	95	72	90	23	108
	$\bar{x}$	0,0003576	0,6148	0,3877	0,1886	0,0003589
	σ	0,0004063	0,1045	0,1073	0,04945	0,0003365
	C.O.S	1,099	1,243	0,4448	0,5955	2,670
	C.O.K	2,630	4,447	2,884	2,762	10,48
	α	0,7745	34,5957	13,0435	14,5561	1,1377
	β	0,0004	0,0177	0,0297	0,0129	0,0003
DISTRIBUTION		GAMMA	NORMAL	LOGNORMAL	LOGNORMAL	GAMMA
			*	**	***	
Unloading Time (Hr/kg)	N	95	72	90	23	108
	$\bar{x}$	0,0004384	0,8190	0,4118	0,1421	0,0003403
	σ	0,0005190	0,1132	0,1157	0,04442	0,0003183
	C.O.S	1,109	0,1770	0,5887	0,8434	2,064
	C.O.K	2,871	2,675	2,711	3,244	7,173
	α	0,7135	52,2575	12,6601	10,2422	1,143
	β	0,0006	0,0156	0,0325	0,0138	0,0002
DISTRIBUTION		GAMMA	NORMAL	LOGNORMAL	LOGNORMAL	GAMMA
Load Empty Time (Hr)	N	N/A	N/A	N/A	13	53
	$\bar{x}$				0,4869	0,7586
	σ				0,2908	0,4717
	C.O.S				0,6000	0,7339
	C.O.K				1,963	2,733
	α				2,8018	2,5868
	β				0,1737	0,2932
DISTRIBUTION					GAMMA	GAMMA
Unload Empty Time (Hr)	N	N/A	N/A	N/A	13	53
	$\bar{x}$				0,3784	0,7969
	σ				0,2047	0,5915
	C.O.S				1,059	1,613
	C.O.K				2,898	5,526
	α				3,4167	1,8152
	β				0,1107	0,4390
DISTRIBUTION					GAMMA	GAMMA

Note: * - per trip
** - per barrel
*** - per P.V

TABLE G1 (CONTD)

VARIABLE		PRODUCT CODE 1	2	3	4	5
Number of Orders Per Day	N	41	37	39	16	38
	$\bar{x}$	8,487	3,702	4,589	3,187	7,736
	σ	3,364	1,557	1,890	1,423	4,766
	C.O.S	-0,3598	0,1574	-0,0595	0,4470	1,108
	C.O.K	2,201	1,651	2,098	2,716	3,801
	α	6,363	5,653	5,892	5,012	2,635
	β	1,334	0,6549	0,7789	0,6360	2,937
DISTRIBUTION		GAMMA	GAMMA	GAMMA	GAMMA	GAMMA
Size of Order (kg)	N	348	N/A	179	51	294
	$\bar{x}$	4270		2,195	2,607	2158
	σ	6303		1,088	1,738	2472
	C.O.S	1,582		0,5680	0,9717	1,461
	C.O.K	4,240		2,033	2,616	4,534
	α	0,4590		4,067	2,250	0,7623
	β	9303,69		0,3598	1,159	2831,81
DISTRIBUTION		GAMMA		GAMMA	GAMMA	GAMMA
Time to Inspect (Hr)	N	423	423	423	423	423
	$\bar{x}$	0,3529	0,3529	0,3529	0,3529	0,3529
	σ	0,00702	0,07702	0,07702	0,07702	0,07702
	C.O.S	0,00453	0,00453	0,00453	0,00453	0,00453
	C.O.K	4,648	4,648	4,648	4,648	4,648
	α	20,994	20,994	20,994	20,994	20,994
	β	0,01681	0,01681	0,01681	0,01681	0,01681
DISTRIBUTION		NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
Lunch Time (Hr)	N	389	389	389	389	389
	$\bar{x}$	0,6712	0,6712	0,6712	0,6712	0,6712
	σ	0,02463	0,02463	0,02463	0,02463	0,02463
	C.O.S	0,01123	0,01123	0,01123	0,01123	0,01123
	C.O.K	3,276	3,276	3,276	3,276	3,276
	α	742,63	742,63	742,63	742,63	742,63
	β	0,0009038	0,0009038	0,0009038	0,0009038	0,0009038
DISTRIBUTION		NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
Repair Time (Hr)	N	58	58	58	58	58
	$\bar{x}$	2,106	2,106	2,106	2,106	2,106
	σ	1,584	1,584	1,584	1,584	1,584
	C.O.S	1,012	1,012	1,012	1,012	1,012
	C.O.K	3,266	3,266	3,266	3,266	3,266
	α	1,768	1,768	1,768	1,768	1,768
	β	1,191	1,191	1,191	1,191	1,191
DISTRIBUTION		GAMMA	GAMMA	GAMMA	GAMMA	GAMMA

TABLE G1 (CONTD)

VARIABLE		PRODUCT CODE 1	2	3	4	5
Km Travelled Per Trip	N	98	72	90	27	108
	$\bar{x}$	108,0	94,2	138,8	115,8	111,3
	σ	30,99	5,239	74,74	46,68	33,40
	C.O.S	0,6771	4,035	1,728	1,148	0,7813
	C.O.K	3,367	21,98	5,203	4,499	4,977
	α	12,16	323,4	3,448	6,616	11,11
	β	8,89	0,2913	40,25	18,81	10,02
DISTRIBUTION		LOGNORMAL	NORMAL	LOGNORMAL	LOGNORMAL	LOGNORMAL
Vehicle Speed (Km/Hr)	N	98	72	90	27	108
	$\bar{x}$	43,54	49,00	50,24	50,30	46,86
	σ	9,614	5,294	5,606	11,01	9,685
	C.O.S	0,7541	0,007807	0,2141	0,07590	0,5404
	C.O.K	3,835	7,798	4,092	3,308	5,514
	α	20,51	85,67	80,33	20,86	23,41
	β	2,123	0,5720	0,6254	2,411	2,002
DISTRIBUTION		NORMAL	NORMAL	NORMAL	LOGNORMAL	LOGNORMAL
Away Time Per Trip (Hr)	N	323	72	323	323	323
	$\bar{x}$	1,518	0,9905	1,518	1,518	1,518
	σ	0,7204	0,1093	0,7204	0,7204	0,7204
	C.O.S	1,098	2,463	1,098	1,098	1,098
	C.O.K	3,756	14,76	3,756	3,756	3,756
	α	4,442	82,00	4,442	4,442	4,442
	β	0,3418	0,0120	0,3418	0,3418	0,3418
DISTRIBUTION		GAMMA	NORMAL	GAMMA	GAMMA	GAMMA

TABLE G2 - Variables Used in the Model

DESCRIPTION	VALUE
Maximum waiting time for one Barrel only (Hour)	40,0
Maximum waiting time for one P.V. only (Hour)	40,0
Target demand time (Hour)	48,0
Maintenance time for vehicles (Hour)	24,0
Maintenance frequency for vehicles - Products 1, 3, 4, 5 (km)	5000,0
Maintenance time for forklift trucks (Hour)	5,0
Maintenance frequency for forklift trucks (day)	30,0
Time to change Horse/Trailer combination (Hour)	0,5
Time to change Barrel/Trailer combination (Hour)	1,0
Time to change Cradles (Hour)	0,5
Inspection time for vehicles (Hour)	0,353
Duration of lunch (Hour)	0,67
Time to wash Ammonium Nitrate Trailers - Friday p.m. (Hour)	0,5
Required % load utilization on vehicles for Products 1 & 5	70,0
Maximum overtime per trip	6,0
Probability of repair for vehicles	0,0972
Probability of taking empties (Products 4 & 5)	0,3241
Maintenance frequency for vehicles delivering Product 2 (day)	30,0

APPENDIX H

SIMULATION RESULTS FOR ACTUAL SITUATION

CURRENT TIME .4344+004
STATISTICAL ARRAYS CLEARED AT TIME .2880+004

1.**STATISTICS FOR VARIABLES BASED ON OBSERVATION**

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
DEMAND TIME P1	.650+002	.425+002	.653+000	.106+001	.189+003	109
TRIP TIME A P1	.139+002	.142+002	.102+001	.177+001	.887+002	109
TRIP TIME B P1	.141+002	.142+002	.100+001	.197+001	.887+002	109
TRIP TIME C P1	.145+002	.147+002	.101+001	.197+001	.887+002	109
DEMAND TIME P2	.234+002	.186+002	.796+000	.294+001	.912+002	167
TRIP TIME A P2	.337+001	.284+000	.845-001	.269+001	.410+001	167
TRIP TIME B P2	.361+001	.657+000	.182+000	.275+001	.652+001	167
TRIP TIME C P2	.419+001	.369+001	.881+000	.275+001	.275+002	167
DEMAND TIME P3	.372+002	.220+002	.589+000	.486+001	.989+002	104
TRIP TIME A P3	.641+001	.230+001	.360+000	.327+001	.179+002	104
TRIP TIME B P3	.660+001	.237+001	.359+000	.327+001	.179+002	104
TRIP TIME C P3	.776+001	.553+001	.713+000	.327+001	.316+002	104
DEMAND TIME P4	.195+002	.176+002	.901+000	.208+001	.911+002	64
TRIP TIME A P4	.476+001	.182+001	.382+000	.276+001	.111+002	64
TRIP TIME B P4	.493+001	.189+001	.384+000	.276+001	.111+002	64
TRIP TIME C P4	.568+001	.459+001	.809+000	.276+001	.295+002	64
DEMAND TIME P5	.561+002	.514+002	.917+000	.140+001	.193+003	115
TRIP TIME A P5	.545+001	.253+001	.464+000	.175+001	.129+002	115
TRIP TIME B P5	.554+001	.260+001	.470+000	.175+001	.129+002	115
TRIP TIME C P5	.596+001	.388+001	.651+000	.175+001	.288+002	115

2.**STATISTICS FOR TIME-PERSISTENT VARIABLES**

	MEAN VALUE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	TIME INTERVAL	CURRENT VALUE
KM TRAVELLED 412	1417.843	696.699	.00	2400.93	1464.000	2400.93
FUEL CONSUMED	215.512	105.898	.00	364.94	1464.000	364.94
KM TRAVELLED 414	1911.927	770.767	107.85	3017.73	1464.000	3017.73
FUEL CONSUMED	336.499	135.655	18.98	531.12	1464.000	531.12
KM TRAVELLED 467	2895.496	1468.430	169.38	5445.64	1464.000	5445.64
FUEL CONSUMED	810.739	411.160	47.43	1524.78	1464.000	1524.78
KM TRAVELLED 469	722.547	445.820	.00	1588.25	1464.000	1588.25
FUEL CONSUMED	192.920	119.034	.00	424.06	1464.000	424.06
KM TRAVELLED 471	3150.765	1724.395	.00	6270.41	1464.000	6270.41
FUEL CONSUMED	1112.220	608.711	.00	2213.45	1464.000	2213.45
KM TRAVELLED 472	3762.772	1787.646	213.63	6525.61	1464.000	6525.61
FUEL CONSUMED	1128.832	536.294	64.09	1957.68	1464.000	1957.68
KM TRAVELLED 305	2218.627	1166.885	115.94	4275.29	1464.000	4275.29
FUEL CONSUMED	998.382	525.098	52.17	1923.88	1464.000	1923.88
KM TRAVELLED 422	3847.515	2013.167	192.68	7115.66	1464.000	7115.66
FUEL CONSUMED	1719.839	899.886	86.13	3180.70	1464.000	3180.70
KM TRAVELLED 423	3423.062	1545.678	.00	5831.06	1464.000	5831.06
FUEL CONSUMED	1903.223	859.397	.00	3242.07	1464.000	3242.07
KM TRAVELLED 424	3702.209	1892.287	193.61	6939.75	1464.000	6939.75
FUEL CONSUMED	1788.167	913.974	93.51	3351.90	1464.000	3351.90
KM TRAVELLED 426	3566.429	1828.039	278.68	6559.67	1464.000	6559.67
FUEL CONSUMED	1868.809	957.893	146.03	3437.27	1464.000	3437.27
KM TRAVELLED 427	3995.182	2371.357	123.65	8275.88	1464.000	8275.88
FUEL CONSUMED	1614.053	958.028	49.95	3343.46	1464.000	3343.46
TOTAL KM	34614.345	17614.390	1395.42	64245.88	1464.000	64245.88
TOTAL FUEL	13689.182	7001.859	558.29	25495.31	1464.000	25495.31
TRIPS 4 BARRELS	44.975	24.919	3.00	86.00	1464.000	86.00
TRIPS 3 BARRELS	7.614	5.093	.00	17.00	1464.000	17.00
TRIPS 2 BARRELS	1.000	.000	1.00	1.00	1464.000	1.00
TRIPS 1 BARREL	.000	.000	.00	.00	1464.000	.00
TOTAL BARRELS	204.743	114.718	14.00	397.00	1464.000	397.00
NO. OF BARRELS	2.034	2.792	.00	8.00	1464.000	.00
NO. OF DRIVERS	6.467	2.045	1.00	12.00	1464.000	4.00
NO. OF ASSISTANT	7.903	2.739	1.00	15.00	1464.000	5.00
NO. OF TRUCKS	2.334	1.301	.00	6.00	1464.000	1.00
NO. OF HORSES	4.133	1.343	.00	6.00	1464.000	3.00
NO. OF TRAILERS	4.133	1.343	.00	6.00	1464.000	3.00
O. TIME WEEK END	91.885	49.212	.00	176.92	1464.000	176.92
O. TIME WEEK DAY	271.737	136.009	18.85	512.02	1464.000	512.02
TOTAL OVERTIME	363.622	183.986	18.85	688.94	1464.000	688.94
TRIPS N. TIME	141.020	74.111	4.00	266.00	1464.000	266.00
TRIPS WAITING	48.218	21.621	1.00	83.00	1464.000	83.00
TRIPS O. TIME	118.458	61.397	4.00	219.00	1464.000	219.00
NUMBER OF DAYS	151.000	17.607	121.00	182.00	1464.000	182.00
LOAD UTILIZATION	70.000	.000	70.00	70.00	1464.000	70.00

3.**FILE STATISTICS**

FILE NUMBER	ASSOC* NODE LABEL/TYPE		AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAIT TIME
1	AL1	AWAIT	.705	1.498	6	0	39.689
2	AL2	AWAIT	.824	1.225	5	1	26.210
3	AL3	AWAIT	.997	1.121	4	1	36.491
4	FORK	AWAIT	.011	.174	3	0	.145
5	AL4	AWAIT	1.252	1.854	10	0	10.974
6	AL5	AWAIT	1.393	1.435	6	0	19.796
7	GTRY	AWAIT	.007	.082	1	0	.096
8	BAR1	AWAIT	.000	.000	1	0	.000
9	BAR2	AWAIT	.000	.000	1	0	.000
10	BAR3	AWAIT	.009	.094	1	0	.227
11	FPT1	AWAIT	.013	.114	1	0	.186
12	FPT2	AWAIT	.002	.048	1	0	.059
13	AL6	AWAIT	.030	.170	1	0	2.737
14	AL7	AWAIT	.207	.434	2	0	6.439
15	AL8	AWAIT	.059	.238	2	0	3.750
16	AL9	AWAIT	.410	.692	4	0	13.055
17	AL10	AWAIT	1.686	2.287	9	0	52.517
18		CALENDAR	13.315	8.531	52	7	.759

Note: * - The meaning of each label is as follows:

AL1, 2, 3 :Allocation of small-sized, medium-sized and large-sized vehicles respectively for Product 1.
FORK :Forklift Truck.
AL4 :Allocation of vehicles for Product 2.
AL5 :Allocation of vehicles for Product 3.
GTRY :Gantry.
BAR1, 2, 3:Barrel Type 1, 2 and 3 respectively.
FPT1, 2 :Fillpoint 1 and 2 respectively.
AL6, 7 :Allocation of small-sized and large-sized vehicles respectively for Product 4.
AL8, 9, 10:Allocation of small-sized, medium-sized and large-sized vehicles respectively for Product 5.

4.**REGULAR ACTIVITY STATISTICS**

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
11 SMALL D. P1	.0000	.0000	1	0	20
12 MEDIUM D. P1	.0000	.0000	1	0	46
13 LARGE D. P1	.0000	.0000	1	0	40
14 CHG HORSE 1	.0058	.0760	1	0	17
15 NO REP VEH 1	.0000	.0000	1	0	98
16 REP VEH 1	.0145	.1194	1	0	11
21 CHG HORSE 2	.0068	.0824	1	0	20
22 WASH VEH 2	.0092	.1089	3	0	27
23 REP VEH 2	.0187	.1390	2	0	15
24 NO REP VEH 2	.0000	.0000	1	0	152
30 BARREL 1	.0000	.0000	1	0	225
31 BARREL 2	.0000	.0000	1	0	90
32 BARREL 3	.0000	.0000	1	0	69
33 CHG BARREL	.0704	.2557	1	0	103
34 CHG HORSE 3	.0109	.1040	1	0	32
35 FILLPT 2 ONLY	.0000	.0000	0	0	0
36 FILLPT 1 ONLY	.0000	.0000	1	0	47
37 BOTH FILLPTS	.0000	.0000	1	0	57
38 NO REP VEH 3	.0000	.0000	1	0	94
39 REP VEH 3	.0139	.1171	1	0	10
41 CHG CRADLE	.0000	.0000	0	0	0
42 P5 WITH VEH 4	.0000	.0000	0	0	0
43 NO REP VEH 4	.0000	.0000	1	0	58
44 REP VEH 4	.0073	.0853	1	0	6
51 SMALL D. P5	.0000	.0000	1	0	23
52 MEDIUM D. P5	.0000	.0000	1	0	46
53 LARGE D. P5	.0000	.0000	1	0	39
54 NO REP VEH 5	.0000	.0000	1	0	110
55 REP VEH 5	.0070	.0831	1	0	5

5. **RESOURCE STATISTICS**

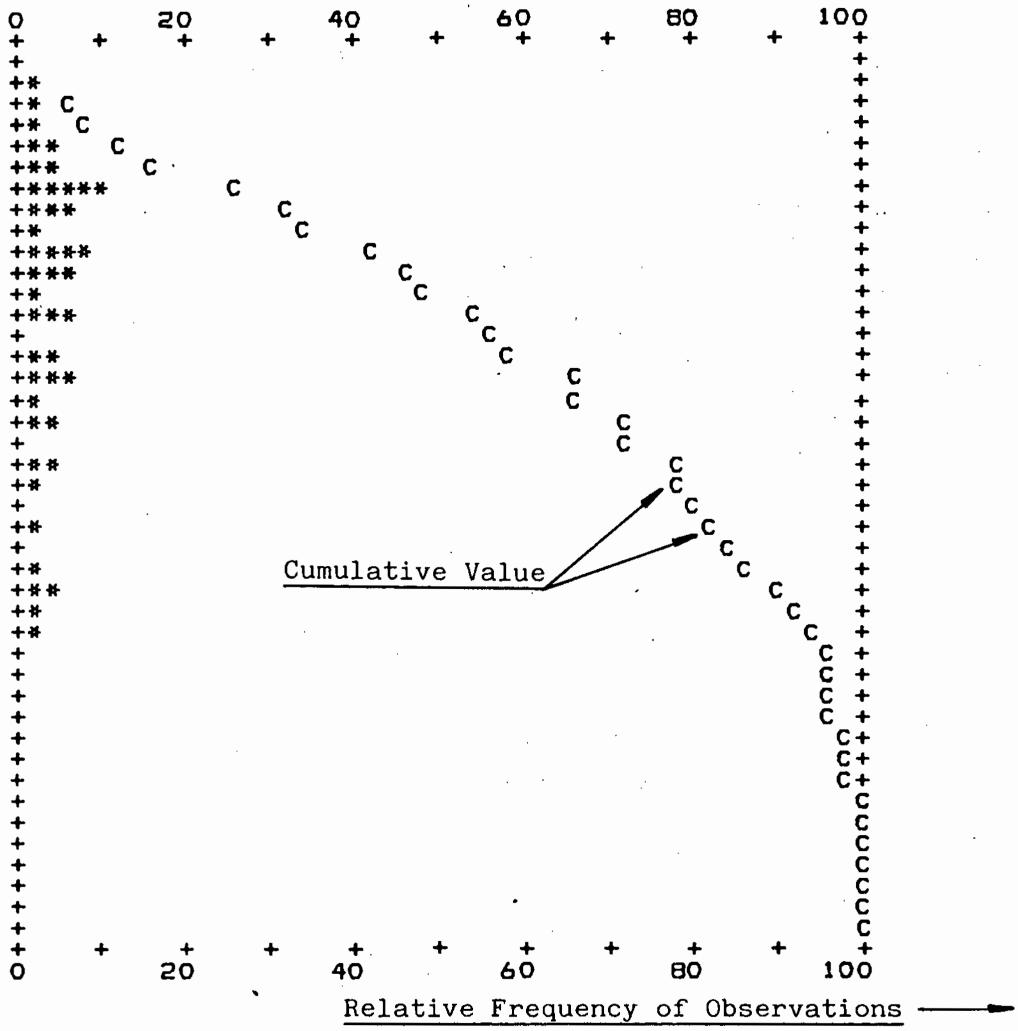
RESOURCE NUMBER	RESOURCE LABEL	CURRENT CAPACITY	AVERAGE UTIL	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL
1	TRUCK412	0	.19	.393	1	0
2	TRUCK414	0	.39	.487	1	0
3	TRUCK467	0	.41	.492	1	0
4	TRUCK469	0	.18	.384	1	0
5	TRUCK471	0	.53	.499	1	0
6	TRUCK472	0	.64	.481	1	1
7	HORSE305	0	.67	.469	1	0
8	HORSE422	0	.71	.453	1	1
9	HORSE423	0	.60	.489	1	0
10	HORSE424	0	.76	.424	1	1
11	HORSE426	0	.72	.448	1	1
12	HORSE427	0	.66	.475	1	0
13	TRAIL318	0	.62	.485	1	0
14	TRAIL430	0	.61	.488	1	1
15	TRAIL431	0	.68	.467	1	0
16	TRAIL438	0	.67	.469	1	0
17	TRAIL441	0	.78	.416	1	0
18	TRAIL449	0	.54	.499	1	1
19	TRAIL453	0	.23	.423	1	1
20	GANTRY	1	.07	.256	1	0
21	FILLPT1	1	.09	.281	1	0
22	FILLPT2	1	.02	.141	1	0
23	FORKLIFT	5	.35	.620	3	0
24	BARREL1	7	1.20	1.748	7	0
25	BARREL2	6	.45	.864	5	0
26	BARREL3	3	.39	.719	3	0
27	CRADLE2	2	2.00	.000	2	2
28	CRADLE3	2	2.00	.000	2	2

RESOURCE NUMBER	RESOURCE LABEL	CURRENT AVAILABLE	AVERAGE AVAILABLE	MINIMUM AVAILABLE	MAXIMUM AVAILABLE
1	TRUCK412	0	.7666	-1	1
2	TRUCK414	0	.5702	-1	1
3	TRUCK467	0	.5448	-1	1
4	TRUCK469	0	.7781	-1	1
5	TRUCK471	0	.4291	-1	1
6	TRUCK472	-1	.3213	-1	1
7	HORSE305	0	.2836	-1	1
8	HORSE422	-1	.2450	-1	1
9	HORSE423	0	.3536	-1	1
10	HORSE424	-1	.1928	-1	1
11	HORSE426	-1	.2359	-1	1
12	HORSE427	0	.3003	-1	1
13	TRAIL318	0	.3353	-1	1
14	TRAIL430	-1	.3472	-1	1
15	TRAIL431	0	.2786	-1	1
16	TRAIL438	0	.2836	-1	1
17	TRAIL441	0	.1798	-1	1
18	TRAIL449	-1	.4201	-1	1
19	TRAIL453	-1	.7239	-1	1
20	GANTRY	1	.9017	-1	1
21	FILLPT1	1	.8857	-1	1
22	FILLPT2	1	.9519	-1	1
23	FORKLIFT	5	4.6120	0	5
24	BARREL1	7	5.8021	0	7
25	BARREL2	6	5.5530	1	6
26	BARREL3	3	2.6110	0	3
27	CRADLE2	0	.0000	0	0
28	CRADLE3	0	.0000	0	0

HISTOGRAM NUMBER 1
DEMAND TIME P1

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
3	.028	.500+001
3	.028	.100+002
2	.018	.150+002
4	.037	.200+002
5	.046	.250+002
11	.101	.300+002
6	.055	.350+002
3	.028	.400+002
8	.073	.450+002
6	.055	.500+002
2	.018	.550+002
6	.055	.600+002
1	.009	.650+002
4	.037	.700+002
7	.064	.750+002
2	.018	.800+002
5	.046	.850+002
1	.009	.900+002
5	.046	.950+002
2	.018	.100+003
1	.009	.105+003
3	.028	.110+003
1	.009	.115+003
3	.028	.120+003
4	.037	.125+003
3	.028	.130+003
2	.018	.135+003
1	.009	.140+003
0	.000	.145+003
1	.009	.150+003
0	.000	.155+003
1	.009	.160+003
0	.000	.165+003
1	.009	.170+003
1	.009	.175+003
0	.000	.180+003
0	.000	.185+003
1	.009	.190+003
0	.000	.195+003
0	.000	.200+003
0	.000	INF

109		

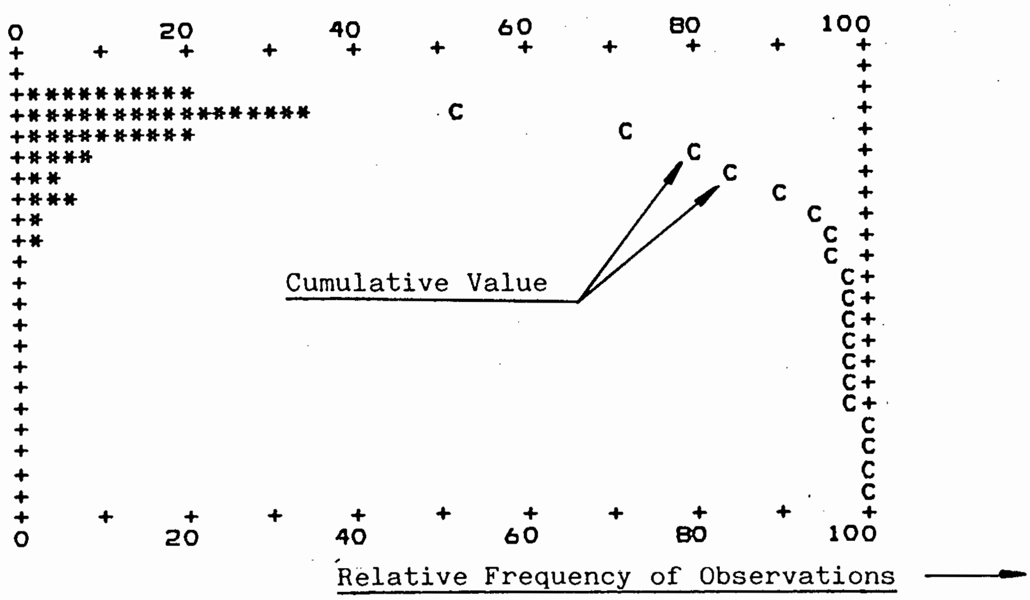


STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
DEMAND TIME P1	.650+002	.425+002	.653+000	.106+001	.189+003	109

HISTOGRAM NUMBER 2
TRIP TIME A P1

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
21	.193	.500+001
36	.330	.100+002
22	.202	.150+002
9	.083	.200+002
4	.037	.250+002
7	.064	.300+002
3	.028	.350+002
3	.028	.400+002
0	.000	.450+002
1	.009	.500+002
0	.000	.550+002
1	.009	.600+002
0	.000	.650+002
0	.000	.700+002
0	.000	.750+002
0	.000	.800+002
1	.009	.850+002
1	.009	.900+002
0	.000	.950+002
0	.000	INF
109		

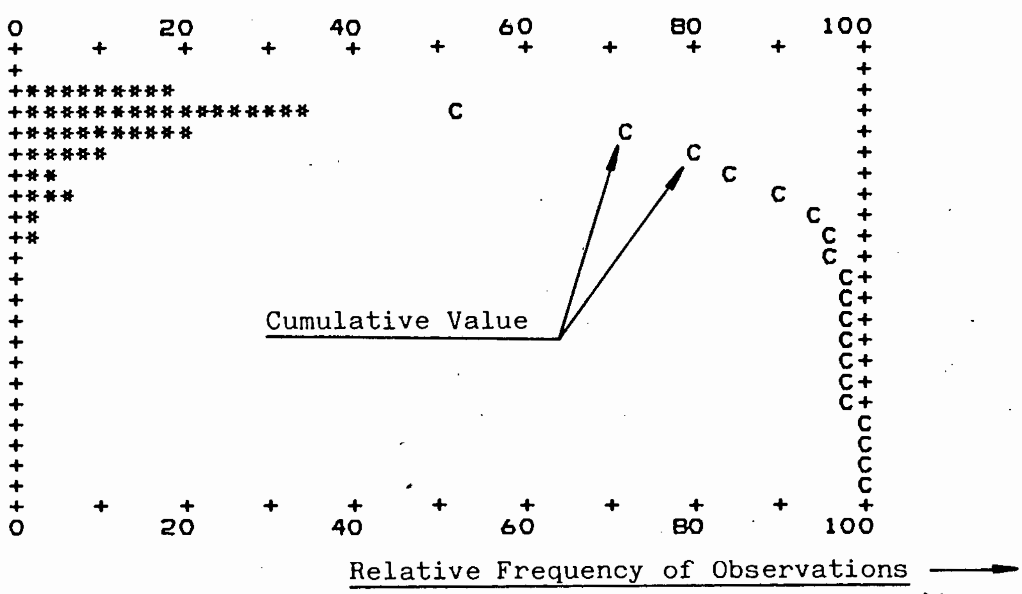


STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME A P1	.139+002	.142+002	.102+001	.177+001	.887+002	109

HISTOGRAM NUMBER 3
TRIP TIME B P1

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
19	.174	.500+001
38	.349	.100+002
21	.193	.150+002
10	.092	.200+002
4	.037	.250+002
7	.064	.300+002
3	.028	.350+002
3	.028	.400+002
0	.000	.450+002
1	.009	.500+002
0	.000	.550+002
1	.009	.600+002
0	.000	.650+002
0	.000	.700+002
0	.000	.750+002
0	.000	.800+002
1	.009	.850+002
1	.009	.900+002
0	.000	.950+002
0	.000	INF
109		

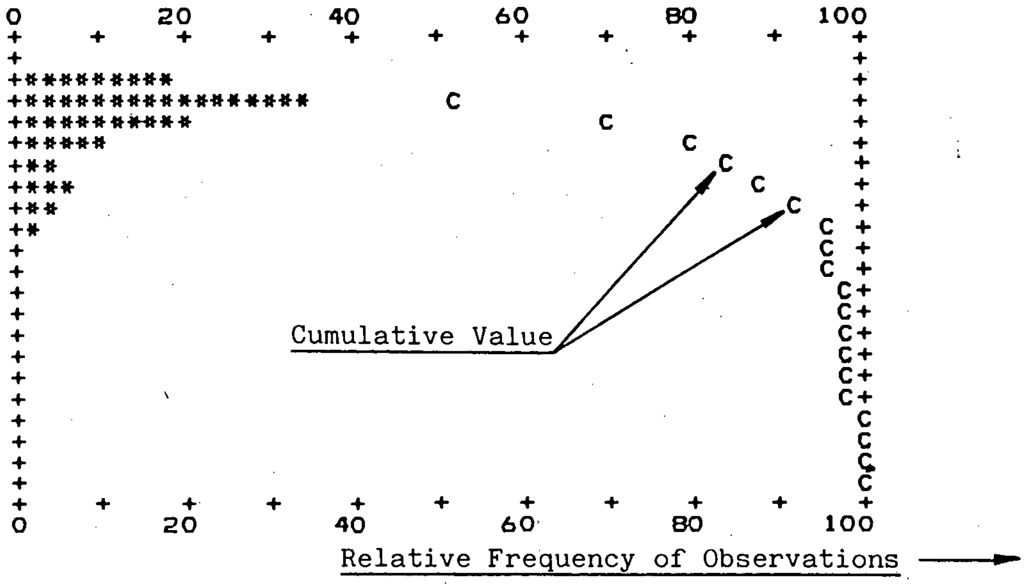


STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME B P1	.141+002	.142+002	.100+001	.197+001	.887+002	109

HISTOGRAM NUMBER 4
TRIP TIME C P1

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
19	.174	.500+001
37	.339	.100+002
21	.193	.150+002
10	.092	.200+002
4	.037	.250+002
6	.055	.300+002
4	.037	.350+002
3	.028	.400+002
0	.000	.450+002
1	.009	.500+002
1	.009	.550+002
1	.009	.600+002
0	.000	.650+002
0	.000	.700+002
0	.000	.750+002
0	.000	.800+002
1	.009	.850+002
1	.009	.900+002
0	.000	.950+002
0	.000	INF
109		

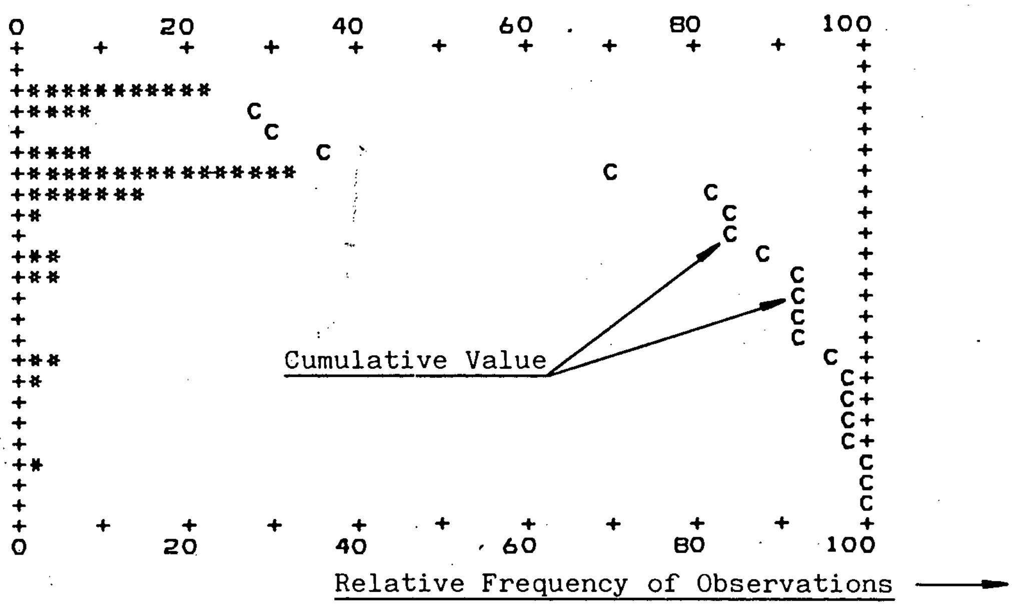


STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME C P1	.145+002	.147+002	.101+001	.197+001	.887+002	109

HISTOGRAM NUMBER 5
DEMAND TIME P2

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
36	.216	.500+001
12	.072	.100+002
1	.006	.150+002
12	.072	.200+002
55	.329	.250+002
22	.132	.300+002
3	.018	.350+002
0	.000	.400+002
7	.042	.450+002
6	.036	.500+002
0	.000	.550+002
0	.000	.600+002
0	.000	.650+002
6	.036	.700+002
4	.024	.750+002
1	.006	.800+002
0	.000	.850+002
0	.000	.900+002
2	.012	.950+002
0	.000	.100+003
0	.000	INF
167		



STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
DEMAND TIME P2	.234+002	.186+002	.796+000	.294+001	.912+002	167

```
                         **HISTOGRAM NUMBER 6**
                            TRIP TIME A P2

OBS  RELA    UPPER
FREQ FREQ   CELL LIM 0         20        40        60        80        100
                     +    +    +    +    +    +    +    +    +    +    +
  0  .000   .000     +                                                  +
  0  .000   .100+001 +                                                  +
  0  .000   .200+001 +                                                  +
 16  .096   .300+001 +*****                                             +
150  .898   .400+001 +********************************************      C
  1  .006   .500+001 +                                                  C
  0  .000   .600+001 +                 Cumulative Value                 C
  0  .000     INF    +                                                  C
---                  +    +    +    +    +    +    +    +    +    +    +
167                  0         20        40        60        80        100
                                   Relative Frequency of Observations
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME A P2	.337+001	.284+000	.845-001	.269+001	.410+001	167

```
                         **HISTOGRAM NUMBER 7**
                            TRIP TIME B P2

OBS  RELA    UPPER
FREQ FREQ   CELL LIM 0         20        40        60        80        100
                     +    +    +    +    +    +    +    +    +    +    +
  0  .000   .000     +                                                  +
  0  .000   .100+001 +                                                  +
  0  .000   .200+001 +                                                  +
 12  .072   .300+001 +****                                              +
126  .754   .400+001 +**************************************  C         +
 22  .132   .500+001 +*******                                        C  +
  3  .018   .600+001 +*                                               C +
  4  .024   .700+001 +*                Cumulative Value                 C
  0  .000   .800+001 +                                                  C
  0  .000     INF    +                                                  C
---                  +    +    +    +    +    +    +    +    +    +    +
167                  0         20        40        60        80        100
                                   Relative Frequency of Observations
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME B P2	.361+001	.657+000	.182+000	.275+001	.652+001	167

HISTOGRAM NUMBER 8
TRIP TIME C P2

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
0	.000	.100+001
0	.000	.200+001
11	.066	.300+001
123	.737	.400+001
22	.132	.500+001
3	.018	.600+001
4	.024	.700+001
0	.000	.800+001
0	.000	.900+001
0	.000	.100+002
0	.000	.110+002
0	.000	.120+002
0	.000	.130+002
0	.000	.140+002
0	.000	.150+002
0	.000	.160+002
0	.000	.170+002
0	.000	.180+002
0	.000	.190+002
0	.000	.200+002
0	.000	.210+002
0	.000	.220+002
0	.000	.230+002
0	.000	.240+002
0	.000	.250+002
0	.000	.260+002
1	.006	.270+002
3	.018	.280+002
0	.000	.290+002
0	.000	INF
167		

0 20 40 60 80 100

Cumulative Value

Relative Frequency of Observations →

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME C P2	.419+001	.369+001	.881+000	.275+001	.275+002	167

HISTOGRAM NUMBER 9
DEMAND TIME P3

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
1	.010	.500+001
6	.058	.100+002
2	.019	.150+002
0	.000	.200+002
19	.183	.250+002
29	.279	.300+002
9	.087	.350+002
2	.019	.400+002
5	.048	.450+002
13	.125	.500+002
1	.010	.550+002
0	.000	.600+002
0	.000	.650+002
5	.048	.700+002
3	.029	.750+002
4	.038	.800+002
0	.000	.850+002
0	.000	.900+002
2	.019	.950+002
3	.029	.100+003
0	.000	.105+003
0	.000	INF
104		

0 20 40 60 80 100

Cumulative Value

Relative Frequency of Observations →

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
DEMAND TIME P3	.372+002	.220+002	.589+000	.486+001	.989+002	104

```
                        **HISTOGRAM NUMBER10**
                            TRIP TIME A P3

OBS  RELA    UPPER
FREQ FREQ   CELL LIM 0         20        40        60        80        100
                     +    +    +    +    +    +    +    +    +    +    +
   0  .000   .000    +                                                 +
   0  .000   .200+001 +                                                +
   7  .067   .400+001 +***                                             +
  49  .471   .600+001 +************************  C                     +
  34  .327   .800+001 +****************                          C      +
   9  .087   .100+002 +****                                          C +
   2  .019   .120+002 +*                                              C+
   1  .010   .140+002 +                                               C+
   0  .000   .160+002 +                                               C+
   2  .019   .180+002 +*                                               C
   0  .000   .200+002 +                                                C
   0  .000     INF    +                                                C
 ---                  +    +    +    +    +    +    +    +    +    +    +
 104                  0         20        40        60        80        100
```

Cumulative Value

Relative Frequency of Observations

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME A P3	.641+001	.230+001	.360+000	.327+001	.179+002	104

```
                        **HISTOGRAM NUMBER11**
                            TRIP TIME B P3

OBS  RELA    UPPER
FREQ FREQ   CELL LIM 0         20        40        60        80        100
                     +    +    +    +    +    +    +    +    +    +    +
   0  .000   .000    +                                                 +
   0  .000   .200+001 +                                                +
   5  .048   .400+001 +**                                              +
  49  .471   .600+001 +************************  C                     +
  31  .298   .800+001 +***************                          C      +
  12  .115   .100+002 +******                                       C  +
   4  .038   .120+002 +**                                             C+
   1  .010   .140+002 +                                               C+
   0  .000   .160+002 +                                               C+
   2  .019   .180+002 +*                                               C
   0  .000   .200+002 +                                                C
   0  .000     INF    +                                                C
 ---                  +    +    +    +    +    +    +    +    +    +    +
 104                  0         20        40        60        80        100
```

Cumulative Value

Relative Frequency of Observations

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME B P3	.660+001	.237+001	.359+000	.327+001	.179+002	104

HISTOGRAM NUMBER12
TRIP TIME C P3

OBS FREQ	RELA FREQ	UPPER CELL LIM	0 20 40 60 80 100
0	.000	.000	+
0	.000	.200+001	+
5	.048	.400+001	+**
46	.442	.600+001	+********************** C
29	.279	.800+001	+************** C
12	.115	.100+002	+****** C
4	.038	.120+002	+** C
1	.010	.140+002	+ C
0	.000	.160+002	+ C
2	.019	.180+002	+* C
0	.000	.200+002	+ C
0	.000	.220+002	+ C
0	.000	.240+002	+ C
0	.000	.260+002	+ C
0	.000	.280+002	+ C
3	.029	.300+002	+* C
2	.019	.320+002	+* C
0	.000	.340+002	+ C
0	.000	INF	+ C
104			0 20 40 60 80 100

Cumulative Value

Relative Frequency of Observations →

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME C P3	.776+001	.553+001	.713+000	.327+001	.316+002	104

HISTOGRAM NUMBER13
DEMAND TIME P4

OBS FREQ	RELA FREQ	UPPER CELL LIM	0 20 40 60 80 100
0	.000	.000	+
17	.266	.500+001	+*************
4	.063	.100+002	+*** C
0	.000	.150+002	+ C
13	.203	.200+002	+********** C
20	.313	.250+002	+****************
4	.063	.300+002	+*** C
0	.000	.350+002	+ C
0	.000	.400+002	+ C
1	.016	.450+002	+* C
1	.016	.500+002	+* C
0	.000	.550+002	+ C
0	.000	.600+002	+ C
0	.000	.650+002	+ C
2	.031	.700+002	+** C
1	.016	.750+002	+* C
0	.000	.800+002	+ C
0	.000	.850+002	+ C
0	.000	.900+002	+ C
1	.016	.950+002	+* C
0	.000	.100+003	+ C
0	.000	INF	+ C
64			0 20 40 60 80 100

Cumulative Value

Relative Frequency of Observations →

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
DEMAND TIME P4	.195+002	.176+002	.901+000	.208+001	.911+002	64

HISTOGRAM NUMBER14

TRIP TIME A P4

OBS FREQ	RELA FREQ	UPPER CELL LIM	0 20 40 60 80 100
0	.000	.000	+
0	.000	.100+001	+
0	.000	.200+001	+
3	.047	.300+001	+**
24	.375	.400+001	+*******************
15	.234	.500+001	+***********
13	.203	.600+001	+**********
4	.063	.700+001	+***
0	.000	.800+001	+
1	.016	.900+001	+*
2	.031	.100+002	+**
1	.016	.110+002	+*
1	.016	.120+002	+*
0	.000	.130+002	+
0	.000	INF	+

64			

Cumulative Value

Relative Frequency of Observations

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME A P4	.476+001	.182+001	.382+000	.276+001	.111+002	64

HISTOGRAM NUMBER15

TRIP TIME B P4

OBS FREQ	RELA FREQ	UPPER CELL LIM	0 20 40 60 80 100
0	.000	.000	+
0	.000	.100+001	+
0	.000	.200+001	+
3	.047	.300+001	+**
21	.328	.400+001	+****************
15	.234	.500+001	+************
14	.219	.600+001	+***********
4	.063	.700+001	+***
2	.031	.800+001	+**
1	.016	.900+001	+*
1	.016	.100+002	+*
1	.016	.110+002	+*
2	.031	.120+002	+**
0	.000	.130+002	+
0	.000	INF	+

64			

Cumulative Value

Relative Frequency of Observations

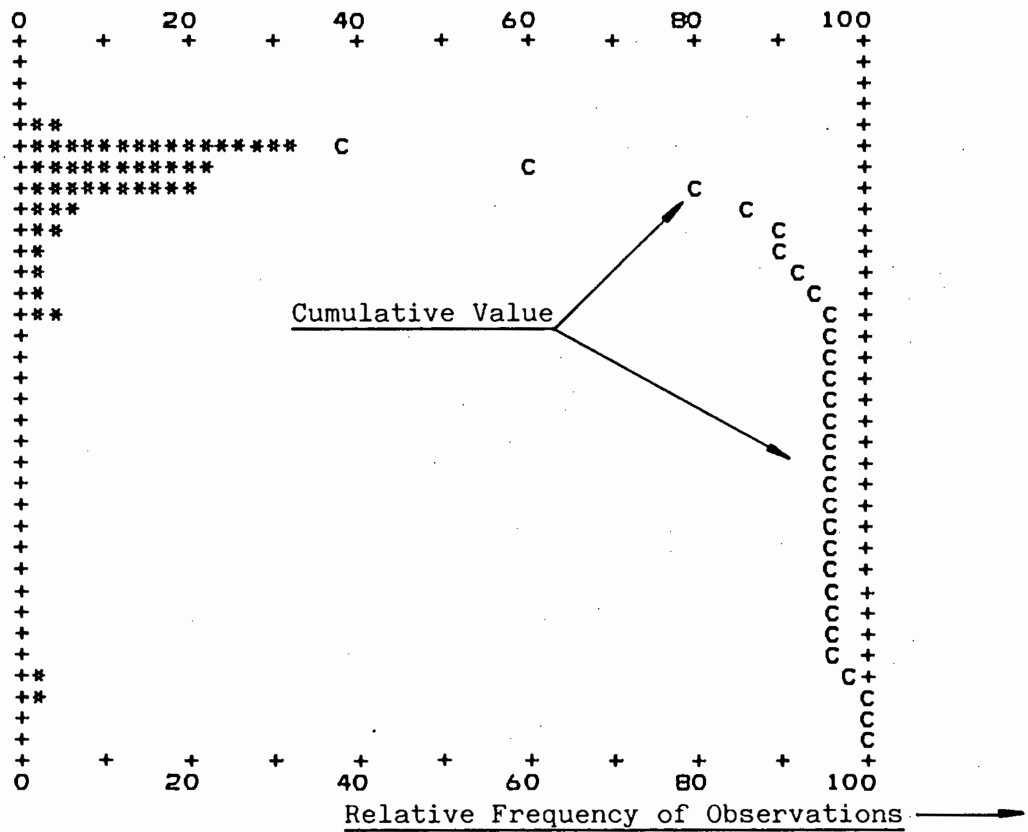
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME B P4	.493+001	.189+001	.384+000	.276+001	.111+002	64

HISTOGRAM NUMBER16
TRIP TIME C P4

OBS FREQ	RELA FREQ	UPPER CELL LIM
0	.000	.000
0	.000	.100+001
0	.000	.200+001
3	.047	.300+001
21	.328	.400+001
14	.219	.500+001
13	.203	.600+001
4	.063	.700+001
2	.031	.800+001
1	.016	.900+001
1	.016	.100+002
1	.016	.110+002
2	.031	.120+002
0	.000	.130+002
0	.000	.140+002
0	.000	.150+002
0	.000	.160+002
0	.000	.170+002
0	.000	.180+002
0	.000	.190+002
0	.000	.200+002
0	.000	.210+002
0	.000	.220+002
0	.000	.230+002
0	.000	.240+002
0	.000	.250+002
0	.000	.260+002
0	.000	.270+002
0	.000	.280+002
1	.016	.290+002
1	.016	.300+002
0	.000	.310+002
0	.000	INF

64		



STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME C P4	.568+001	.459+001	.809+000	.276+001	.295+002	64

HISTOGRAM NUMBER17
DEMAND TIME P5

OBS FREQ	RELA FREQ	UPPER CELL LIM	0 + 20 + 40 + 60 + 80 + 100
0	.000	.000	+
12	.104	.500+001	+*****
4	.035	.100+002	+**
0	.000	.150+002	+
13	.113	.200+002	+******
19	.165	.250+002	+********
10	.087	.300+002	+****
3	.026	.350+002	+*
1	.009	.400+002	+
4	.035	.450+002	+**
4	.035	.500+002	+**
4	.035	.550+002	+**
2	.017	.600+002	+*
0	.000	.650+002	+
0	.000	.700+002	+
5	.043	.750+002	+**
3	.026	.800+002	+*
0	.000	.850+002	+
1	.009	.900+002	+
2	.017	.950+002	+*
7	.061	.100+003	+***
2	.017	.105+003	+*
0	.000	.110+003	+
0	.000	.115+003	+
2	.017	.120+003	+*
2	.017	.125+003	+*
0	.000	.130+003	+
0	.000	.135+003	+
0	.000	.140+003	+
3	.026	.145+003	+*
4	.035	.150+003	+**
1	.009	.155+003	+
0	.000	.160+003	+
1	.009	.165+003	+
3	.026	.170+003	+*
0	.000	.175+003	+
1	.009	.180+003	+
0	.000	.185+003	+
0	.000	.190+003	+
2	.017	.195+003	+*
0	.000	.200+003	+
0	.000	INF	+
115			0 20 40 60 80 100

Cumulative Value (C)

Relative Frequency of Observations →

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
DEMAND TIME P5	.561+002	.514+002	.917+000	.140+001	.193+003	115

HISTOGRAM NUMBER18
TRIP TIME A P5

OBS FREQ	RELA FREQ	UPPER CELL LIM	0 + 20 + 40 + 60 + 80 + 100
0	.000	.000	+
1	.009	.200+001	+
36	.313	.400+001	+****************
41	.357	.600+001	+******************
20	.174	.800+001	+*********
8	.070	.100+002	+***
7	.061	.120+002	+***
2	.017	.140+002	+*
0	.000	.160+002	+
0	.000	INF	+
115			0 20 40 60 80 100

Cumulative Value (C)

Relative Frequency of Observations →

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME A P5	.545+001	.253+001	.464+000	.175+001	.129+002	115

```
                        **HISTOGRAM NUMBER19**
                          TRIP TIME B'P5

OBS   RELA    UPPER
FREQ  FREQ  CELL LIM 0         20         40         60         80        100
                     +    +    +    +    +    +    +    +    +    +    +
  0   .000  .000     +                                                    +
  1   .009  .200+001 +                                                    +
 35   .304  .400+001 +***************C                                    +
 41   .357  .600+001 +*******************                C                +
 20   .174  .800+001 +**********                                   C      +
  8   .070  .100+002 +***                                              C  +
  7   .061  .120+002 +***             Cumulative Value                   C+
  3   .026  .140+002 +**                                                  C
  0   .000  .160+002 +                                                    C
  0   .000    INF    +                                                    C
 ---                 +    +    +    +    +    +    +    +    +    +    +
115                  0         20         40         60         80        100
                                   Relative Frequency of Observations
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME B P5	.554+001	.260+001	.470+000	.175+001	.129+002	115

```
                        **HISTOGRAM NUMBER20**
                          TRIP TIME C P5

OBS   RELA    UPPER
FREQ  FREQ  CELL LIM 0         20         40         60         80        100
                     +    +    +    +    +    +    +    +    +    +    +
  0   .000  .000     +                                                    +
  1   .009  .200+001 +                                                    +
 34   .296  .400+001 +***************                                     +
 40   .348  .600+001 +******************                 C                +
 20   .174  .800+001 +**********                                  C       +
  8   .070  .100+002 +***                                             C   +
  7   .061  .120+002 +***             Cumulative Value                 C  +
  3   .026  .140+002 +**                                                 C+
  0   .000  .160+002 +                                                   C+
  0   .000  .180+002 +                                                   C+
  0   .000  .200+002 +                                                   C+
  0   .000  .220+002 +                                                   C+
  0   .000  .240+002 +                                                   C+
  0   .000  .260+002 +                                                   C+
  1   .009  .280+002 +                                                    C
  1   .009  .300+002 +                                                    C
  0   .000  .320+002 +                                                    C
  0   .000    INF    +                                                    C
 ---                 +    +    +    +    +    +    +    +    +    +    +
115                  0         20         40         60         80        100
                                   Relative Frequency of Observations
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRIP TIME C P5	.596+001	.388+001	.651+000	.175+001	.288+002	115

TABLE NUMBER 1
RUN NUMBER 1

DAY	NO. OF D RIVERS	NO. OF A SSISTANT
MINIMUM	.1000+001	.1000+001
MAXIMUM	.9000+001	.1100+002

PLOT NUMBER 1
RUN NUMBER 1

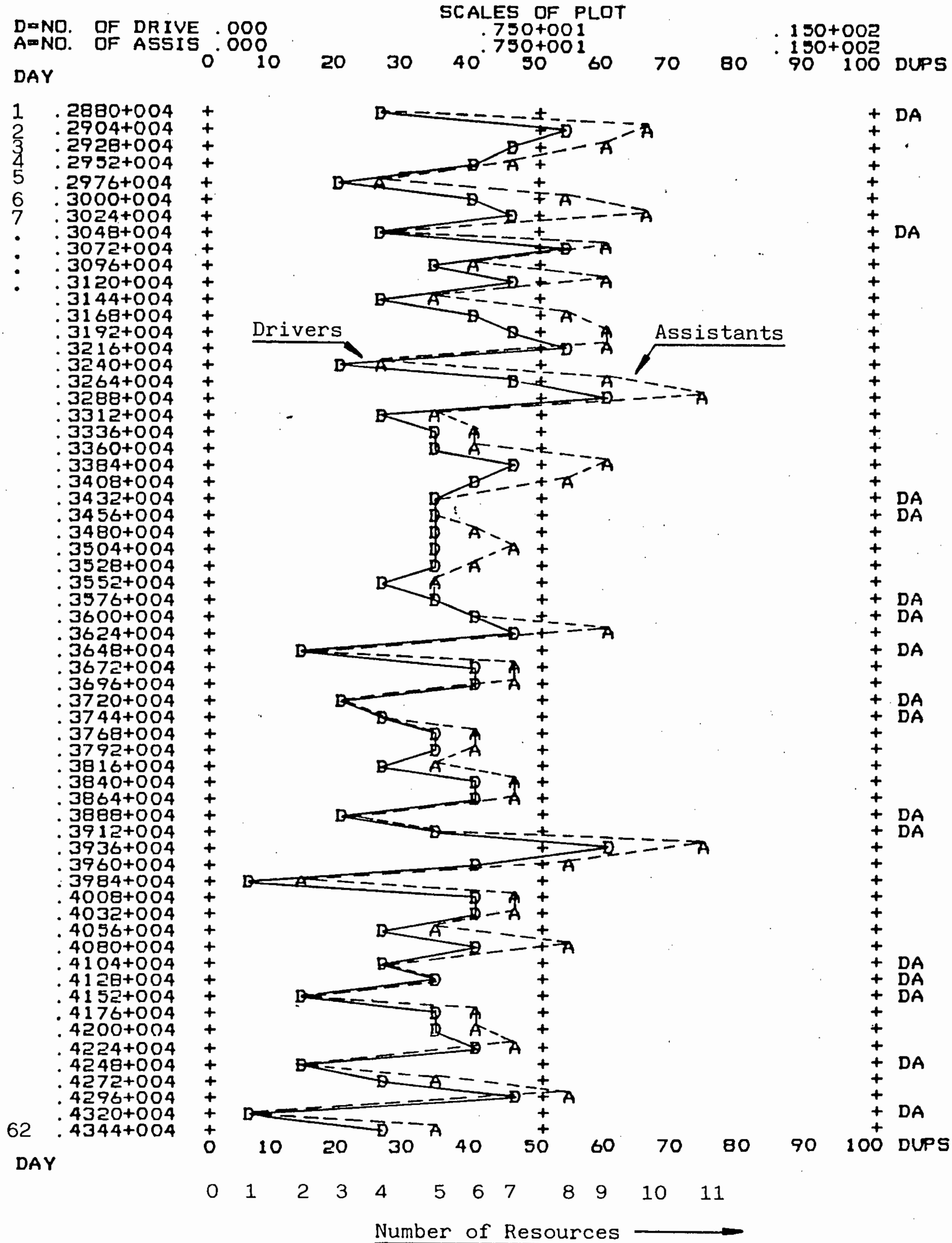


TABLE NUMBER 2
RUN NUMBER 1

DAY	NO. OF T RUCKS	NO. OF H ORSES	NO. OF T RAILERS
MINIMUM	.0000	.0000	.0000
MAXIMUM	.4000+001	.6000+001	.6000+001

**PLOT NUMBER **
RUN NUMBER 1

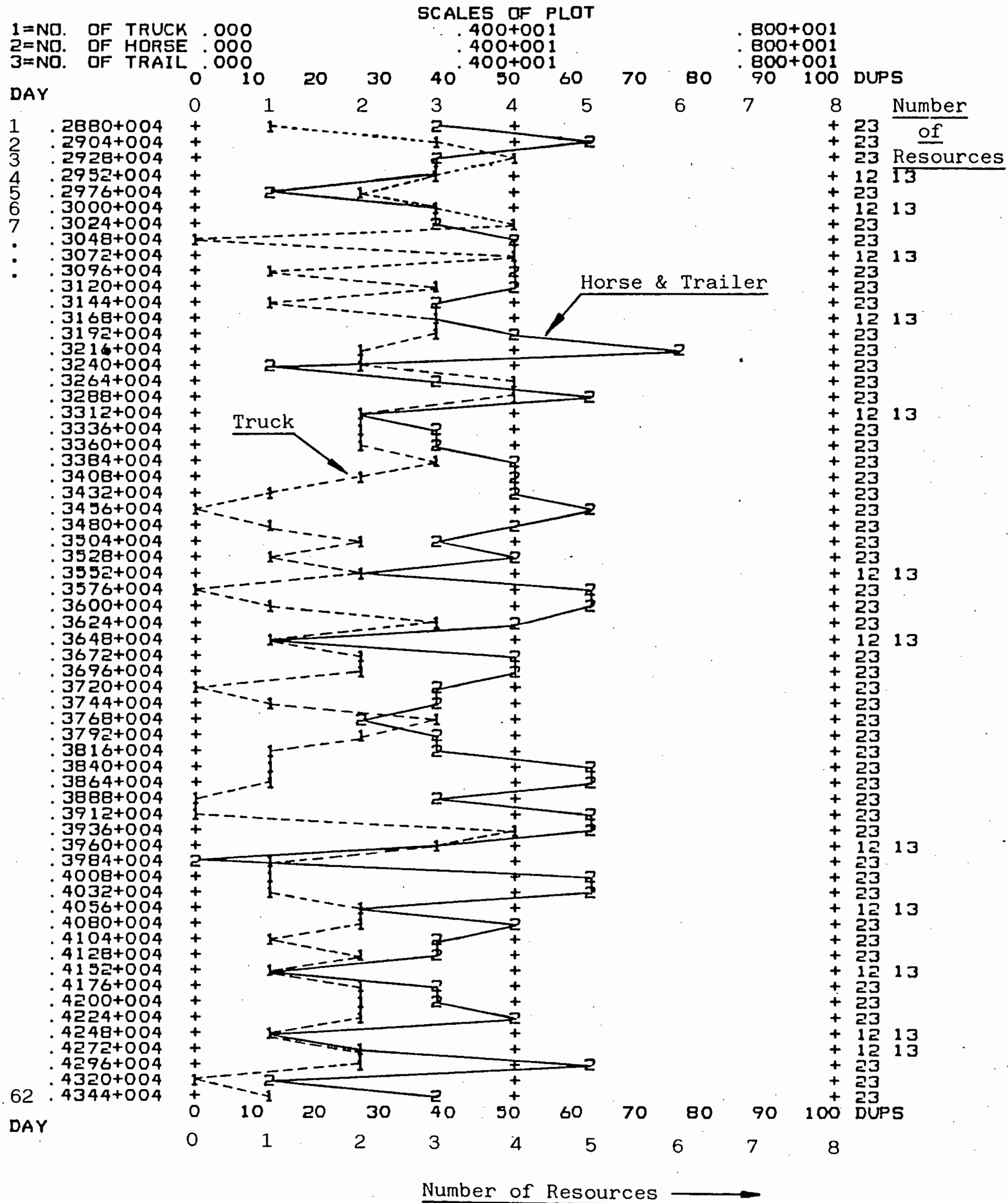


TABLE NUMBER 3
RUN NUMBER 1

DAY	NO. OF BARRELS
MINIMUM	.0000
MAXIMUM	.8000+001

PLOT NUMBER 3
RUN NUMBER 1

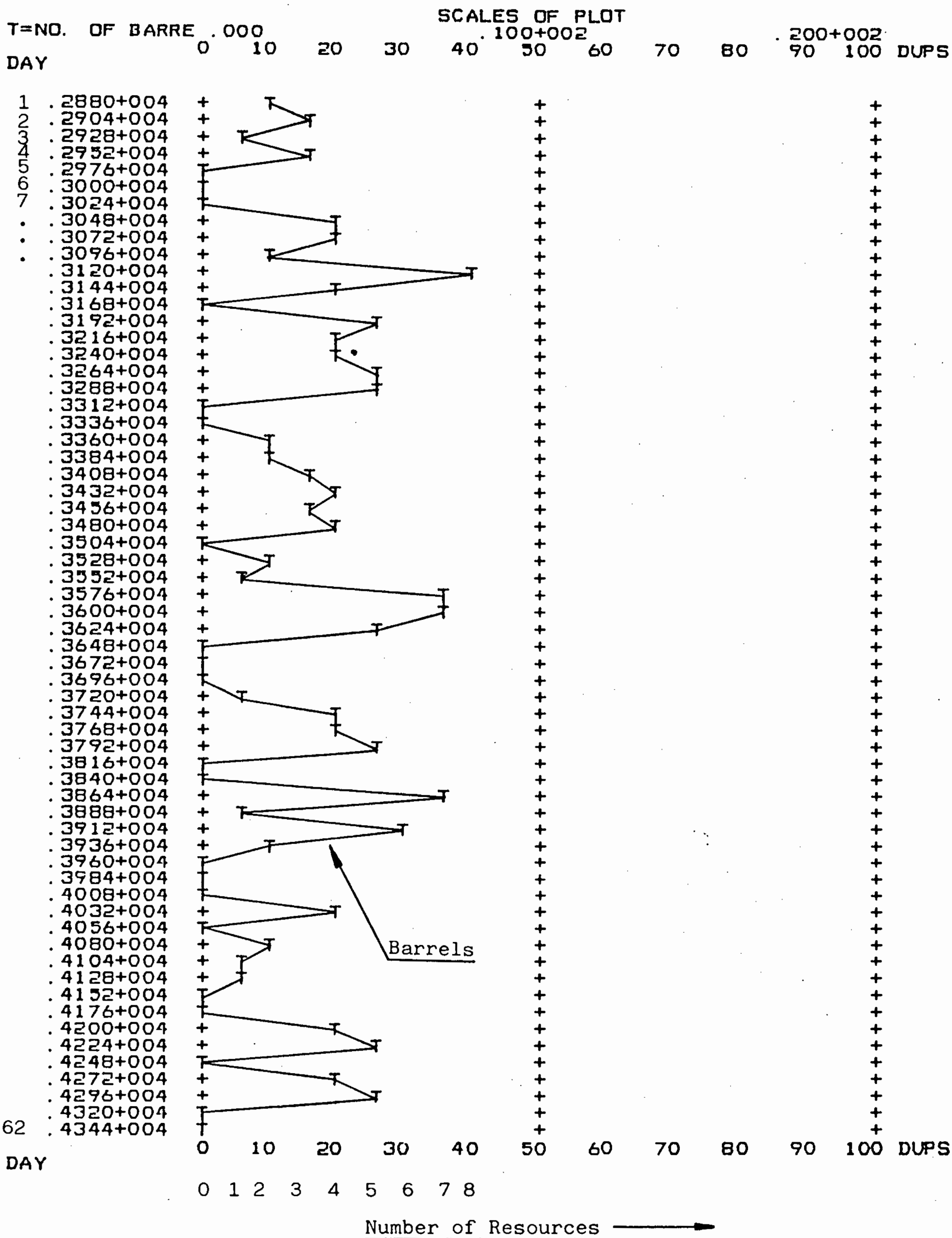
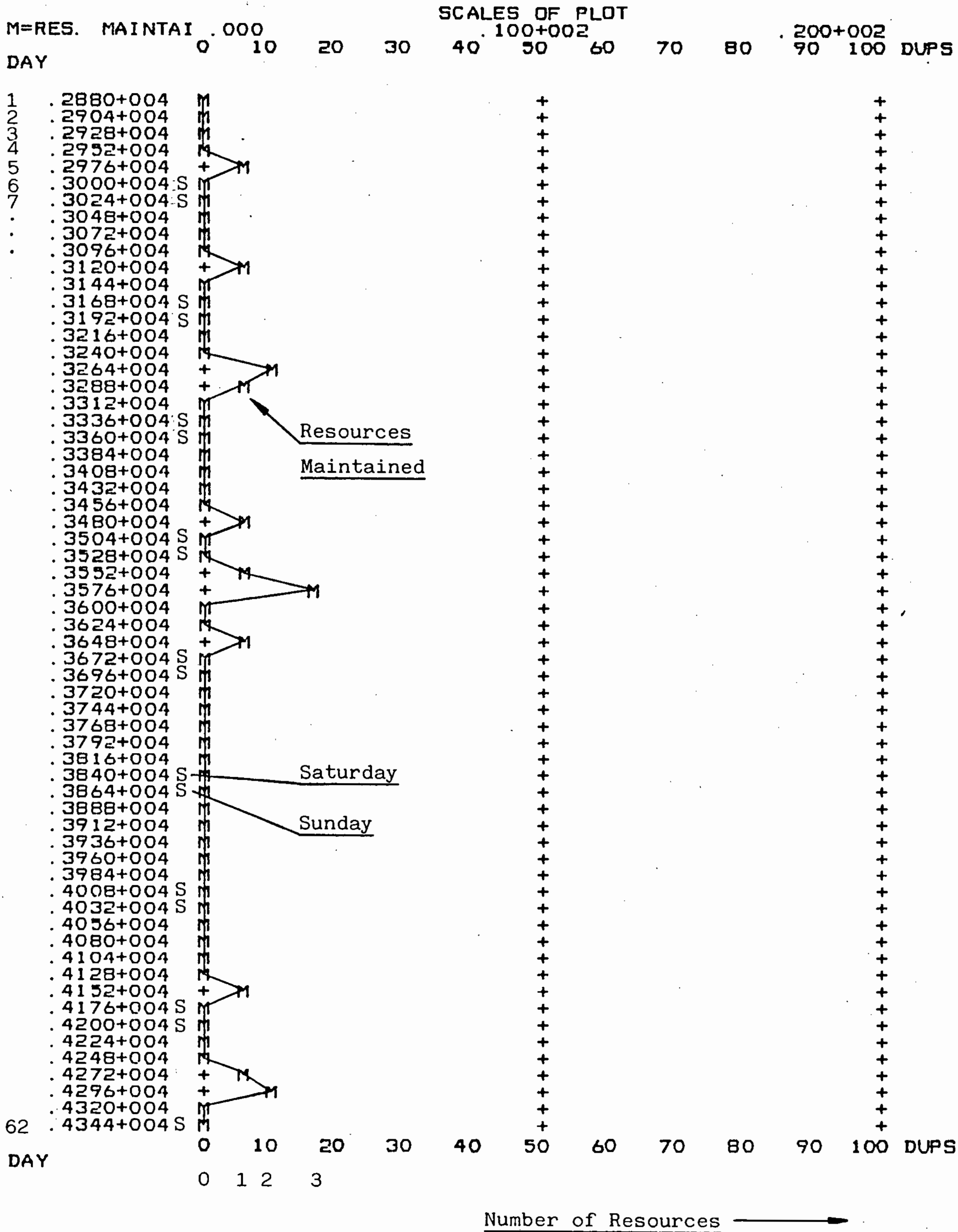


TABLE NUMBER 4
RUN NUMBER 1

DAY	RES. MAI NTAINED
MINIMUM	.0000
MAXIMUM	.3000+001

PLOT NUMBER 4
RUN NUMBER 1



APPENDIX I

SUMMARY OF RESULTS FOR ALTERNATIVE STRATEGIES

TABLE I1 - Variation Of Load Utilization

VARIABLE	% LOAD UTILIZATION				
	50	60	70	80	90
Demand Time P1: Mean	68,2	69,3	65,0	126,0	252,0
(Hour) Maximum	270,0	246,0	189,0	385,0	703,0
Demand Time P2: Mean	22,7	23,0	23,4	23,4	24,1
(Hour) Maximum	91,1	91,2	91,2	91,5	94,9
Demand Time P3: Mean	34,2	40,5	37,2	36,5	35,9
(Hour) Maximum	94,8	98,3	98,9	96,5	95,8
Demand Time P4: Mean	17,6	18,8	19,5	19,3	18,8
(Hour) Maximum	44,5	71,2	91,1	67,9	71,3
Demand Time P5: Mean	36,4	42,0	56,1	40,8	50,7
(Hour) Maximum	147,1	137,0	193,0	173,0	125,0
Weighted Average (Hour)	37,8	39,9	40,4	49,4	77,7
Truck Utilization (%)	46,1	40,7	39,0	36,3	36,6
Horse/Trailer Utilization (%)	68,3	68,8	68,7	69,8	69,5
Overall Vehicle Utilization (%)	57,2	54,8	53,9	53,1	53,0
Fillpt Utilization (%)	5,5	5,0	5,5	5,5	5,0
Forklift Utilization (%)	0,34	0,30	0,35	0,28	0,28
Barrel Utilization (%)	1,95	1,92	2,04	1,95	1,98
Human Resources	15,3	14,5	14,4	14,1	14,1
Number Of Repairs	62	54	47	44	45
Fuel Consumed (ℓ)	26781	26265	24495	25573	26777
Overtime (Hour)	790	857	689	734	825
Load Waiting For Vehicle - P1 (Hour)	45,2	39,0	32,6	86,0	144,5
Load Waiting For Vehicle - P2 (Hour)	9,8	10,5	11,0	10,8	11,4
Load Waiting For Vehicle - P3 (Hour)	18,3	24,1	19,8	19,1	19,5
Load Waiting For Vehicle - P4 (Hour)	5,3	5,3	4,6	6,9	4,1
Load Waiting For Vehicle - P5 (Hour)	19,0	25,3	33,1	15,1	23,1
Weighted Average (Hour)	21,5	21,9	22,2	27,4	39,2

TABLE I2 - Variation Of Target Demand Time

VARIABLE	TARGET DEMAND TIME (Hour)		
	24	48	72
Demand Time P1: Mean	108,0	126,0	91,1
(Hour) Maximum	302,0	355,0	317,0
Demand Time P2: Mean	15,9	23,4	37,7
(Hour) Maximum	68,2	91,5	40,1
Demand Time P3: Mean	28,0	36,5	65,2
(Hour) Maximum	95,2	96,5	145,0
Demand Time P4: Mean	14,0	19,3	18,1
(Hour) Maximum	24,8	67,9	70,4
Demand Time P5: Mean	41,5	40,8	49,1
(Hour) Maximum	142,0	173,0	122,0
Weighted Average (Hour)	40,1	49,4	52,9
Truck Utilization (%)	27,7	36,3	39,0
Horse/Trailer Utilization (%)	54,3	69,8	73,8
Overall Vehicle Utilization (%)	41,0	53,1	56,4
Fillpt Utilization (%)	5,5	5,5	5,0
Forklift Utilization (%)	0,34	0,28	0,33
Barrel Utilization (%)	1,92	1,95	2,04
Human Resources	10,9	14,1	15,0
Number Of Repairs	48	44	49
Fuel Consumed (ℓ)	23602	25573	24050
Overtime (Hour)	915	734	633
Load Waiting For Vehicle - P1 (Hour)	72,8	86,0	54,7
Load Waiting For Vehicle - P2 (Hour)	7,7	10,8	24,6
Load Waiting For Vehicle - P3 (Hour)	14,4	19,1	44,6
Load Waiting For Vehicle (Hour)	3,5	6,9	5,0
Load Waiting For Vehicle - P5 (Hour)	17,4	15,1	18,5
Weighted Average (Hour)	22,5	27,4	30,7

TABLE I3 - Variation Of Maintenance Frequency For Vehicles

VARIABLE	MAINTENANCE FREQUENCY (km)				
	4000	4500	5000	5500	6000
Demand Time P1: Mean (Hour) Maximum	175,0 464,0	185,0 487,0	126,0 355,0	47,9 129,0	177,0 510,0
Demand Time P2: Mean (Hour) Maximum	23,3 90,9	25,6 96,0	23,4 91,5	24,5 95,9	24,6 95,2
Demand Time P3: Mean (Hour) Maximum	36,2 94,9	41,1 127,0	36,5 96,5	30,2 93,9	40,2 117,0
Demand Time P4: Mean (Hour) Maximum	19,1 70,3	17,2 71,1	19,3 67,9	20,4 71,6	20,6 71,1
Demand Time P5: Mean (Hour) Maximum	54,5 187,0	41,8 108,0	40,9 173,0	42,1 145,0	42,9 126,0
Weighted Average (Hour)	61,0	58,5	49,4	32,2	60,1
Truck Utilization (%)	36,0	38,8	36,3	34,7	35,3
Horse/Trailer Utilization (%)	70,8	71,8	69,8	64,2	68,0
Overall Vehicle Utilization (%)	53,4	55,3	53,1	49,4	51,7
Fillpt Utilization (%)	5,5	5,5	5,5	5,0	5,5
Forklift Utilization (%)	0,34	0,30	0,28	0,26	0,31
Barrel Utilization (%)	1,83	2,01	1,95	1,80	1,83
Human Resources	14,1	14,8	14,1	13,1	13,6
Number Of Repairs	48	48	44	42	42
Fuel Consumed (ℓ)	24366	25068	25573	23828	23909
Overtime (Hour)	743	734	730	590	700
Load Waiting For Vehicle - P1 (Hour)	117,3	142,6	86,0	16,9	114,8
Load Waiting For Vehicle - P2 (Hour)	10,4	12,9	10,8	11,0	11,3
Load Waiting For Vehicle - P3 (Hour)	14,8	21,3	19,1	14,2	23,3
Load Waiting For Vehicle - P4 (Hour)	3,2	4,1	6,9	4,4	3,9
Load Waiting For Vehicle - P5 (Hour)	21,7	15,4	15,1	13,4	15,4
Weighted Average (Hour)	32,1	36,9	27,4	12,3	32,8

TABLE I4 - Variation of Maintenance Time For Vehicles

VARIABLE	MAINTENANCE TIME (Hour)		
	16	24	36
Demand Time P1: Mean	98,0	126,0	190,0
(Hour) Maximum	305,0	355,0	549,0
Demand Time P2: Mean	21,1	23,4	26,4
(Hour) Maximum	72,4	91,5	94,6
Demand Time P3: Mean	38,5	36,5	34,3
(Hour) Maximum	95,5	96,5	123,0
Demand Time P4: Mean	17,9	19,3	19,0
(Hour) Maximum	69,3	67,9	71,6
Demand Time P5: Mean	45,1	40,8	38,2
(Hour) Maximum	161,0	173,0	109,0
Weighted Average (Hour)	42,9	49,4	58,9
Truck Utilization (%)	35,8	36,3	33,7
Horse/Trailer Utilization (%)	66,8	69,8	68,0
Overall Vehicle Utilization (%)	51,3	53,1	50,9
Fillpt Utilization (%)	5,5	5,5	5,5
Forklift Utilization (%)	0,33	0,28	0,27
Barrel Utilization (%)	2,01	1,95	1,95
Human Resources	13,7	14,1	13,3
Number Of Repairs	44	44	39
Fuel Consumed (ℓ)	25050	25573	23931
Overtime (Hour)	820	734	685
Load Waiting For Vehicle - P1 (Hour)	59,6	86,0	146,3
Load Waiting For Vehicle - P2 (Hour)	8,5	10,8	13,8
Load Waiting For Vehicle - P3 (Hour)	20,1	19,1	18,6
Load Waiting For Vehicle - P4 (Hour)	5,2	6,9	4,1
Load Waiting For Vehicle - P5 (Hour)	19,3	15,1	15,1
Weighted Average (Hour)	21,7	27,4	37,7

TABLE I5 - Variation of Maximum Overtime Per Trip

VARIABLE	MAXIMUM OVERTIME (Hour)		
	4	6	8
Demand Time P1: Mean	138,0	126,0	73,2
(Hour) Maximum	425,0	355,0	212,0
Demand Time P2: Mean	25,3	23,4	22,9
(Hour) Maximum	91,0	91,5	73,3
Demand Time P3: Mean	95,6	36,5	47,0
(Hour) Maximum	241,0	96,5	105,0
Demand Time P4: Mean	19,0	19,3	24,1
(Hour) Maximum	91,0	67,9	90,0
Demand Time P5: Mean	45,3	40,8	44,8
(Hour) Maximum	118,0	173,0	129,0
Weighted Average (Hour)	64,8	49,4	41,2
Truck Utilization (%)	36,7	36,3	37,5
Horse/Trailer Utilization (%)	75,7	69,8	64,8
Overall Vehicle Utilization (%)	56,2	53,1	51,2
Fillpt Utilization (%)	6,0	5,5	7,0
Forklift Utilization (%)	0,33	0,28	0,22
Barrel Utilization (%)	2,31	1,95	2,50
Human Resources	14,8	14,1	13,5
Number of Repairs	52	44	46
Fuel Consumed (ℓ)	25454	25573	25926
Overtime (Hour)	696	734	857
Load Waiting For Vehicle - P1 (Hour)	95,9	86,0	42,6
Load Waiting For Vehicle - P2 (Hour)	12,3	10,8	10,5
Load Waiting For Vehicle - P3 (Hour)	63,1	19,1	34,5
Load Waiting For Vehicle - P4 (Hour)	4,1	6,9	10,5
Load Waiting For Vehicle - P5 (Hour)	13,5	15,1	20,7
Weighted Average (Hour)	38,4	27,4	23,5

TABLE I6 - Variation Of Probability Of Repair

VARIABLE	PROBABILITY OF REPAIR				
	0,05	0,075	0,10	0,125	0,15
Demand Time P1: Mean	118,0	227,0	126,0	166,0	180,0
(Hour) Maximum	343,0	637,0	355,0	471,0	622,0
Demand Time P2: Mean	27,9	21,6	23,4	23,4	21,9
(Hour) Maximum	91,1	74,5	91,5	72,6	72,4
Demand Time P3: Mean	48,4	37,7	36,5	46,3	34,2
(Hour) Maximum	149,0	105,0	96,5	118,0	96,2
Demand Time P4: Mean	18,6	16,9	19,3	17,9	18,5
(Hour) Maximum	70,3	69,1	67,9	70,0	72,2
Demand Time P5: Mean	41,7	47,2	40,8	46,5	48,2
(Hour) Maximum	118,0	149,0	173,0	141,0	174,0
Weighted Average (Hour)	51,5	70,6	49,4	58,9	59,5
Truck Utilization (%)	34,8	29,8	36,3	35,2	33,8
Horse/Trailer Utilization (%)	69,2	65,7	69,8	69,5	66,3
Overall Vehicle Utilization (%)	52,0	47,7	53,1	52,4	50,1
Fillpt Utilization (%)	5,0	5,5	5,5	5,0	5,0
Forklift Utilization (%)	0,41	0,26	0,28	0,25	0,28
Barrel Utilization (%)	1,92	2,13	1,95	2,04	2,01
Human Resources	13,8	12,6	14,1	14,0	13,2
Number Of Trips	536	522	535	534	524
Number Of Repairs	26	39	44	61	87
Fuel Consumed (ℓ)	25216	24511	25573	24456	23380
Overtime (Hour)	737	812	734	720	802
Load Waiting For Vehicle - P1 (Hour)	86,8	166,3	86,0	103,4	94,2
Load Waiting For Vehicle - P2 (Hour)	15,5	9,4	10,8	10,1	8,9
Load Waiting For Vehicle - P3 (Hour)	25,8	21,6	19,1	27,2	16,9
Load Waiting For Vehicle - P4 (Hour)	6,4	3,6	6,9	4,6	5,1
Load Waiting For Vehicle - P5 (Hour)	13,8	16,9	15,1	21,3	16,7
Weighted Average (Hour)	30,3	43,9	27,4	31,4	26,9

TABLE I7 - Variation Of Inspection Time

VARIABLE	INSPECTION TIME (Hour)			
	0,35	0,45	0,60	0,75
Demand Time P1: Mean	126,0	155,0	204,0	225,0
(Hour) Maximum	355,0	509,0	489,0	623,0
Demand Time P2: Mean	23,4	24,0	25,8	24,4
(Hour) Maximum	91,5	72,4	91,6	72,9
Demand Time P3: Mean	36,5	37,9	40,8	49,9
(Hour) Maximum	96,5	100,0	95,1	148,0
Demand Time P4: Mean	19,3	19,9	17,2	18,9
(Hour) Maximum	67,9	73,6	69,6	69,7
Demand Time P5: Mean	40,8	51,2	73,0	41,3
(Hour) Maximum	173,0	167,0	312,0	121,0
Weighted Average (Hour)	49,4	57,8	67,7	68,6
Truck Utilization (%)	36,3	35,2	30,8	32,2
Horse/Trailer Utilization (%)	69,8	70,3	65,7	67,3
Overall Vehicle Utilization (%)	53,1	52,8	48,2	49,8
Fillpt Utilization (%)	5,5	5,5	5,5	5,5
Forklift Utilization (%)	0,28	0,38	0,30	0,34
Barrel utilization (%)	1,95	1,89	2,07	2,10
Human Resources	14,1	13,9	12,6	13,1
Number Of Repairs	44	53	38	45
Fuel Consumed (ℓ)	25573	24873	24786	24691
Overtime (Hour)	734	828	831	855
Load Waiting For Vehicle - P1 (Hour)	86,0	87,8	135,6	178,7
Load Waiting For Vehicle - P2 (Hour)	10,8	11,0	13,0	12,9
Load Waiting For Vehicle - P3 (Hour)	19,1	20,5	24,2	28,5
Load Waiting For Vehicle - P4 (Hour)	6,9	5,0	3,3	4,5
Load Waiting For Vehicle - P5 (Hour)	15,1	24,8	31,2	16,7
Weighted Average (Hour)	27,4	28,6	37,6	46,4

TABLE I8 - Variation Of Time To Change Horse/Trailer Combination

VARIABLE	DURATION (Hour)		
	0,25	0,50	0,75
Demand Time P1: Mean (Hour) Maximum	53,3 147,0	126,0 355,0	190,0 496,0
Demand Time P2: Mean (Hour) Maximum	22,4 90,7	23,4 91,5	24,1 72,2
Demand Time P3: Mean (Hour) Maximum	36,7 101,0	36,5 96,5	57,5 95,5
Demand Time P4: Mean (Hour) Maximum	21,5 71,4	19,3 67,9	16,9 68,8
Demand Time P5: Mean (Hour) Maximum	39,7 120,0	40,8 173,0	44,3 123,0
Weighted Average (Hour)	33,9	49,4	63,4
Truck Utilization (%)	36,3	36,3	33,8
Horse/Trailer Utilization (%)	63,3	69,8	70,5
Overall Vehicle Utilization (%)	49,8	53,1	52,2
Fillpt Utilization (%)	5,5	5,5	4,5
Forklift Utilization (%)	0,33	0,28	0,30
Barrel utilization (%)	2,31	1,95	1,83
Human Resources	13,2	14,1	13,8
Number Of Repairs	46	44	50
Fuel Consumed (ℓ)	24397	25573	24866
Overtime (Hour)	673	734	803
Load Waiting For Vehicle - P1 (Hour)	22,2	86,0	127,9
Load Waiting For Vehicle - P2 (Hour)	10,1	10,8	10,3
Load Waiting For Vehicle - P3 (Hour)	20,4	19,1	19,9
Load Waiting For Vehicle - P4 (Hour)	4,6	6,9	4,9
Load Waiting For Vehicle - P5 (Hour)	13,9	15,1	16,3
Weighted Average (Hour)	14,4	27,4	35,8

TABLE I9 - Release of Constraint on Horse/Trailer Combination

VARIABLE	WITH ACTUAL COMBINATIONS	ANY COMBINATION POSSIBLE
Demand Time P1: Mean	126,0	110,0
(Hour) Maximum	355,0	322,0
Demand Time P2: Mean	23,4	20,5
(Hour) Maximum	91,5	90,9
Demand Time P3: Mean	36,5	35,7
(Hour) Maximum	96,5	100,0
Demand Time P4: Mean	19,3	17,7
(Hour) Maximum	67,9	69,4
Demand Time P5: Mean	40,8	54,1
(Hour) Maximum	173,0	186,0
Weighted Average (Hour)	49,4	45,2
Truck Utilization (%)	36,3	31,7
Horse/Trailer Utilization (%)	69,8	70,1
Overall Vehicle Utilization (%)	53,1	50,9
Fillpt Utilization (%)	5,5	5,5
Forklift Utilization (%)	0,28	0,34
Barrel Utilization (%)	1,95	1,93
Human Resources	14,1	13,4
Number Of Repairs	44	41
Fuel Consumed (ℓ)	25573	24997
Overtime (Hour)	734	787
Load Waiting For Vehicle - P1 (Hour)	86,0	70,6
Load Waiting For Vehicle - P2 (Hour)	10,8	7,3
Load Waiting For Vehicle - P3 (Hour)	19,1	19,0
Load Waiting For Vehicle - P4 (Hour)	6,9	4,9
Load Waiting For Vehicle - P5 (Hour)	15,1	27,8
Weighted Average (Hour)	27,4	24,1

TABLE I10 - Reduction in Truck Resources

VARIABLE	NO REDUCTION	RESOURCE (REDUCED FROM 1 TO 0)		
		TRUCK 412	TRUCK 414	TRUCK 467
Demand Time P1: Mean	126,0	105,0	201,0	66,1
(Hour) Maximum	355,0	342,0	578,0	174,0
Demand Time P2: Mean	23,4	20,5	23,2	24,1
(Hour) Maximum	91,5	72,2	73,1	91,5
Demand Time P3: Mean	36,5	33,6	33,2	34,0
(Hour) Maximum	96,5	92,8	97,2	93,3
Demand Time P4: Mean	19,3	17,9	16,5	17,7
(Hour) Maximum	67,9	68,2	68,7	74,7
Demand Time P5: Mean	40,8	47,3	41,3	125,0
(Hour) Maximum	173,0	127,0	141,0	273,0
Weighted Average (Hour)	49,4	42,8	55,4	50,0
Truck Utilization (%)	36,3	37,6	35,4	39,0
Horse/Trailer Utilization (%)	69,8	68,3	68,7	67,3
Overall Vehicle Utilization (%)	53,1	53,0	52,1	53,2
Fillpt Utilization (%)	5,5	5,0	5,5	5,5
Forklift Utilization (%)	0,28	0,30	0,30	0,34
Barrel Utilization (%)	1,95	1,83	1,86	1,92
Human Resources	14,1	13,2	12,9	13,1
Number Of Repairs	44	47	55	44
Fuel Consumed (ℓ)	25573	22982	24293	23494
Overtime (Hour)	734	655	708	750
Load Waiting For Vehicle - P1 (Hour)	86,0	66,6	206,0	32,4
Load Waiting For Vehicle - P2 (Hour)	10,8	6,6	10,6	11,4
Load Waiting For Vehicle - P3 (Hour)	19,1	17,2	17,1	16,5
Load Waiting For Vehicle - P4 (Hour)	6,9	4,9	4,9	4,7
Load Waiting For Vehicle - P5 (Hour)	15,1	16,8	18,8	67,8
Weighted Average (Hour)	27,4	70,6	46,1	29,0

TABLE I10 (CONTD)

VARIABLE	NO REDUCTION	RESOURCE (REDUCED FROM 1 TO 0)		
		TRUCK 469	TRUCK 471	TRUCK 472
Demand Time P1: Mean	126,0	141,0	108,0	539,0
(Hour) Maximum	355,0	345,0	342,0	122,0
Demand Time P2: Mean	23,4	20,9	25,0	20,8
(Hour) Maximum	91,5	71,9	94,4	72,2
Demand Time P3: Mean	36,5	35,4	38,5	33,7
(Hour) Maximum	96,5	95,6	119,0	92,0
Demand Time P4: Mean	19,3	21,0	28,9	19,5
(Hour) Maximum	67,9	71,6	79,2	67,0
Demand Time P5: Mean	40,8	43,5	36,0	75,8
(Hour) Maximum	173,0	120,2	103,8	219,0
Weighted Average (Hour)	49,4	50,0	44,7	107,8
Truck Utilization (%)	36,3	38,8	40,8	45,8
Horse/Trailer Utilization (%)	69,8	68,5	70,0	64,7
Overall Vehicle Utilization (%)	53,1	53,7	55,4	55,3
Fillpt Utilization (%)	5,5	5,5	4,5	5,5
Forklift Utilization (%)	0,28	0,31	0,28	0,24
Barrel Utilization (%)	1,95	2,04	1,98	2,07
Human Resources	14,1	13,4	13,7	13,3
Number Of Repairs	44	49	47	59
Fuel Consumed (ℓ)	25573	24760	23992	26587
Overtime (Hour)	734	777	745	800
Load Waiting For Vehicle - P1 (Hour)	86,0	99,1	68,6	400,1
Load Waiting For Vehicle - P2 (Hour)	10,8	7,5	12,7	8,2
Load Waiting For Vehicle - P3 (Hour)	19,1	17,2	24,9	16,4
Load Waiting For Vehicle - P4 (Hour)	6,9	9,9	19,4	8,2
Load Waiting For Vehicle - P5 (Hour)	15,1	17,6	14,4	61,2
Weighted Average (Hour)	27,4	27,2	24,7	85,2

TABLE I11 - Reduction in Mechanical Horse Resources

VARIABLE	NO REDUCTION	RESOURCE (REDUCED FROM 1 TO 0)		
		HORSE 422	HORSE 423	HORSE 424
Demand Time P1: Mean	126,0	71,6	135,0	151,0
(Hour) Maximum	355,0	191,0	386,0	533,0
Demand Time P2: Mean	23,4	226,0	30,6	75,7
(Hour) Maximum	91,5	336,0	95,0	147,0
Demand Time P3: Mean	36,5	35,7	102,0	34,1
(Hour) Maximum	96,5	92,9	190,0	102,0
Demand Time P4: Mean	19,3	17,7	18,5	20,0
(Hour) Maximum	67,9	71,0	68,5	90,1
Demand Time P5: Mean	40,8	46,6	44,9	38,7
(Hour) Maximum	173,0	142,0	143,0	124,0
Weighted Average (Hour)	49,4	105,7	66,3	68,8
Truck Utilization (%)	36,3	35,2	40,7	33,0
Horse/Trailer Utilization (%)	69,8	66,2	79,6	70,6
Overall Vehicle Utilization (%)	53,1	50,7	60,2	51,8
Fillpt Utilization (%)	5,5	5,5	5,5	5,5
Forklift Utilization (%)	0,28	0,34	0,42	0,32
Barrel Utilization (%)	1,95	1,83	2,10	1,86
Human Resources	14,1	12,2	14,4	12,1
Number Of Repairs	44	48	46	41
Fuel Consumed (ℓ)	25573	25355	24019	24088
Overtime (Hour)	734	790	856	854
Load Waiting For Vehicle - P1 (Hour)	86,0	36,1	95,5	76,6
Load Waiting For Vehicle - P2 (Hour)	10,8	199,2	18,2	63,4
Load Waiting For Vehicle - P3 (Hour)	19,1	18,3	82,1	17,0
Load Waiting For Vehicle - P4 (Hour)	6,9	4,5	4,9	6,1
Load Waiting For Vehicle - P5 (Hour)	15,1	19,7	14,5	13,4
Weighted Average (Hour)	27,4	81,3	43,7	40,5

TABLE I11 (CONTD)

VARIABLE	NO REDUCTION	RESOURCE (REDUCED FROM 1 TO 0)	
		HORSE 426	HORSE 427
Demand Time P1: Mean	126,0	371,0	116,2
(Hour) Maximum	355,0	1020,0	202,0
Demand Time P2: Mean	23,4	30,4	28,7
(Hour) Maximum	91,5	94,9	95,0
Demand Time P3: Mean	36,5	37,2	45,8
(Hour) Maximum	96,5	142,0	121,0
Demand Time P4: Mean	19,3	19,1	17,6
(Hour) Maximum	67,9	70,6	69,5
Demand Time P5: Mean	40,8	46,4	43,5
(Hour) Maximum	173,0	146,0	140,0
Weighted Average (Hour)	49,4	93,6	50,2
Truck Utilization (%)	36,3	37,5	37,5
Horse/Trailer Utilization (%)	69,8	74,6	77,6
Overall Vehicle Utilization (%)	53,1	56,1	57,6
Fillpt Utilization (%)	5,5	5,5	5,0
Forklift Utilization (%)	0,28	0,25	0,31
Barrel Utilization (%)	1,95	2,04	1,92
Human Resources	14,1	13,3	13,6
Number Of Repairs	44	44	57
Fuel Consumed (ℓ)	25573	24563	24351
Overtime (Hour)	734	836	748
Load Waiting For Vehicle - P1 (Hour)	86,0	265,4	79,6
Load Waiting For Vehicle - P2 (Hour)	10,8	18,9	16,6
Load Waiting For Vehicle - P3 (Hour)	19,1	17,2	30,3
Load Waiting For Vehicle - P4 (Hour)	6,9	4,5	3,9
Load Waiting For Vehicle - P5 (Hour)	15,1	21,5	17,0
Weighted Average (Hour)	27,4	61,0	30,0

TABLE I12 - Reduction in Trailer Resources

VARIABLE	NO REDUCTION	RESOURCE (REDUCED FROM 1 TO 0)		
		TRAILER 318	TRAILER 430	TRAILER 431
Demand Time P1: Mean	126,0	74,2	120,0	120,0
(Hour) Maximum	355,0	185,0	356,0	356,0
Demand Time P2: Mean	23,4	19,0	30,9	30,9
(Hour) Maximum	91,5	70,4	95,7	95,7
Demand Time P3: Mean	36,5	1150,0	41,4	41,4
(Hour) Maximum	96,5	1380,0	143,0	143,0
Demand Time P4: Mean	19,3	17,5	18,8	18,8
(Hour) Maximum	67,9	70,6	70,7	70,7
Demand Time P5: Mean	40,8	35,0	38,4	38,4
(Hour) Maximum	173,0	157,0	130,0	130,0
Weighted Average (Hour)	49,4	210,4	51,2	51,2
Truck Utilization (%)	36,3	31,7	37,8	37,8
Horse/Trailer Utilization (%)	69,8	55,2	70,7	70,7
Overall Vehicle Utilization (%)	53,1	43,5	54,3	54,3
Fillpt Utilization (%)	5,5	4,0	5,5	5,5
Forklift Utilization (%)	0,28	0,26	0,40	0,40
Barrel Utilization (%)	1,95	1,44	2,04	2,04
Human Resources	14,1	11,6	14,4	14,4
Number Of Repairs	44	59	53	53
Fuel Consumed (ℓ)	25573	22297	24632	24632
Overtime (Hour)	734	785	878	878
Load Waiting For Vehicle - P1 (Hour)	86,0	40,3	80,3	80,3
Load Waiting For Vehicle - P2 (Hour)	10,8	6,5	18,2	18,2
Load Waiting For Vehicle - P3 (Hour)	19,1	705,6	19,0	19,0
Load Waiting For Vehicle - P4 (Hour)	6,9	5,2	5,3	5,3
Load Waiting For Vehicle - P5 (Hour)	15,0	8,8	16,4	16,4
Weighted Average (Hour)	27,4	218,9	28,3	28,3

TABLE I12 (CONTD)

VARIABLE	NO REDUCTION	RESOURCE (REDUCED FROM 1 TO 0)		
		TRAILER 441	TRAILER 449	TRAILER 453
Demand Time P1: Mean	126,0	74,2	786,0	120,0
(Hour) Maximum	355,0	185,0	1260,0	356,0
Demand Time P2: Mean	23,4	19,0	18,1	30,9
(Hour) Maximum	91,5	70,4	71,8	95,7
Demand Time P3: Mean	36,5	1150,0	34,6	41,4
(Hour) Maximum	96,5	1380,0	96,9	143,0
Demand Time P4: Mean	19,3	17,5	20,1	18,8
(Hour) Maximum	67,9	70,6	73,1	70,7
Demand Time P5: Mean	40,8	35,0	46,4	38,4
(Hour) Maximum	173,0	157,0	138,0	130,0
Weighted Average (Hour)	49,4	210,4	161,2	51,2
Truck Utilization (%)	36,3	31,7	37,3	37,8
Horse/Trailer Utilization (%)	69,8	55,2	65,6	70,7
Overall Utilization (%)	53,1	43,5	51,5	54,3
Fillpt Utilization (%)	5,5	4,0	5,0	5,5
Forklift Utilization (%)	0,28	0,26	0,22	0,40
Barrel Utilization (%)	1,95	1,44	2,04	2,04
Human Resources	14,1	11,6	13,7	14,4
Number Of Repairs	44	59	50	53
Fuel Consumed (ℓ)	25573	22297	23884	24632
Overtime (Hour)	734	785	648	878
Load Waiting For Vehicle - P1 (Hour)	86,0	40,3	481,7	80,3
Load Waiting For Vehicle - P2 (Hour)	10,8	6,5	4,6	18,2
Load Waiting For Vehicle - P3 (Hour)	19,1	705,6	16,43	19,0
Load Waiting For Vehicle - P4 (Hour)	6,9	5,2	6,4	5,3
Load Waiting For Vehicle - P5 (Hour)	15,1	8,8	17,0	16,4
Weighted Average (Hour)	27,4	218,9	99,7	28,3

APPENDIX J

DATA ON DISTRIBUTION FOR JANUARY AND FEBRUARY 1988

TABLE J1 - Distribution Details

VEHICLE	CAPACITY	TRIPS	LOAD CARRIED	DISTANCE TRAVELLED	OVERTIME
--	kg	--	kg	km	Hr
TRUCK 412 - P5	2583	21	35166	2196	14,1
TRUCK 414 - P1	2060	31	48460	3842	13,8
TRUCK 467 - P5	6270	48	175095	4936	21,3
TRUCK 469 - P4/P5	6060	44*	147464	5137	59,8
TRUCK 471 - P4/P5	11512	63*	176982	6613	36,1
TRUCK 472 - P1	13332	49	441364	5010	22,3
HORSE 305 - P1	22690	53	867039	5183	13,0
HORSE 422 - P2	N/A	85	N/A	7436	60,5
HORSE 423 - P3	N/A	58	N/A	7168	154,3
HORSE 424 - P1	22690	1	20136	120	1,0
- P2	N/A	19	N/A	1803	21,9
- P3	N/A	51	N/A	8617	110,0
HORSE 426 - P1	11540	2	18573	212	0,0
- P2	N/A	52	N/A	2813	28,2
- P3	N/A	4	N/A	741	31,2
HORSE 427 - P1	11540	1	10118	117	0,0
- P3	N/A	34	N/A	7041	88,9
TOTAL	--	616	1940397	68985	676,4

The average load utilization for the vehicles carrying Products 1 and 5 is evaluated as follows:

$$\text{Average Load Utilization} = \frac{\text{Total Load Carried}}{\text{Maximum Load That Can Be Carried}}$$

$$= \frac{\text{Total Load Carried}}{\sum(\text{Number of Trips} * \text{Load Capacity})}$$

$$= \frac{1940397 \text{ kg}}{(21*2583 + 31*2060 + 48*6270 + 22*6060 + 28*11512 + 49*13332 + 53*22690 + 22690 + 2*11540 + 11540) \text{ kg}}$$

$$= 0,696.$$

Note: * - These values include the number of trips for Product 4. The number of trips for Product 5 were 22 and 28 respectively, and are used in the above calculation.

23 DEC 1988