AN ABSTRACT OF THE THESIS OF

Elias Jonatansson for the degree of Master of Science in Industrial Engineering presented on June 13, 1985.

Title: A Network Simulation Model of a Fish Processing Plant

Redacted for Privacy

Abstract approved: Sabah Randhawa

The fish processing industry is the most important industry in Iceland. The single most important processing method is quickfreezing, and the major market is in the United States. With increasing competition in the market from countries like Canada, productivity of fish processing plants is becoming increasingly important.

This research focuses on developing a simulation model of a fish processing plant, whose products are quickfrozen fish. In the study, the process in a typical fish processing plant is described. A network simulation model of the process is then developed, using the Simulation Language for Alternative Modeling (SLAM). Among the results from the model are statistics

on utilization of machines and workers in the process, size of in-process inventory at different locations in the process and throughput times. Sensitivity analysis is performed on some of the major factors that can affect the efficiency of the system. A front-end interface to the simulation model is developed which facilitates the user in entering input parameters to the model without the need to learn the simulation language. The model provides a methodology for evaluating alternative production strategies for a fish processing facility, and provides the production manager with a tool to develop short term production policies.

A Network Simulation Model of a Fish Processing Plant

by

Elias Jonatansson

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed June 13, 1985

Commencement June 1986

APPROVED:

Redacted for Privacy

Professor of Industrial Engineering in charge of major

Redacted for Privacy

Head of department of Industrial Engineering

Redacted for Privacy

Dean of Graduate School

Date thesis is presented June 13, 1985

Typed by Elias Jonatansson for Elias Jonatansson

ACKNOWLEDGEMENTS

I would like to use this oppourtunity to express my thanks to individuals whom I consulted during the course of this study. Special thanks are due to :

Dr. Sabah Randhawa, my major professor, for his professional counsel as well as the countless hours of his time, throughout the course of this study.

Einar Gudmundsson, supervisor at "Ishusfelag Bolungarvikur" for his help in data collection.

Kristin, my wife, for her continuous support, encouragement and patience throughout this project.

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

GLOSSARY OF TERMS

BLOCK--small pieces of fish removed from a fillet in order to give it a better look.

BOX EMPTYING STATION--work station where fish is removed from boxes.

COOLER--storage area for raw material, fish.

FILLET--boneless or pinbone in, sides of fish, cut away from the backbone and removed in one piece.

FILLETING MACHINE--a machine that performs the filleting operation.

FILLETING OPERATION--the operation of removing the sides of a fish in one piece.

FISH PROCESSING PLANT--a facility where fish is processed; headed, filleted, skinned, trimmed, packed, and quickfrozen.

FISHMEAL FACTORY--a facility where fish is ground and dried to turn it into fishmeal.

FLAP--see nape

FREEZER--storage area for fish products

FREEZING PLANT--same as fish processing plant.

HEADER--a machine that performs the heading operation.

HEADING MACHINE--see header.

HEADING OPERATION--the operation of removing the head from a fish.

NAPE--the thinnest part of a fillet, also refered to as the flap.

PACKING OPERATION--the operation of wrapping fish in foil and putting it into boxes.

PACKING STATION-- work station where the packing operation is performed.

PACKING WORKER--worker that performs the packing operation.

PARASITES--The most commonly observed parasites in marine food fishes are roundworms called nematodes, often called herring worms or cod worms.

PLATE QUICKFREEZER--the equipment that quickfreezes fish in pans.

QUICKFREEZER--see plate quickfreezer.

SKINNER--machine that performs the skinning operation.

SKINNING MACHINE--see skinner.

SKINNING OPERATION--the operation of removing the skin from a fillet of fish.

SORTING MACHINE--machine that grades fish into sizes.

TRIMMING OPERATION--the operation of cutting a fillet to the right size, cutting off the nape and cutting off any "loose" fish.

TRIMMING STATION--work station where trimming is performed.

TRIMMING WORKER--worker that performs the trimming operation.

WEIGHING STATION--work station where the fish are weighed.

A NETWORK SIMULATION MODEL OF A FISH PROCESSING PLANT

I. INTRODUCTION

Iceland's most important industry is the fish industry. Fish products, of which frozen fish is about 40 percent, constitute approximately 70 percent of the nation's exports [19].

Quick freezing in Iceland has its origin in Vestmannaeyjar 1910, when experiments were made to quick freeze halibut for export [8]. The experiments proved unsuccessful. In 1929 experiments were made with brine freezing, but this also failed. It was not until 1935 that quick freezing got its third chance when the markets for salted fish collapsed. In 1936, 6 freezing plants were built in Iceland, in 1937 there were 14, 44 in 1942, and presently there are more than a hundred quick freezing plants in Iceland. On the approximately 40,000 square miles island of 240,000 inhabitants, "fishing is the country's number one foreign currency earner and a true cornerstone of the economy" [12]

Most of the freezing plants in Iceland are a part of, either the Icelandic Freezing Plants Corporation (IFPC), or the Samband of Iceland, both of whom have established their own sales affiliates in the United States.

Both firms are using a differentiation strategy to get a higher than average price for their products; for example, the wholesale price of Icelandic 5-lb. boneless Cod fillets was $1.80 in December 1984 and had been constant for at least two consecutive years, while for instance the wholesale price of major competitors from Canada 5-lb. boneless Cod had been in the range of $1.15 to $1.35 and was at $1.25 in December 1984 [18].

The planning needs for a strategy center such as a business organization, according to Lorange [11], follows two dimensions -- business growth rate and relative market share. A strategy center facing a rapid growth rate in its industry will be confronted with planning issues -- primarily adaptation-oriented in nature, such as expansion into new geographic markets, reaction to new consumer tastes, or attaining a position in the market by developing more effective competitive strategies than the competitor.

High relative market share calls for action to develop strategic programs for increased efficiency, more efficient planning of production, development of more raw material and/or energy, efficient production processes, and better scheduling of distribution. Figure 1 illustrates four different types of planning needs for a strategy center, depending on the two variables -- business growth and market share.

Business growth rate	High relative market share	Low relative market share
High	**STAR** High adaptation High integration	**QUESTION MARK** High adaptation Low integration
Low	**CASH COW** Low adaptation High integration	**DOG** Low adaptation Low integration

Relative market share

Figure 1. Strategic Position Grid for a Product/Market Element [5]

The Icelandic freezing plant industry would probably fall in the "Cash Cow" catagory. This implies that the integrative planning needs are becoming increasingly important to the firms involved in the fish industry, compared to the adaptive planning needs. Thus, a slightly better facility design or layout, or better production scheduling can mean large cost savings.

Presently, many of the freezing plants in Iceland have computer systems that constantly monitor throughput and yield at different places in the production line, as well as collect data for calculating wage incentives

[13]. Currently, online information systems are being designed, whose main purpose is to act as a decision support system for management, by making use of data that is currently being collected.

One procedure that may be used to improve the productivity of existing systems without disturbing the production process or to design more efficient future systems is that of simulation. Simulation provides a mechanism for combining different facets of the manufacturing organization - production, economic, technical - into an integrated model, testing different scenarios and performing sensitivity analysis to select the "best" combination of process variables and strategies.

Modeling a fish processing plant has certain complexities associated with it. For example, modeling a plant involves modeling both manual work stations and machines. There are more than 100 types of products that may constitute the output from a freezing plant, with as many as 20 products for only one species of fish. Fortunately though, processing of different products is similar in that, regardless of the product type, all products have to go through similar processing steps.

For different types of product, the task times at different work stations may be different. Moreover, the size of the fish affects the throughput of some of the work stations but not that of others. The right balance of workers between the different work stations is of importance in order to avoid high in-process inventories. Breakdowns of machines, or breakage of machine tools such as cutting knives occur occasionally, thereby creating a possible bottleneck in the process.

The simulation model presented here is a case study of "Ishusfelag Bolungarvikur h/f", Iceland (Bolungarvik Freezing Plant Ltd.). Features of the model developed in this research include process line, machine breakdowns and repairs, quickfreezing and transportation of fish. Given this model, it should be an easy task to adapt this model for any other fish processing plant.

Another characteristic of the model developed here is its ability to conduct sensitivity analysis. By running the model under different scenarios, such as different number of workers or different sizes of fish, it may be possible to spot the bottlenecks in the process for a given type of product.

The inputs to the model consist of machine rates, number of workers at different types of work stations and size of fish, among others. The model provides statistics for various resources. These include:

a) statistics for variables based on observation such as waiting time and throughput time.

b) statistics for variables that are a function of time such as inventory levels and resource utilizations.

c) statistics for all resources used in the model including different types of machines, workers and material handling equipment, and

d) statistics for queues where entities wait to be processed.

Sensitivity analysis performed on the system provides a mechanism for evaluating different production and planning strategies. The results from the model are a valuable aid for the designer of a fish processing facility in evaluating the current facility and designing a future facility, and to the management of a facility for resource allocation, production planning and scheduling other regular production decisions.

II. PROBLEM ANALYSIS

Literature Review

Although the simulation of a fish processing plant was not to be found in the literature, some work has been done in related areas. In a thesis "Production Scheduling in freezing plants" Einarsson [3], discusses the problem facing the decision maker in a freezing plant when deciding which type of packing to use on a particular day. The thesis includes :

1. A general discussion concerning the factors which are the most important in choosing among different types of packing, and the flexibility among the different types of packings used. A discussion on how actual decisions related to packing are made is also included.

2. Some simple rules of thumb to choose between different packings are investigated.

3. A computer program, designed at the Computer Center of the University of Iceland is evaluated. This program uses Linear Programming (LP) to meet the goal of maximizing profit. The model has a planning horizon of five days, and tries to maximize profit on a five day basis. Given the available raw material as well as the

expected raw material the model suggests which packings to use for each day of the five day period. The LP model takes into account constraints such as manpower at different stages of the process, machine time, age of raw material and quantity of raw material. Linear programming on an industrial scale, is primarily used to solve large complex problems involving a lot of variables and constraints. Therefore, the problem of deciding which of the more than 100 packings (there are over 20 different packings for Cod alone) to use for available raw material in a freezing plant, can be structured as a typical LP problem. Such an LP model can be of enormous help in decision making and the advantages, by far, outweigh the disadvantages.

Asgeirsson [1] in a thesis on "A test of a Linear Programming Model for Production Planning in a Freezing Plant", expanded on the work of Einarsson. Asgeirsson's objective was to use the LP model in industry to test the applicability and flexibility of the model in practical applications, and to investigate procedures to make the model more user friendly to potential users. For the coefficients of the model, average numbers over a given time period were used. The results reported in the study show that the output from the model is generally in agreement with the decisions made by the production manager. Asgeirsson concludes that, given a good users manual it should be a fairly easy task for any potential user to use the model.

Tryggvason [20], in a thesis, on "Production Capacity of Freezing Plants" did some sensitivity analysis using the LP model mentioned above. The objective of the study was to estimate capacity of freezing plants in different raw material situations while accounting for the main restrictions, such as the number of workers in trimming and packing and number of filleting machines and different raw materials. The study also looked at the effects of these restrictions on the total profit.

Tryggvason develops methods of deciding optimum numbers of trimming and packing workers, and the optimum number of filleting machines for a certain type of raw material. However, the procedures developed in Tryggvason's research are for the simplified case where the objective is to maximize profit. In an effort to estimate the capacity of the freezing plant, Tryggvason first studies the different interpretations given to the term "capacity of a plant" in fish processing industry. The capacity of a plant may imply the throughput that results in the maximum profit, which may be somewhat less than the maximum throughput, or the throughput that gives the highest marginal profit. The LP model is used to obtain different solutions for different arrival rates of raw material per week. From the study, Tryggvason draws the conclusions that for a given rate of incoming raw material, the optimal size of freezing plant can be calculated, or vice versa.

Jensson, the designer of the LP model and Maack [9] applied the linear programming model to a real situation, and obtained very promising results. However, one of the drawbacks of the LP model is that it demands satisfactory information about incoming raw material over the planning horizon being considered. This kind of information would have to come from the fishing ship; however, such information is very difficult to obtain until the ship is ashore. To be useful for decision makers the model still needs some design on the "front end" in order to be simple to use, both in decision making and updating of information it's based on.

There are further limitations associated with Linear Programming. One such limitation is that it cannot deal with uncertainty or probabilistic estimates. For example, fish brought to processing plants as raw material is generally in 60 kilogram boxes. The number of fishes in a 60 kilogram box is a variable depending on the size and weight of the contents. LP assumes a deterministic value for the number of fishes in a box. Condition of the raw material is another important factor. In the LP model it is assumed that either the raw material is good enough to be packed in every kind of packing, or that it's too old or spoiled to be used for quick-freezing and has to be sold to a fishmeal factory, where the fish is ground and dried to make fishmeal that is only worth a fraction of good raw material. In the real situation, the fraction of the fish that actually can be packed as fillets, depends on the freshness of the fish. Generally, as the raw material ages, the proportion of fish packed as fillets decreases, and the proportion packed as less expensive products increases. In the simulation model presented in this study, the age of the fish may be specified by specifying the proportions of the raw material to be used as fillets and other less expensive products, thus giving the simulation model added flexibility.

Simulation

Simulation has been widely used in the past to study different kinds of processes. It is an excellent tool for reviewing systems responses over time -- systems that in many cases cannot be modeled analytically or systems that involve a lot of uncertain factors. Simulation gives the opportunity to analyse a real system without actually making any changes to it. For instance, the effect of adding a new machine or more workers can be investigated without disturbing the process. It can also aid in evaluating a systems performance before it is built, thus giving the designer a chance to evaluate the design before making monetary commitments, and to redesign the "weak spots". In surveys of the use of management science techniques, simulation has been at or near the top of the list [14].

Models of systems may be classified as either discrete or continuous models. In continuous simulation, the model is constructed by defining equations for a set of variables. These equations are called state variables and define the behaviour of the system. For discrete simulation modeling, three different approaches may be used:

1) Event Orientation, where the system is modeled by defining the changes that occur at event times. The modeler determines the events that can change the state of the system and then develops the logic associated with each event type. The simulation of the system is then produced by executing the logic associated with each event in a time ordered sequence.

2) Activity Scanning Orientation, where the activities in which the entities in the system engage are described, and conditions which cause an activity to start or end are prescribed. Events which start or end the activity are initiated from the conditions specified

for an activity. Conditions for either starting or ending an activity are scanned every time simulated time is advanced, so the entire set of activities has to be scanned for every time advance to ensure that each event is accounted.

3) Process Orientation combines features of both the event orientation and activity scanning orientation, providing a description of the flow of entities through a process consisting of resources.

Simulation is an excellent tool to view complex systems that cannot be modeled analytically, making it possible to explore systems in their totality rather than just considering the different aspects of them, one at a time. Simulation is an invaluable tool where uncertainty is involved. Rather than giving a specific answer, such as the optimizing procedures like Linear Programming do, simulation typically turns out a "range" of answers showing the outcome under different operating conditions. Sensitivity analysis can easily be conducted using simulation. For example, effects of adding a machine to a process, or the effects of laying off workers in some department can easily be tested. Compared to Linear Programming, simulation does have a major drawback -- it is not an optimizing technique. However, in many cases when maximization or minimization is the objective, an upper or lower value for the parameter being optimized can be calculated, thus making it possible to tell when a reasonably good solution has been reached.

In SLAM (Simulation Language for Alternative Modeling), the three alternate modeling approaches are combined, thus providing an executive control program to control the simulation by advancing time and initating calls to the appropriate event subroutines at the proper points in simulated time, relieving the modeler of the task of sequencing events to occur chronologically. The main reason for choosing SLAM for this research was to be able to use the network structure it offers for building a simulation model, comprised of specialized symbols called nodes and branches. These model elements in a process such as queues, servers, and decision points. The modeler then combines these symbols into a network model which pictorially represents the system. This network usually has similarities with the layout of the physical system itself, thus enhancing the modelers understanding of the real system. Furthermore, in network simulation the emphasis is on the representation and modeling of the system, rather than on understanding and writing computer codes.

Although SLAM has only been around since 1979, it has been used in a variety of situations. Examples of its application include simulation of a production and distribution system for grain in the United States [6], investigation of the potential for controlling the tobacco budworm through hybrid sterilization [10], analysis of the proposed designs of an aerospace manufacturing facility, assessment of material handling and storage requirements at a blast furnace, and evaluation of the throughput of a new pharmaceutical production line [16]. A detailed description and documentation of the SLAM simulation language is provided in [15].

Process description

Fish processing encompasses the entire process from the arrival of raw fish to a factory to packing. The steps involved in processing the fish are common to most industries. As an example of the process in a fish processing factory the process used in "Ishusfelag Bolungarvikur", (Bolungarvik Iceland), will now be described. The material flow is shown in Figure 2.

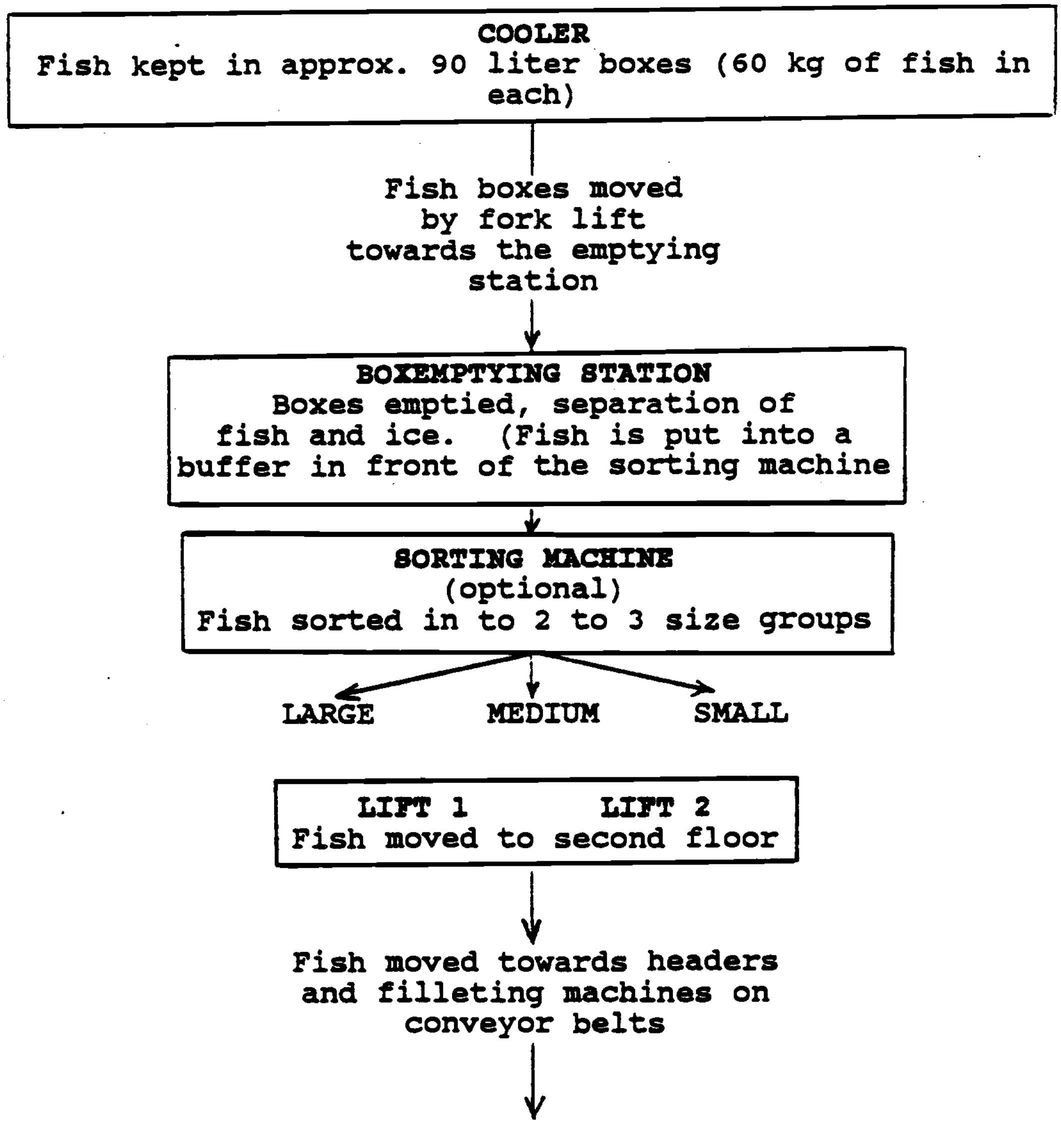


Figure 2. A Rough Description of the Process in a Typical Fish Processing Plant.
(Continued on next page)

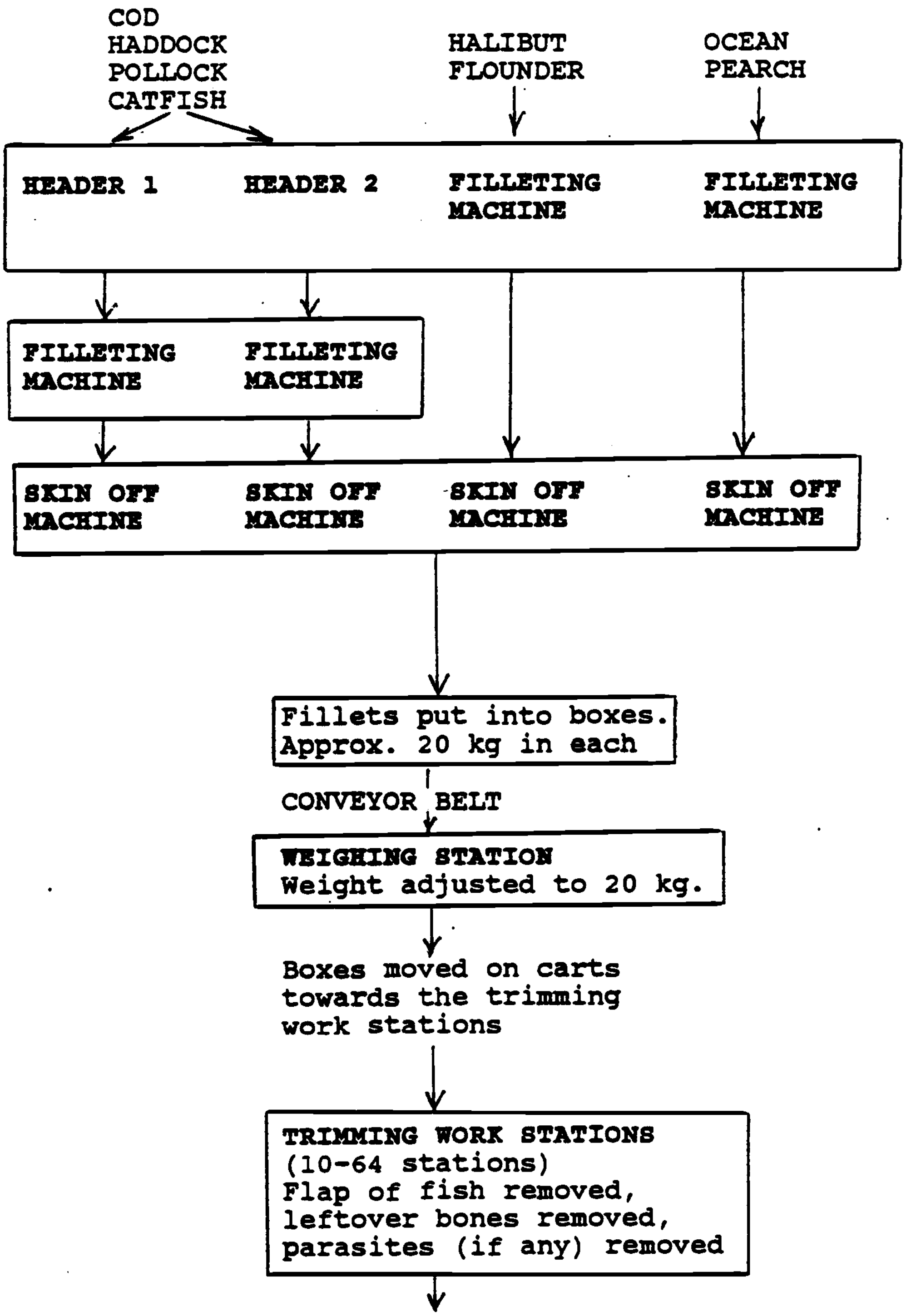


Figure 2. (Continued) A Rough Description of the Process in a Typical Fish Processing Plant.
(Continued on next page)

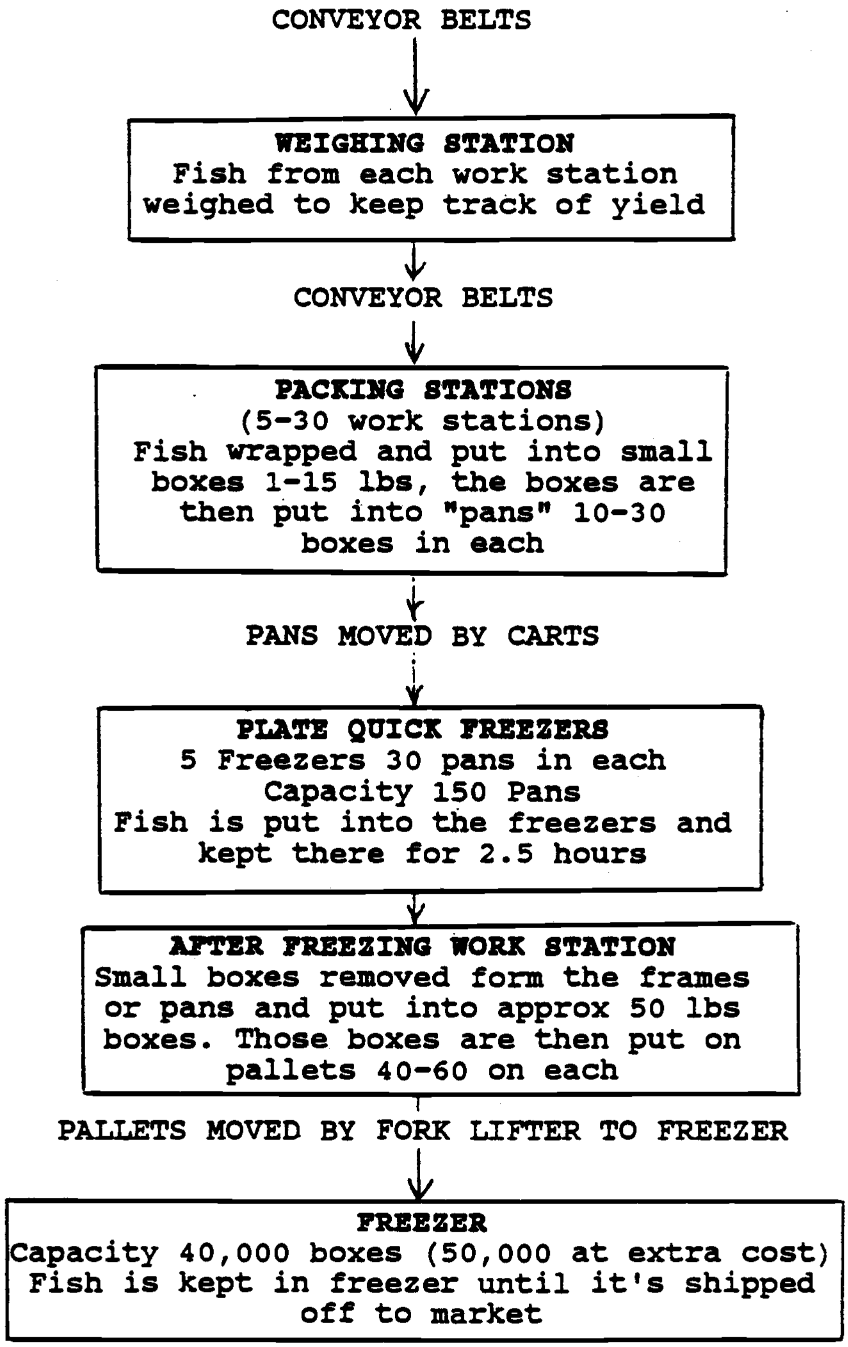


Figure 2. (Continued) A Rough Description of the Process in a Typical Fish Processing Plant.

The raw material (fish) is delivered to the factory by two trawlers and by boats. One of the trawlers is about 350 tons and can bring in 0 to 140 tons on each fishing trip. The other trawler is a 500 ton trawler and can bring in 0 to 200 tons on each fishing trip. A fishing trip can take 2 to 11 days. The boats usually go out in the morning and bring in their catch in the evening; their total catch ranging from 10 to 70 tons.

The fish is bleed (the throat is cut) and gutted (the guts taken out) onboard the ships. It is then iced and put into boxes, each box containing approximately 60 kilograms of fish. Once ashore, the fish (still in the boxes) is put into a cooler at the plant. The cooler capacity is around 300 tons, or about 5000 boxes.

When work starts on the fish, it is moved by a fork lift, eight boxes at a time, from the cooler to a "box-emptying station". The boxes are emptied and the fish separated from the ice. The fish then goes to a sorting machine. The sorting procedure, which is optional, grades the fish into 2 to 3 sizes. The main processing area in this particular plant is located on the second floor, so after grading, the fish is moved by an elevator to the second floor. Currently, two elevators are in operation. Next, the fish undergoes three sequential machining operations.

1. The heading operation : The fish is put through a machine (header) that takes the head off the fish. The head is put away to be sold to a fishmeal factory. The head is approximately 30 percent of the weight of the fish (as it comes to the factory). When the fish comes out of the header it is ready to be put through the filleting machine. There is no transportation required to move the fish from the heading machine to the filleting machine. There is a small buffer between the header and the filleting machine though. Each header requires one operator.

2. The filleting operation : Fillets are the boneless or pinbone in, sides of a fish, cut away from the backbone and removed in one piece [17]. The fish are put through a filleting machine, which fillets the fish. The backbone and the rest of the fish, excluding the fillets, is put away to be sold to a fish meal factory. The backbone constitutes approximately 17 percent of a gutted fish; hence, the fillets are approximately 53 percent of a gutted fish. Each fish yields two fillets, and each filleting machine requires one operator.

3. The skinning operation : The fillets from the filleting machine are next processed by a skinning machine. Skinning a fillet means to

remove the skin from the fillet. The fillets, coming out of the filleting machine, are within reach of the operator of the skinning machine. The skinning machine requires one operator to feed it. Some filleting machines automatically feed the fillets into the skinning machines. The skin which constitutes 3 to 10 percent of the weight of the fish coming into the plant is put away with the bones and heads to be sold to a fishmeal factory. The overall yield from the three machines varies from about 38 to about 48 percent.

When the fillets come out of the skinning machine they are put into trays, approximately 20 kilograms in each tray. These trays are sent to a weighing station to ensure that the weight of each tray be as close to 20 kilograms as possible. Once weighed, the trays are stored in a "buffer" until being worked on at the trimming stations. The output from the trimming stations consists of these products:

1. Napes: The thinnest part of a fillet, the part that covered the guts before the fish was gutted. Napes are also refered to as the flaps.

2. Block : To give a trimmed fillet a better look, some parts of the fillet are removed. The parts removed, other than the napes, are referred to as block.

3. Trimmed fillet : A fillet can be trimmed in many ways. One way is to cut off the nape, remove the pinbone (a bone leftover by the filleting machines) and then cut the fillet to make it look better, which often involves cutting off some of the tail or other parts of the fillet that may look "loose".

At the trimming station the fillets are trimmed, the pinbone and any other leftover bones are removed, the nape is cut off and parasites removed if any. After the trimming of one 20 kilogram tray is completed, the resulting three products, trimmed fillets, napes and block are sent to a weighing station, where they are weighed and stacked in a buffer waiting to be packed.

The primary task at a packing station is the wrapping of fillets, napes and block, and storage of these products in boxes. There are three types of packing stations for each species, one for fillets, one for napes and one for block. The packing for the fillets is a function of the procedure used for trimming the fillets and the species of the fish. For the napes and the block there are fewer alternatives, hence for most species there are only two types of packings for these two products. The weight of the packed fish boxes ranges from 5 to 20 lbs. After the fish has been packed, the boxes are put into pans. The number of boxes in one pan may range from 4 to 45, depending on the size of the box. As the pans are filled, they are taken to a buffer in front of the quickfreezer units where they wait until a quickfreezer unit becomes available. Since the capacity of each quickfreezer unit is 30 pans, the pans are not put into the quickfreezer until there are at least 30 pans waiting. After the fish has been quickfrozen, the packages are put into boxes, approximately 50 lbs in each. Those boxes are then put on pallets and stored in the freezer until being shipped for export.

III. MODELING APPROACH

Programming Language

The simulation model for a fish processing facility was developed using SLAM network modeling. The SLAM network approach uses the concept of nodes and branches to translate a system into a simulation model.

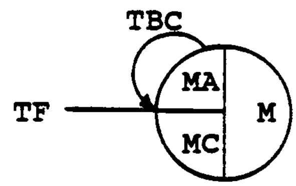
In the simulation model developed in this research, the fish boxes are modeled as entities in the system. The machines, operators and material handling equipment represent resources in the system. As the entities (that is, fish) move through the system, they are processed by resources. Processing may involve transformation in the state of entities, division of the entity into components (as for example, when a fish is divided into napes, block and fillets), or simple movement of entities in the system. A series of variables that model the state of the system are referred to as global variables. The value of a global variable, if changed at a specific location in the network, changes throughout the entire network. An example of a global variable is the number of entities in the system. A second set of variables is unique to each entity, and are called the attributes of an entity.

An example of an attribute is the weight of a tray of fillets. The objective in the simulation model is to describe the changes affecting the entities in terms of the attributes and global variables, and to evaluate statistics of interest to the user of the model such as resource utilization's, throughput times, and in-process inventory levels.

Before describing the simulation model, the nodes used in this model are briefly reviewed. A detailed descripition of the nodes is given in Pritsker and Pegden [15].

The CREATE node

The CREATE node is used to generate entities and route them into the system. Its main function is to start the simulation by scheduling the first arrival to the system, and then continuing the simulation by generating subsequent arrivals. The CREATE node and its parameters are illustrated in Figure 3.



TF = time of creation of first entity

TBC = time between creation of entities, can be :

a) constant
b) random variable described by a statistical distribution

MA = the creation time of an entity is stored in the MA-th attribute of the entity

MC = the maximum number of entities that can be created at the node

M = the maximum number of branches to be taken from the node

Figure 3. The CREATE node

The ASSIGN node

The ASSIGN Node is essentially used for assigning values to global variables and attributes of an entity. The SLAM network provides a set of 100 global variables and 100 attributes that are defined by the vector **XX(I)** and **ATRIB(I)**, respectively, where I is an integer number ranging from 1 to 100. Thus, the system has provision for the user to define upto 100 global variables or attributes.

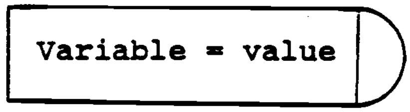


Figure 4. The ASSIGN node.

ACTIVITIES

ACTIVITIES are modeled by branches. Explicit time delays for entities flowing through the network can only be prescribed at branches. For each branch there is one starting node and one ending node. A number of branches can emanate from the same start node. When an entity departs from the start node it is routed through one or more branches emanating from the node. The number of branches to be taken by an entity are specified at the start node. Given more than one branch from a node, the branch to be selected by an entity may be specified using either probabilistic or conditional branching. For probabilistic branching each branch is assigned a certain probability of selection; in case of conditional branching a branch is selected if the entity meets certain prescribed conditions.

DUR, PROB OR COND

DUR = the duration specified for the activity

PROB = the probability of selecting the activity

COND = a condition for selecting the activity

Figure 5. ACTIVITIES

The RESOURCE BLOCK

The RESOURCE BLOCK identifies the resource name, the initial capacity of the resource and the order in which files, associated with the AWAIT Nodes, are to be selected in order to allocate freed units of the resource to entities. The files represent queues where entities wait for a unit of resource to become available. During simulation, the resource capacity may be altered, as for example, the decrease in available fork lifts when no more fish is to be entered into the system.

RLBL(IRC)	IFL1	IFL2	...

RLBL = the RESOURCE name

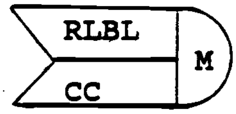
IRC = number of units of the resource that are allocated at the beginning of a run

IFL1, IFL2,... = file numbers where entites wait for RESOURCE to become available

Figure 6. The RESOURCE BLOCK

The ALTER node

The ALTER node is used to change the units of RESOURCE available for allocation in the network. When an entity flows through an ALTER node, the capacity of a given RESOURCE is changed by the number of units specified by the user. The units specified may be positive, if resource level is to be increased, or negative if the resource level is to be decreased. However, any attempt to decrease the resource level below zero is ignored by the system.



RLBL = RESOURCE name

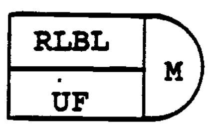
CC = number of units the RESOURCE is altered by

M = the maximum number of branches to take from the node

Figure 7. The ALTER node

The FREE node

At a FREE node, units of a RESOURCE that were allocated to an entity at an AWAIT node are released. Those units of RESOURCE can then be instantly allocated to entities waiting for the RESOURCE at an AWAIT node.



RLBL = RESOURCE name

UF = units of resource type RLBL released

M = maximum number of branches to be taken from the node

Figure 8. The FREE node

The GATE BLOCK

A GATE BLOCK, like the RESOURCE BLOCK, is a declaration node and is used to define a GATE, that is, the name of the GATE, the initial status of the GATE (whether initially open or closed), and the file numbers associated with entities waiting for a gate to be opened at AWAIT nodes. A GATE BLOCK is essentially a RESOURCE block with infinite capacity. The entities may pass through a GATE if the GATE is open; otherwise, the flow of entities is halted in the network.

GLBL	OPEN or CLOSE	IFL1	IFL2	...

GLBL = name of the GATE

OPEN = declares that the GATE is initially OPEN

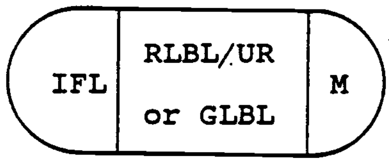
CLOSE = declares that the GATE is initially CLOSED

IFL1, IFL2,... = file numbers where entities wait for the GATE to open

Figure 9. The GATE BLOCK

The AWAIT node

Entities waiting for one or more units of a RESOURCE, or entities waiting for a GATE to open, wait at AWAIT nodes. The AWAIT nodes represent queues or files associated with RESOURCES and GATES, and automatically maintain statistics on such measures as average number of entities in the file and the average waiting time for an entity in the file.



RLBL = name of RESOURCE

UR = units of resource RLBL

IFL = the file or queue for storing the entities

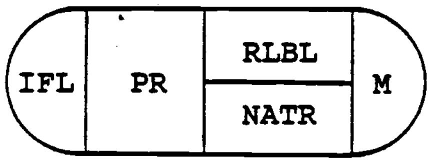
GLBL = name of GATE

M = the maximum number of branches to be taken from the node

Figure 10. The AWAIT node

The PREEMPT node

If an entity encounters a PREEMPT node it can preempt a resource that has already been allocated to another entity. Preemption may be made based on a priority assigned to an entity that arrives at the node. The preempted entity is routed to a specified node; if no node is specified the entity is routed to the AWAIT or PREEMPT node it originated from, where it is placed at the head of the queue to be processed when a RESOURCE becomes available. The remaining processing time for the entity at the time of preemption may be stored as an attribute value of the entity.



PR = priority specification for preemption; may be based on low or high value of an attribute.

RLBL = name of RESOURCE

NATR = Attribute number which contains the remaining processing time of the preempted entity

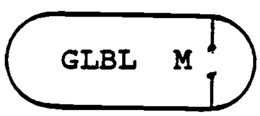
IFL = the file or queue for storing the entities

M = maximum number of branches to take

Figure 11. The PREEMPT node

The OPEN node

When an entity flows through an OPEN node it causes a gate specified at the OPEN node to be opened. This causes all entities waiting at an AWAIT node associated with the gate to be released to the network.



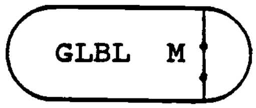
GLBL = name of GATE to be opened

M = maximum number of branches to take

Figure 12. The OPEN node

The CLOSE node

A CLOSE node causes all subsequent entities arriving at an AWAIT node associated with a GATE to wait until the gate is reopened using the OPEN node.



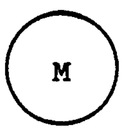
GLBL = the name of the gate to be closed

M = maximum number of branches to take

Figure 13. The CLOSE node

The GOON node

The GOON node is used to model sequential activities, that is, to separate one activity from another. Its function is equivalent to the CONTINUE statement in FORTRAN.



M = maximum number of branches to take from the node

Figure 14. The GOON node

The COLCT node

At a COLCT node statistics may be collected on the following variables:

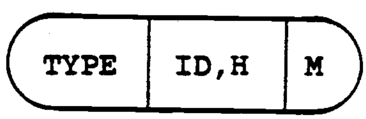
a) FIRST : The time of first arrival to the node.

b) ALL : The arrival time of all entities to the node

c) BETWEEN : The time between arrivals of entities.

d) INTERVAL : The arrival time of an entity to the COLCT node minus the attribute value of that entity stored in the mark attribute (as specified in the CREATE node)

e) SLAM variable : The value of a SLAM variable is recorded as an observaiton every time an entity arrives to the node.



TYPE = type of variable to be collected

ID = a 16 character identifier for the node

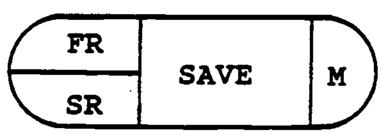
H = specifications for a histogram

M = number of branches to take from the node

Figure 15. The COLCT node

The ACCUMULATE node

The ACCUMULATE node is released only when a prescribed number of entities have arrived to the ACCUMULATE node. As an example, consider an aircraft which may only leave after 150 passengers have boarded. An ACCUMULATE node will hold the aircraft until the specified number of passengers have arrived. Since only one entity is released for n entities arriving to an ACCUMULATE node, a specification is required for the attribute to be saved. For example, the user may specify that attributes of first or last entity causing the release of ACCUMULATE to be saved, or some additive or multiplicative measure of the attributes of all entities to be saved. A specification is required, as to how many entities are needed to release the node, both for the first time and for subsequent releases.



FR = first release requirement, for node

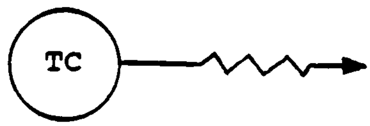
SR = subsequent release requirement

SAVE = rule for saving attributes when entities are accumulated

Figure 16. The ACCUMULATE node

The TERMINATE node

A TERMINATE node causes an entity to be removed from the network after all the requested processing has been performed.



TC = number of entities at the node to terminate a simulation

Figure 17. The TERMINATE node

Simulation Model

In an effort to keep the model as simple as possible but realistic, it is designed to handle two species of fish at a time. Furthermore, species-1 can be processed into two different products of fillets, referred to as type-1 and type-2, and the two side products, napes and block, so that there are four different products that can be made from species-1, on any given day. From species-2 there are three products that can be made; the fillets, and the side products, napes and block. Species-1 or species-2 can represent any species processed at the fish processing plant. Therefore, the above restrictions should not limit the generality of the model, particularly since no more than 7 types of products are produced at a fish processing plant on any given day.

To accomplish this objective, three types of trimming workstations and seven types of packing stations are required. A complete listing of the SLAM model is given in Appendix 2, and definitions of all variables used are given in Appendix 1.

The model consists of five separate sub-networks. As shown in Figures 18 to 22, the resources and the gates which represent declarative nodes, have to be declared before being used in the network. The resources used in the model are :

1) Fork lifter for species-1
2) Fork lifter for species-2
3) Box emptying station for either species
4) Elevator for transporting fish
5) Machine performing the heading, filleting and skinning operations for species-1
6) Machine performing the heading, filleting and skinning operations for species-2
7) Trimming stations for species-1, type-1
8) Trimming stations for species-1, type-2
9) Trimming stations for species-2

10) Weighing station for trimmed fillets, napes and block

11) Packing station for fillets of species-1, type-1

12) Packing station for fillets of species-1, type-2

13) Packing stations for napes of species-1 (either type)

14) Packing stations for block of species-1 (either type)

15) Packing stations for fillets of species-2

16) Packing stations for napes of species-2

17) Packing stations for block of species-2

18) Quick freezer units for pans

At the start of the simulation the user is asked to provide interactively, the values of the system parameters. The system parameters include, number of trimming work stations, number of packing work stations, yield of machines, yield of trimming workers, division of raw material between the products, and the breakdown and the repair rates of the machines. Default values for each parameter are built into the model; if the user wants to overwrite these values, new values may be provided. This facility is designed using a FORTRAN written front-end program which is run prior to running the simulation model itself. The FORTRAN program reads the values into a file that is later called by the SLAM network program. The call is made by a user function, also written in FORTRAN. The user function and the front-end program are described later in this chapter and their listings are given in Appendices 3 and 4, respectively.

The function of the first network, shown in Figure 18, is to change the capacity of resources during the simulation execution. SLAM requires that the resource block specify a non-zero level of resources at the start of the simulation. However, work does not start at the same time throughout the fish processing plant. So although work may have started on some machines at the start of the day, work further down the line starts some 30 to 60 minutes later. Thus, the capacity of these resources is decreased to zero until 30 minutes after the start of the simulation, when entities have reached the stations represented by these resources. At this stage, the resource capacity of these resources is increased to the specified level. The decrement in resources not being initially utilized is required so as not to affect the resource utilization.

The second network, illustrated in Figure 19, serves to to stop the flow of fish from the cooler into the network after five hours (300 minutes) of

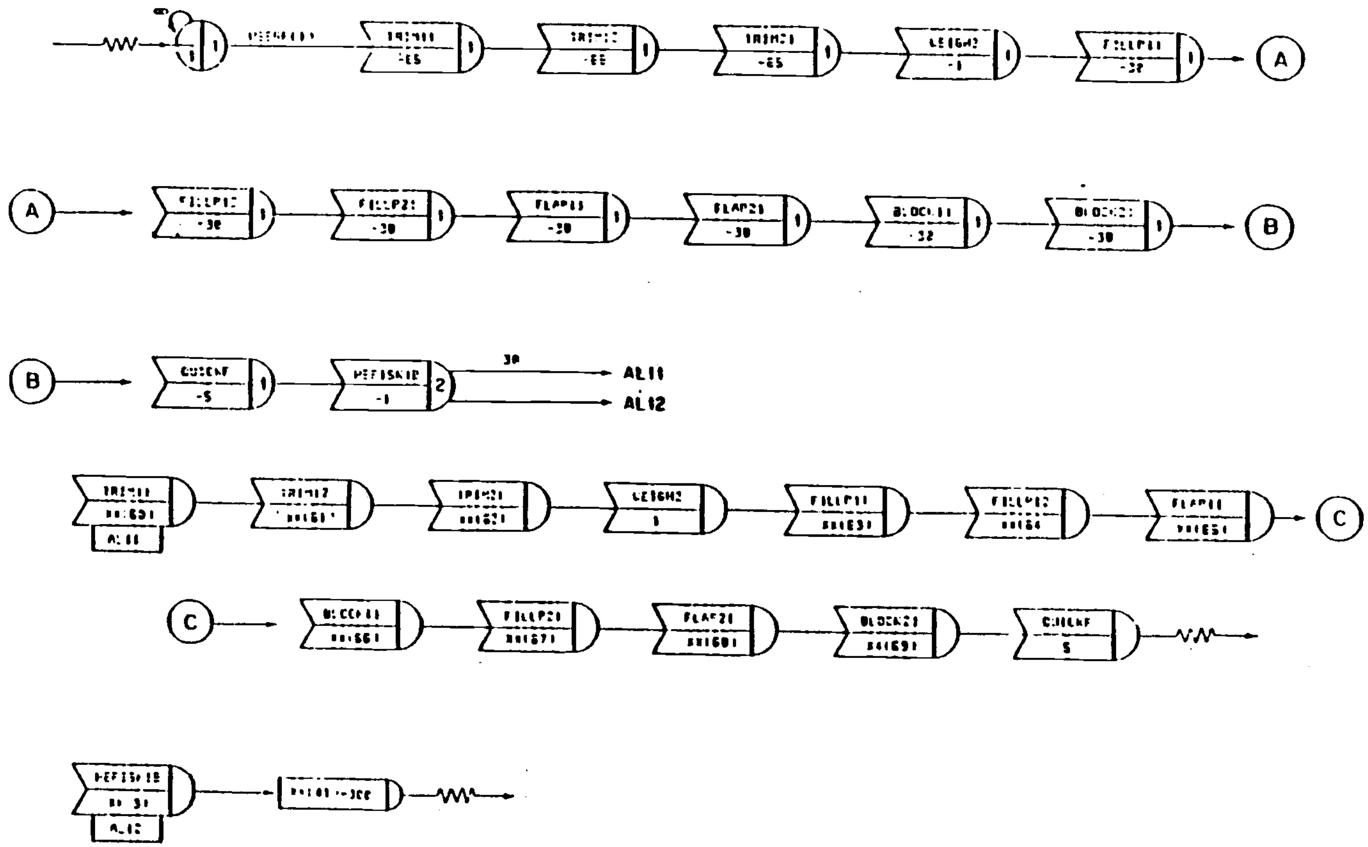


Figure 18. Network 1 : Control of Resource Capacities.

processing. This is accomplished by altering the capacity of the two fork lifters to zero, and thereby making them unavailable to transfer more fish to the system. The reason for stopping the flow of fish to the network after five hours is to ensure that no fish is left in the system as process inventories at the end of the work day; otherwise, any unprocessed fish will deteriorate by the next workday.

The third network, shown in Figure 20, is used to keep track of the utilization of the machine representing the heading, filleting, and the skinning operations. At intervals of ten minutes, a user written function is called to record the current utilization of the machines.

The fourth network, illustrated in Figure 21, models breakdowns and repair of filleting machines. To accomplish this, PREEMPT nodes are used to release the resources that represent the machines performing heading, filleting and the skinning operations. The time between breakdowns is assumed to have a triangular distribution, whose parameters are supplied by the user. The repair time is assumed to be uniformly distributed between a low and a high value, these parameters are also supplied by the user. The parameters may vary for different machines. The distributions and the default values for the parameters of both distributions used in

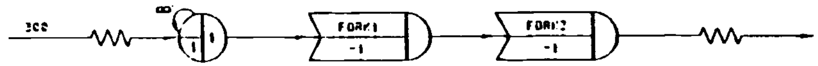


Figure 19. Network 2 : Control of Raw Material.

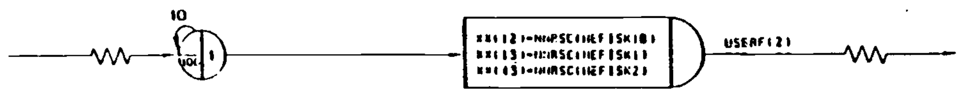


Figure 20. Network 3 : Utilization of Machines.

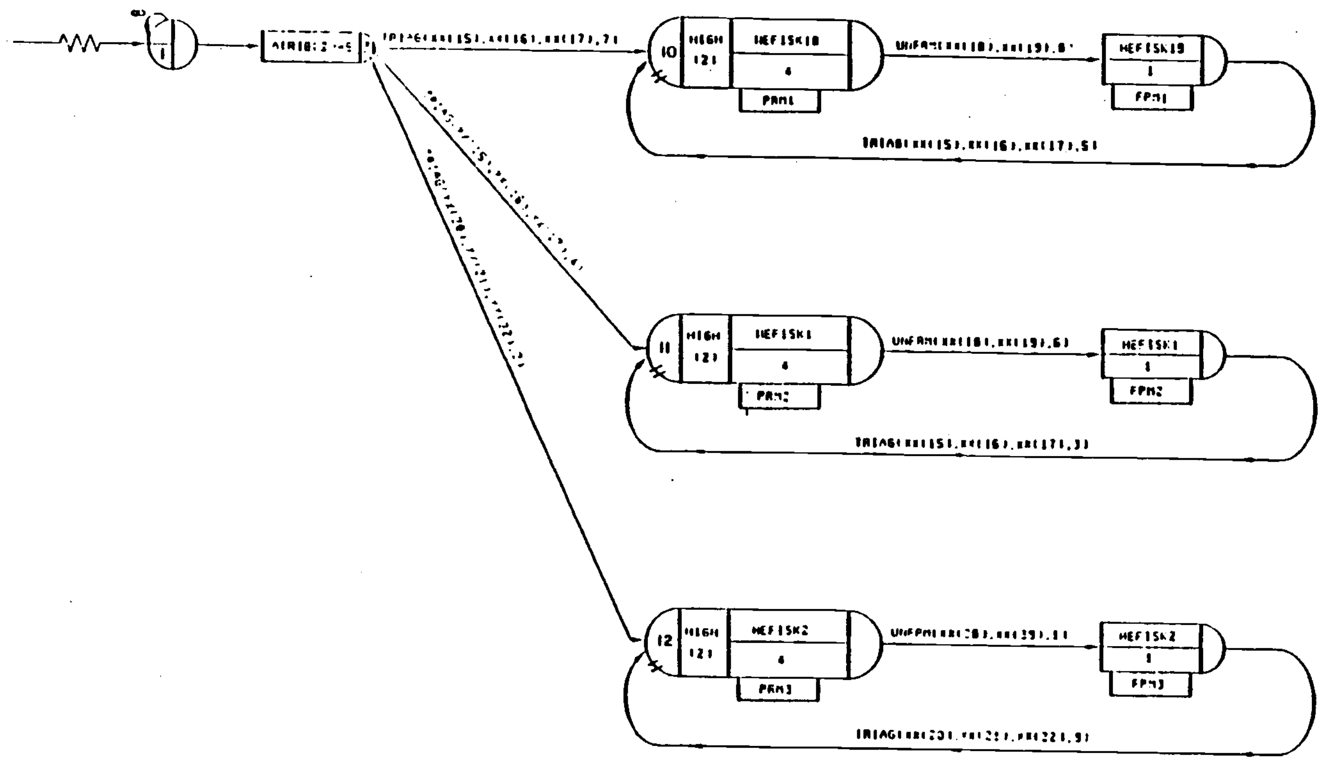


Figure 21. Network 4 : Machine Breakdown and Repair.

the model are based on assesments of the production supervisor at "Ishusfelag Bolungarvikur" [5].

The fifth network which is the main network, is illustrated in Figure 22. It should be noted that one entity, represents different things in different parts of the network. For instance early in the network an entity represents loads of 8-60 kilogram boxes, later it represents 1-60 kilogram box. This change is reflected by the assignments at the different ASSIGN nodes in the network.

Most of the nodes are labeled, both for clarity, and to facilitate the movement of entities over non-sequential nodes. In the following decription the labels will often be used to refer to the specific nodes in Figure 22. To distinguish between different types of nodes, the labels for each type of node begin with a letter corresponding to the name of the node. For example for a CREATE node, the node label is CRxx, where xx is an alphanumeric assignment differentiating the node. Similarly, labels for other nodes include : Axxx for or ASSIGN nodes, Gxxx for AWAIT nodes associated with a GATE, Rxxx for an AWAIT node associated with a RESOURCE, Prxx for PREEMPT nodes, Fxxx for FREE nodes, Oxxx for OPEN nodes, Cxxx for CLOSE nodes, GOxx for GOON nodes, LCxx for COLCT nodes, and TExx for the TERMINATE node.

The RESOURCE BLOCK

RLBL	IFL1	IFL2
COOLER1(5000)	1	
FORK1(1)	3	
FORK2(1)	4	
BOXEM(1)	5	
ELEV(2)	9	
HEFISK1(1)	11	13
HEFISK2(1)	12	14
HEFISK1B(1)	10	15
TRIM11(65)	22	
TRIM12(65)	23	
TRIM21(65)	24	
WEIGH2(1)	25	
FILLP11(30)	27	
FILLP12(30)	26	
FILLP21(30)	28	
FLAP11(30)	29	
FLAP21(30)	30	
BLOCK11(30)	31	
BLOCK21(30)	32	
QUICKF(5)	35	

The GATE BLOCK

GLBL	OPEN or CLOSE	IFL1	IFL2
GMACHOUT	OPEN	19	
GWEIGH	OPEN	21	
GQUICK	CLOSED	33	

Figure 22. Network 5 : The Main Network.

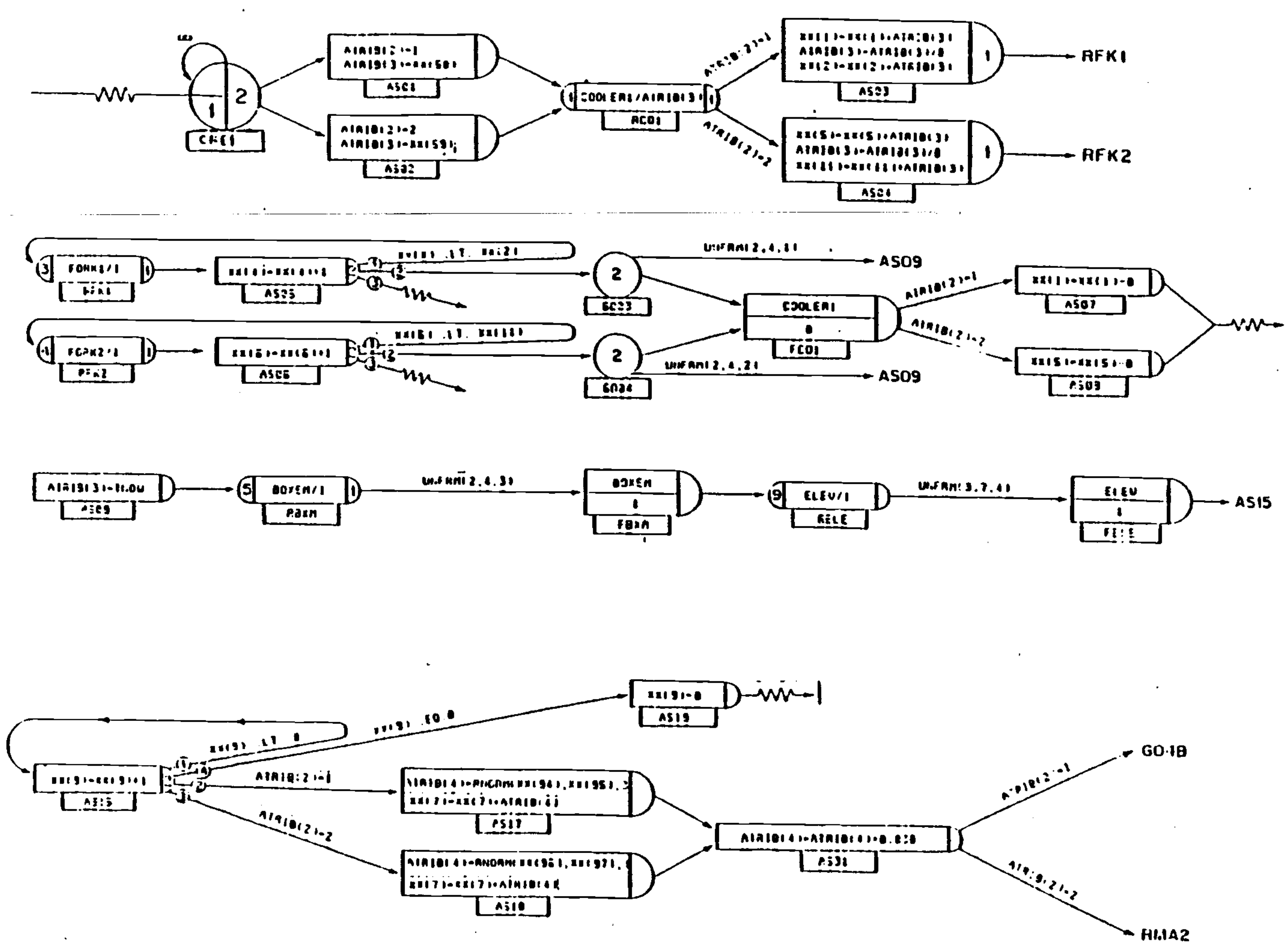


Figure 22. Network 5 : The Main Network (continued).

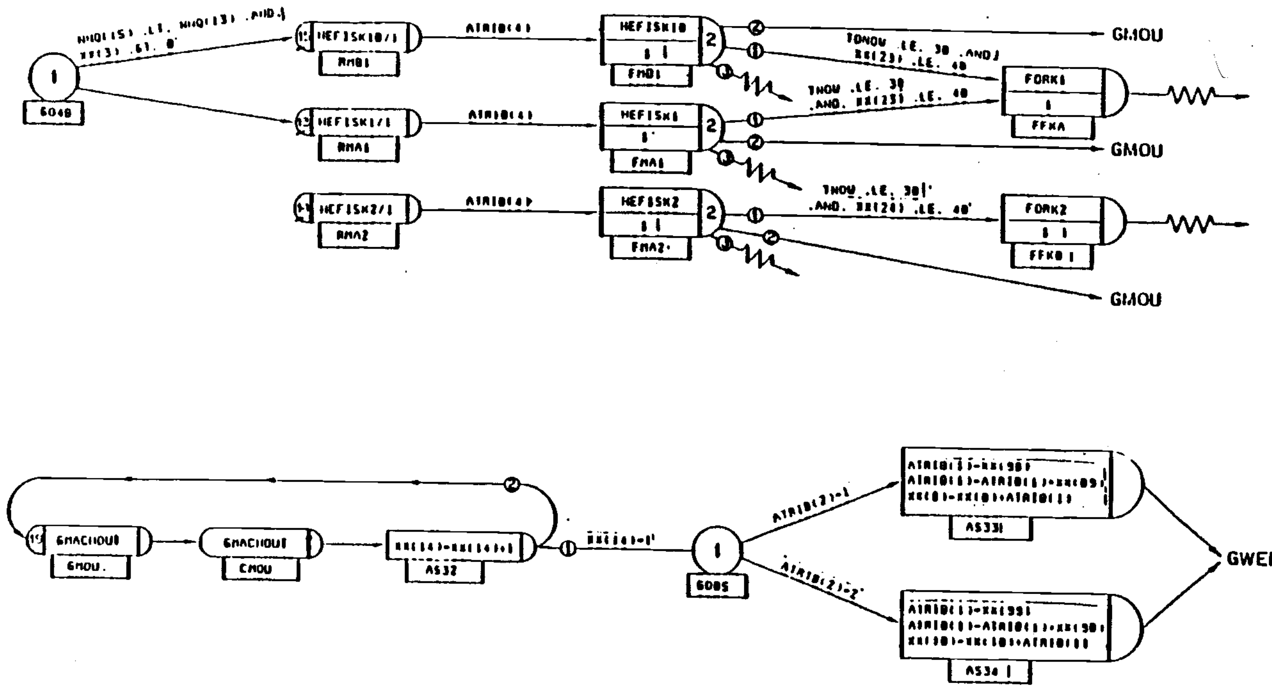


Figure 22. Network 5 : The Main Network (continued).

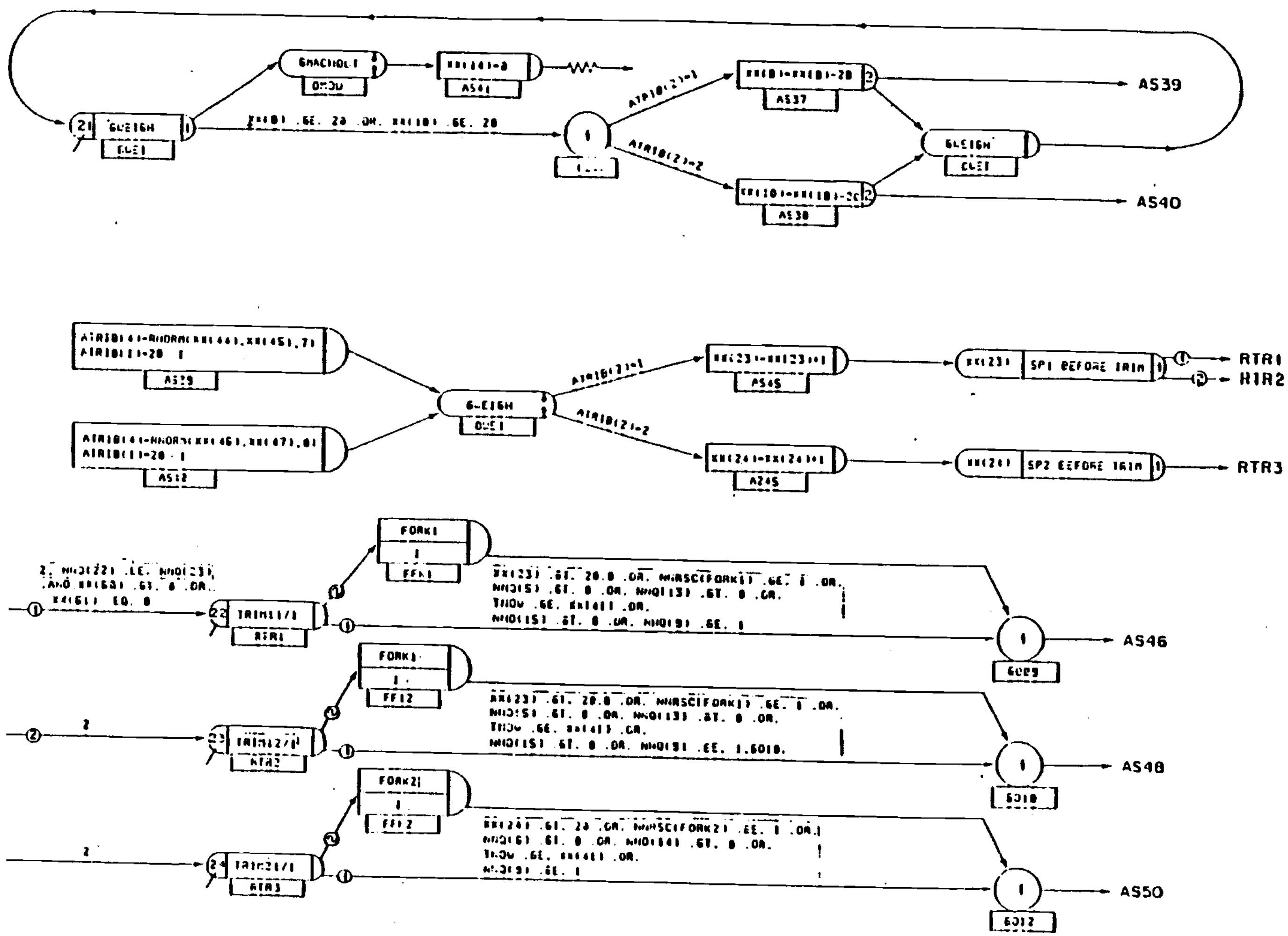


Figure 22. Network 5 : The Main Network (continued).

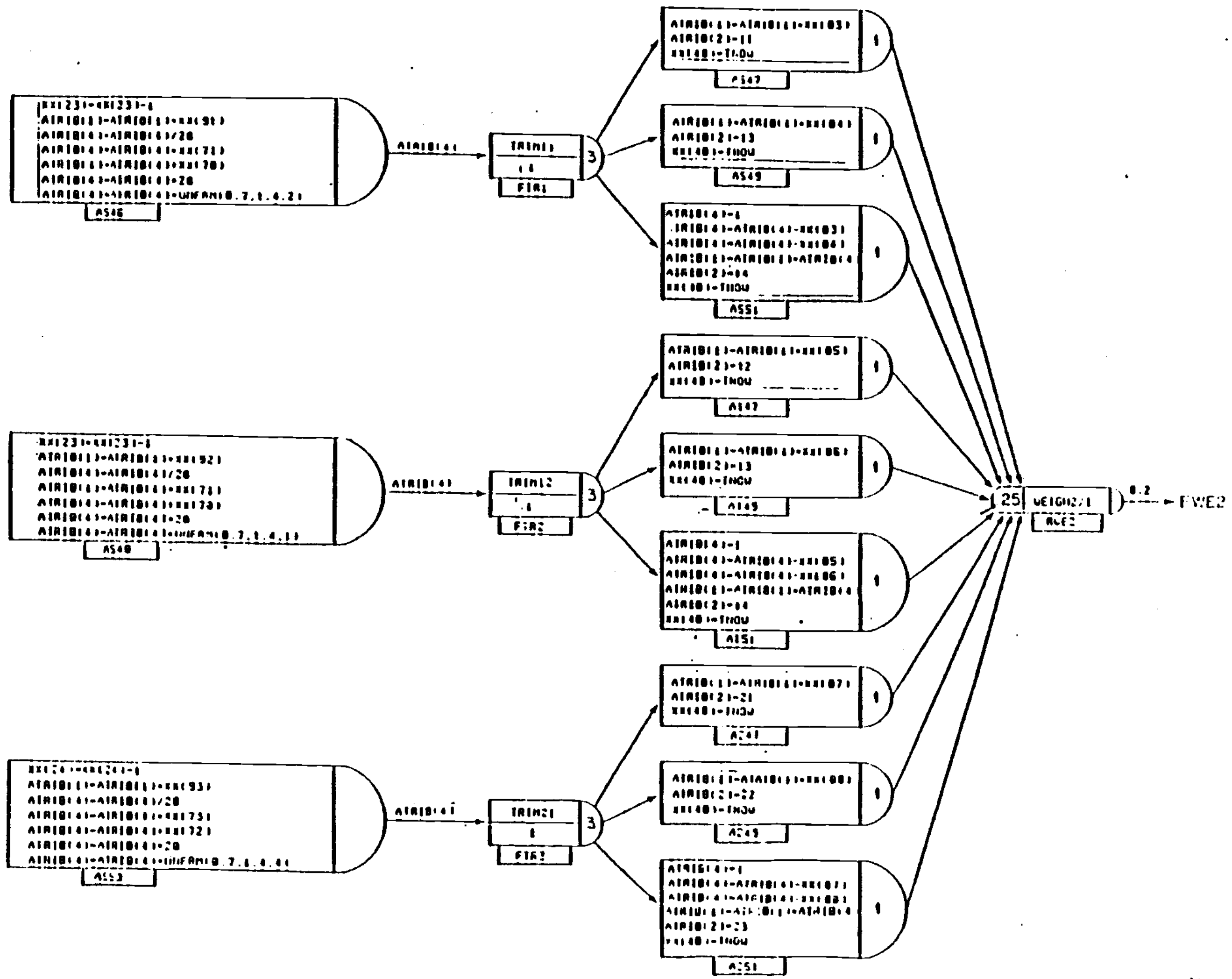


Figure 22. Network 5 : The Main Network (continued).

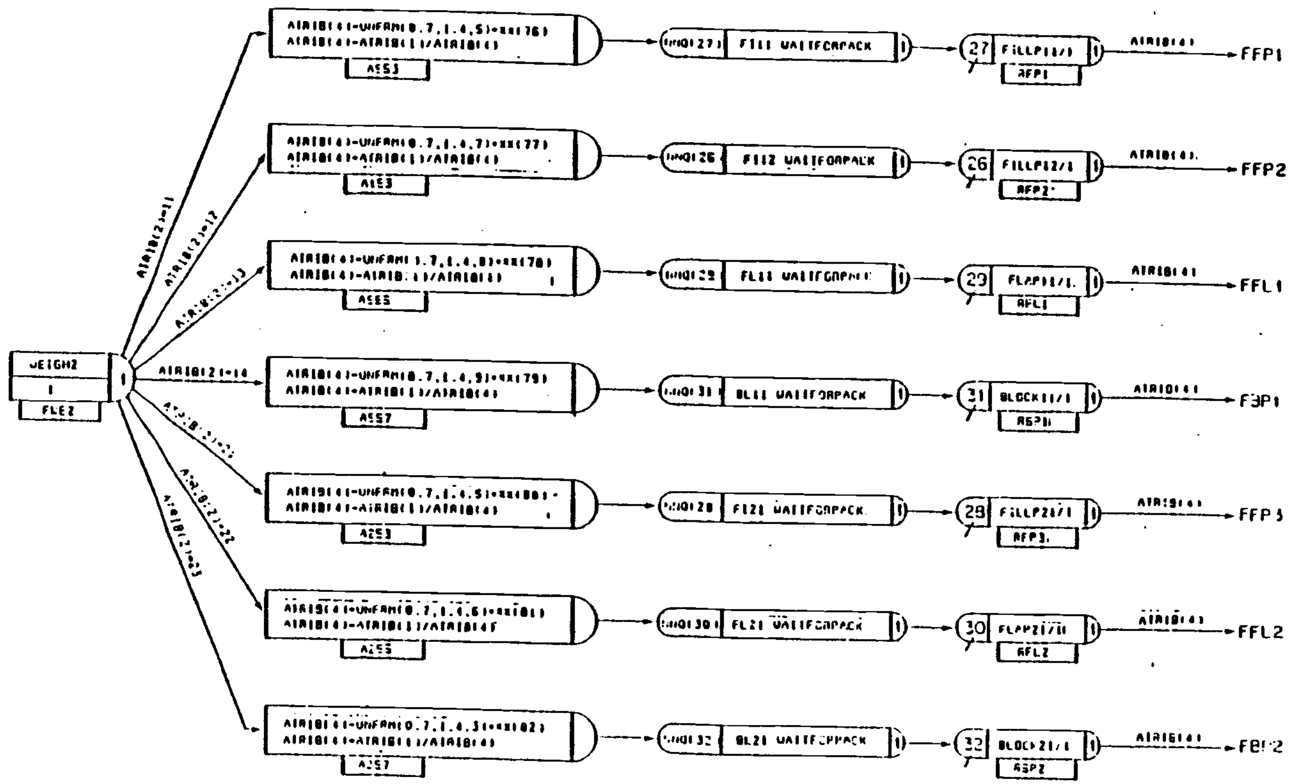


Figure 22. Network 5 : The Main Network (continued).

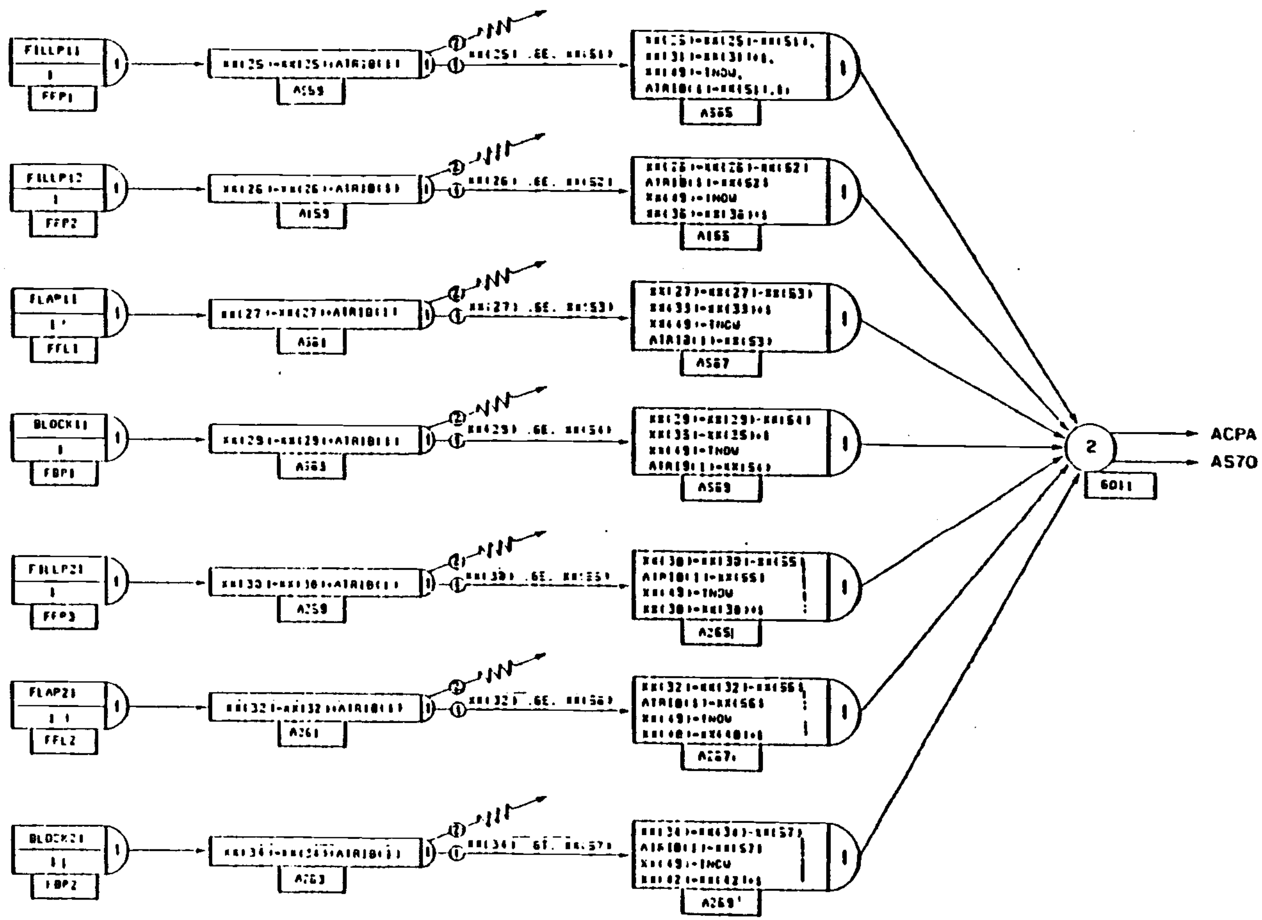


Figure 22. Network 5 : The Main Network (continued).

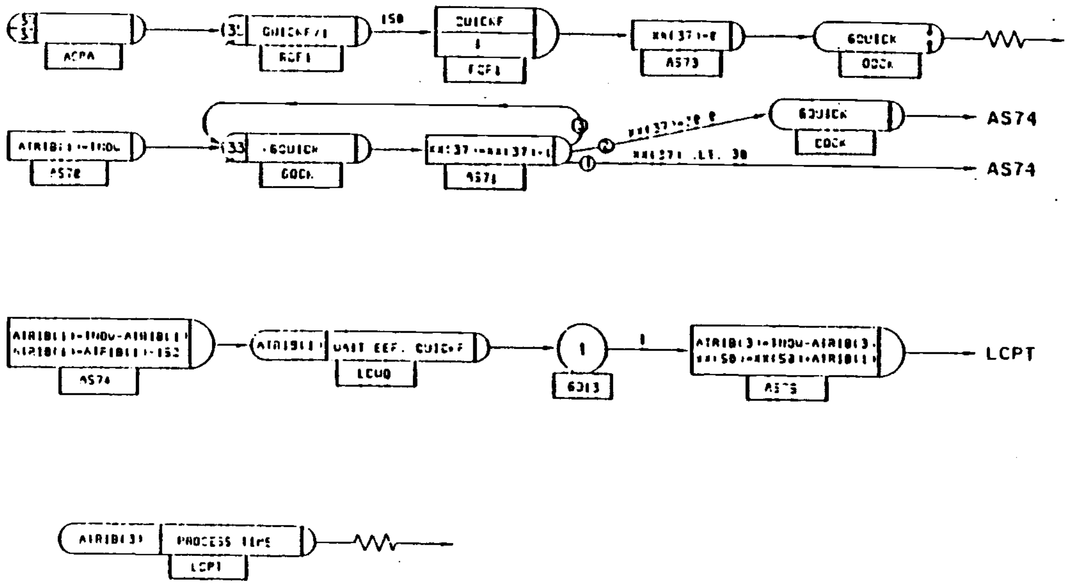


Figure 22. Network 5 : The Main Network (continued).

The simulation starts at time zero corresponding to the start of the work day. At this time, an entity is created at the CREATE node, CRE1. This entity is used to generate the boxes of species-1 at the assign node AS01, and the number of boxes of species-2 at the Assign node, AS02. Both entities go to the resource node RC01 to be stored in the cooler. The entity to be processed is removed from the cooler; the processing depends on the type of fish species. For species-1, an entity at this stage represents an 8-box load. At the await node, RFK1 the entity waits for the availability of the fork lift, FORK1, which transports it to the box emptying station.

In the decription that follows, the simulation model corresponding to the production line for the fish of species-1 producing fillets of type-1 is described. Species-1 can be any one of the species processed at the fish processing plant, and type-1 from that species can represent any of the fillet product from that species. Besides the fillets, napes, block and other side products are also produced. The simulation model for the processing of other raw material (for example, fish of species-2) is identical to the description given below.

On the way to the box emptying station, the current time is recorded to represent the time the fish is removed from the cooler. This time is later on used to calculate the total processing time for the fish. The entity waits for a worker to become available at the box emptying station, RBXM. It takes two to four minutes to empty the eight boxes the entity represents. The fish is then moved by means of a conveyor to the elevator. The elevator moves the fish from the first floor to the main processing area which is on the second floor in the particular plant being modeled. The time it takes to put the fish into the elevator, move it to the second floor, empty it and return it down again is uniformly distributed between three and seven minutes.

An entity still represents the quantity of 8-60 kilogram boxes. For each entity that comes out of the elevator, seven additional entites are entered into the network. Hence, one entity now represents the quantity in 1-60 kilogram box. The number of fishes in the 60 kilogram box is normally distributed with a mean and standard deviation that may be supplied by the user.

Next the fish is taken through three operations -- the heading operation, the filleting operation and the skinning operation. These three operations are modeled as being performed by only one machine since in the real situation the three machine speeds are very well synchronized. Entities waiting for this machine to become available, wait at either one of the await nodes

RMA1 or RMB1. The processing time for each entity is the time it takes to process fish from one 60 kilogram box. The processing time for each fish is constant, therefore, the processing time of one box of fish is dependent on the number of fishes in that box. The product from this machine consists of fillets, head, skin and bones. Fillets, the main product, are stored in 20 kilogram trays. As mentioned earlier, trimming and the subsequent operations start 30 minutes into the workday. Thus, an attempt is made to build inventory of fillets before the trimming operation begins. After entities have undergone the heading, filleting and the skinning operations, their weight has decreased because the heads and bones have been removed, and only fillets are left. An entity continuing to the trimming station represents 20 kilograms of fillets. The assignments reflecting this change are made at the assign nodes AS39 and AS40. The heads and bones are sent to a fishmeal factory, where they are ground and dried, to make fishmeal. The number of fillets in a tray follows a normal distribution, whose parameters are derived from the distribution for number of fishes in a 60 kilogram box.

When a trimming worker becomes available, a check is made on the inventory of 20 kilogram trays; the forklift is allowed to put more 60 kilogram boxes into the system if the inventory is below 20. The standard trimming time, supplied by the user, depends on the species being processed, and on the number of fillets in a tray. In general, for a given number of fillets in a tray, the trimming speed varies from 70 to 140 percent of the standard speed. For each tray processed by the worker, three entities continue through the process. The first entity represents the trimmed fillets from a 20 kilogram tray; the second entity represents the napes from a 20 kilogram tray; and the third entity represents the block from a 20 kilogram tray. These three entities are weighed at the weighing station, RWE2, before being packed.

The three products -- fillets, napes and block -- are packed at separate work stations. The processing time for an entity depends on the type of product being produced; for a particular product, the standard time to pack each kilogram may be supplied by the user. At the plant being modeled, the speed of a worker to pack each kilogram of fillets, napes and block is uniformly distributed between 70 and 140 percent of the standard speed. The three products are accumulated separately. For example, the packed fillets are collected in pans. After a specified weight of fillets have been loaded in a pan, it waits at the await node, GQCK, until 30 pans have collected. When 30 pans have arrived at the freezer waiting area, the entire load consisting of 30 pans is ready to be loaded into a quickfreezer unit as soon as one becomes available. The entity representing 30 pans, occupies the quickfreezer unit for 150 minutes, after which the quickfreezer unit is released for storage of new loads. The 30 pans released from the quickfreezer unit are now available as frozen pans. The small boxes from the pans are packed in larger boxes, and these boxes then transported to a freezer; the transportation time being one minute for the quantity from one pan. The pans are stored in the freezer until the time of distribution.

Uncertainty Modeling

Uncertainty in the system has been modeled using probability distributions. The factors that represent uncertainty include the number of fishes in a box, the number of fillets in a tray, and the service time for activities. The choice of the distributions used in this model was based on either the data obtained from "Ishusfelag Bolungarvikur", or an assessment of a production supervisor at "Ishusfelag Bolungarvikur".

The activity distributions and their parameters are summarized below.

Table 1. Activity distributions and their parameters.

Activity	Distribution	Parameters
Forklift operation	UNIFORM	Minimum=3 Maximum=7
Boxemptying operation	UNIFORM	Minimum=2 Maximum=4
Elevator roundtrip	UNIFORM	Minimum=3 Maximum=7
Heading + Filleting + Skinning	CONSTANT per fish	0.038 minutes per fish
Transportation to Trimming stations	CONSTANT per tray	2 minutes
Trimming Speed	UNIFORM	Minimum=0.7 Maximum=1.4
Weighing	CONSTANT	0.1 minute
Packing Speed	UNIFORM	Minimum=0.7 Maximum=1.4
Quick freezing	CONSTANT	150 minutes
Number of fishes per 60 kilograms	NORMAL	Mean=28.5 Std.dev.=3.26
Number of fillets in a 20 kilogram tray	NORMAL	Mean=42.22 Standard deviation=4.83

A brief discussion of some of the more critical distributions follows.

The machine time for, heading, filleting and skinning operations of one 60 kilogram box of fish is dependent on the number of fishes in the box. This is because the fishes are processed individually. Therefore, although the machine speed is a known constant, that alone is not sufficient to predict the processing time for a box of fish. The data for one shipment of fish brought in at Bolungarvik Freezing Plant ("Ishusfelag Bolungarvikur") was made available by the management of the organization. The data included the weight of the boxes and the number of fishes in a box.

To evaluate the distribution for the number of fishes in a 60 kilogram box, the number of fishes in a box was divided by the weight of the box and then multiplied by 60. By doing this, an entity representing one box could be assumed to have a constant weight of 60 kilograms, and a certain distribution for the number of fishes in the box. The normalized data is shown in Table 2.

Table 2. Number of fishes in a 60 kilogram box.

Cell Number	Number of Fishes per 60 kilograms	Observed Frequency
1	18	1
2	19	0
3	20	1
4	21	2
5	22	3
6	23	7
7	24	10
8	25	13
9	26	18
10	27	27
11	28	20
12	29	19
13	30	34
14	31	19
15	32	20
16	33	8
17	34	2
18	35	1
19	36	2
20	37	2
21	38	1

Number of observations = 210
Number of fishes, Mean = 28.48
Standard Deviation = 3.259

By plotting out the data it appeared that a normal distribution could be fitted to the data. Fig. 23, shows the histogram of the data and of a normal distribution with the same mean and standard deviation. The Chi squared test [2], used to test the appropriateness of the normal distribution to the data, also indicated that the normal distribution represents an adequate fit to the data.

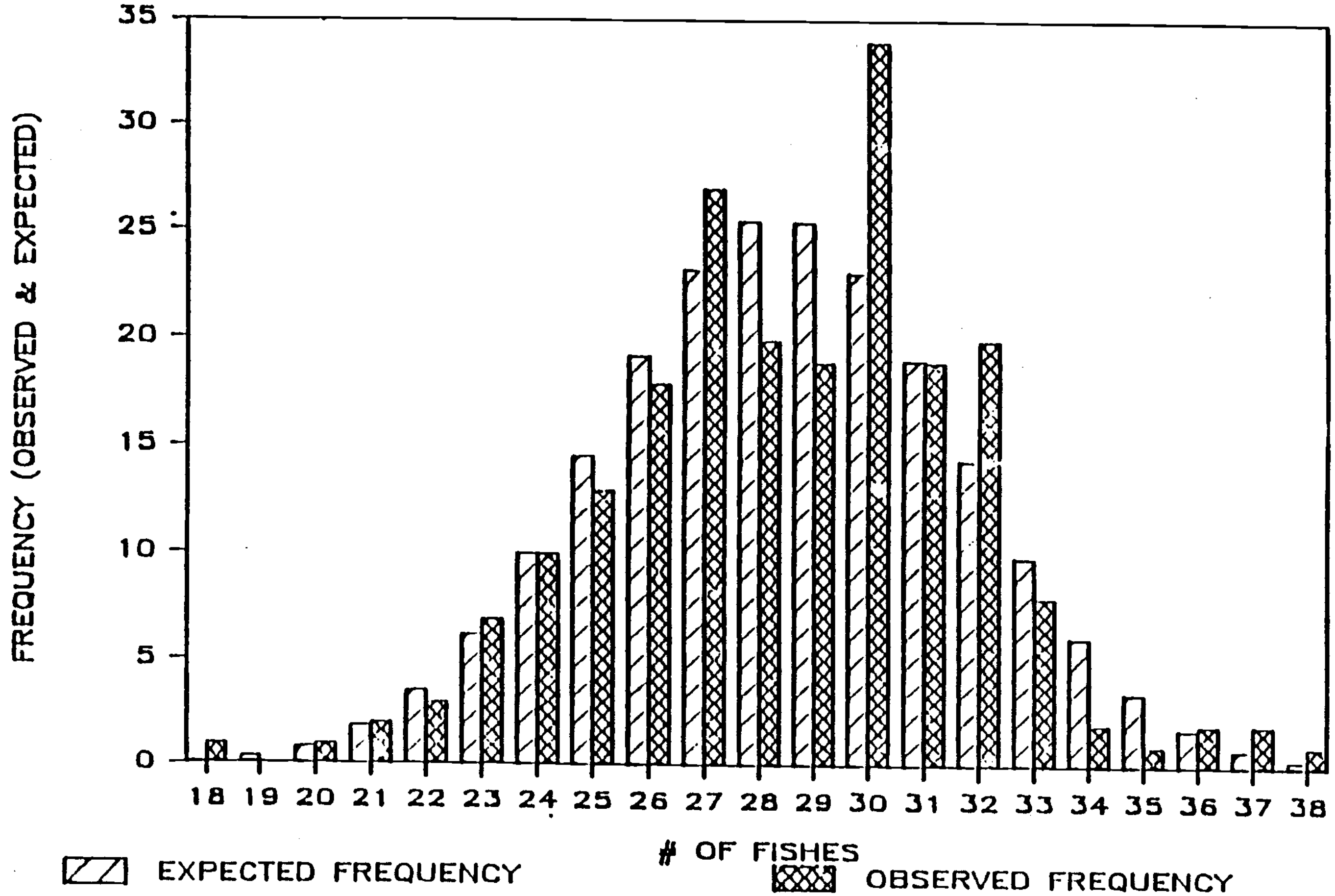


Figure 23. Number of fishes in a 60 kilogram box.

To apply the chi-squared test, the intervals for which the expected frequency is too small to be treated separately, have to be combined to form a larger frequency interval. "Too small" here implies an expected frequency less than five. This procedure is valid if there are more than 10 categories, and less than 20 percent of the expected frequencies is below five. In Table 3, the data has been rearranged to reflect the above change.

Table 3. Number of fishes in a box, observed and expected frequency.

Cell Number	Number of Fishes	Observed Frequency	Expected Frequency
1	21	4	3.2
2	22	3	3.6
3	23	7	6.3
4	24	10	10.0
5	25	13	14.6
6	26	18	19.3
7	27	27	23.2
8	28	20	25.5
9	29	19	25.4
10	30	34	23.1
11	31	19	19.1
12	32	20	14.3
13	33	8	9.8
14	34	2	6.1
15	35	6	6.5
Sum		210	210

The data now has 15 cells. To calculate the expected frequencies three quantities obtained from the observed data were used -- the mean, the standard deviation and the total observed frequency. Therefore, the number of degrees of freedom is 12, that is, total cells minus the number of parameters estimated from the data.

According to Walpole and Myers [22], a goodness-of-fit test between observed and expected frequencies is based on the quantity,

$$Chi^2 = \sum_{i=1}^{n} (o_i - e_i)^2 / e_i$$

where Chi^2 is a value of the random variable X^2 whose sampling distribution is approximated very closely by the chi-square distribution. The symbols o_i and e_i represent the observed and the expected frequencies, respectively, for the i-th cell. The chi-squared test is used here to test the following hypothesis :

Null hypothesis : The normal distribution gives a good fit to the data.

versus the alternative hypothesis,

Alternative hypothesis : The normal distribution is not a good fit to the data.

Using the above equation the calculated value of X^2 is 14.55. From tables for the Chi-squared distribution [2], for a confidence level of 0.95 and 12 degrees of freedom, the critical value for X^2 is 21.03. To be significant the calculated value has to be greater than the critical value obtained from tha tables. Since the calculated value of 14.55 is less than the critical value of 21.03 at the 5 percent level, the null hypothesis that the number of fishes per 60 kilograms has a normal distribution with mean of 28.5 and standard deviation of 3.26 may be accepted.

Another uncertainty to be dealt with is the trimming time of one tray of fillets. The trimming times may be based on standard times. Currently, a wage incentive system is being used at fish processing plants in Iceland, that takes into account both the working speed of a worker and the yield. To calculate the wage incentives, the worker's speed is compared to a standard speed. The following formula, obtained from "Working Methods, Guide and Standards for Wage Incentives in Freezing Plants" [21] may be used for calculating standard times.

Standard time = c1 +
c2 * number of fillets per kilogram +
c3 * number of parasites +
c4 * number of filleting defects per kilogram

where

c1,c2,c3 and c4 are constants depending on the type of product being produced, and are given for all the different product types in [21].

The model can be simplified by assuming that the number of parasites is constant for each run, and also that the filleting defects are constant during a run. Incorporating these assumptions reduces the formula to :

Standard time = C1 +
C2 * number of fillets per kilogram.

Once the distribution for the number of fish per 60 kilograms is known, a distribution for number of fillets per 20 kilogram tray may be derived. This is because the yield of the heading, filleting and skinning machines is generally constant. Furthermore, when filleted, the fish is divided into two equally big parts, the two fillets. Therefore the distribution of the number of fishes in a 20 kilogram tray is a constant multiple of the number of fishes in a 60 kilogram box. That constant is (20 kg/60 kg)*(2 fillets/fish)/(yield of machines). According to Giffin [4] multiplying a random variable by a constant, C, has the following effect.

new mean = old mean * C, and

new variance = old variance * C^2

The task time, for exactly the same kind of task, also varies between workers, and an estimate from Gudmundsson [5], shows that the lowest speed for a worker was about 70 percent of the standard speed and the highest speed was about 140 percent of the standard speed. Using this information, a uniform distribution seems to be appropriate for estimating the speed of a trimming worker, using 0.7 as a minimum and 1.4 as a maximum value for the parameters of the uniform distribution. The actual trimming time is therefore evaluated by first calculating the standard time which varies with the number of fillets in a tray, and then dividing by the uniform distribution.

There is also some uncertainty associated with the packing times. For a given type of packing, the standard time is given in [21], as the standard time for trimming. The standard time is a constant for a given type of packing and is not dependent on parameters like number of fillets per kilogram. The packing speed of a worker is estimated by [5] to vary in the same fashion as the trimming speed of a worker, that is, a uniform distribution, with minimum of 0.7 and maximum of 1.4 of the standard speed. The default values specified for other distributions are similarly based on the current practices at "Ishusfelag Bolungarvikur", Iceland.

Front End Design

To make the model more user friendly and flexible, a "front end" to the model was designed. The objective was to allow the user to input parameters of the system or to change default parameters. Another advantage of the front end is that a user can effectively use the model without any knowledge of the SLAM simulation language.

The front-end, called READIN, is listed in Appendix 4. It is a separate FORTRAN based program, that is executed at the start of the simulation. The values the user wants to change on input are read into a file which is then called by the SLAM network program.

The program, READIN, starts by asking for names of two files that it creates. The first file contains the values of all the variables input by the user, as well as default values that are not changed by the user. This file is later linked to the SLAM network system. The second file contains the user-computer dialog as the front end program is executed. This file may later be printed for the user, so that the user can review the information and make pertinent changes before running the network program itself.

The program displays the default values for each parameter and prompts the user for making any changes, if desired. The user has the option of changing the following parameters :

(1) Trimming workers: Since three different types of trimming workers can be used at a time to turn out three different types of fillets (two for species-1, and one for species-2), three types of trimming workers are modeled.

(2) Packing workers : As mentioned earlier, two types of fillets can come from species-1, and one type from species-2. Although the two types of fillets for species-1 are cut differently, the napes and the block are similar for both types of cuts. Therefore, there are four different products that come from species-1, the two types of fillets, the napes and the block. For species-2, there are three different products, the fillets, the napes and the block. Altogether there are seven products that can be made at the plant, in a given day. This implies that seven types of packing workers are required to pack, four types of products for species-1 and three types of products for species-2.

(3) Parameters for calculating standard times for trimming and for packing : The standard times for trimming are based on the following formula :

Standard time = C1 +
C2*[number of fillets per kilogram]

Therefore, only the values of C1 and C2 have to be read in. Those values are usually different for different types of fillets, or for different species. The default values are taken from [1].

The standard times for packing are given in [21]. The standard time for packing depends on the product being packed. It is different for each species, for different types of fillet packing within the same species, and different for fillets, napes and block within each species.

(4) The proportion of fillet, flap and block in an untrimmed fillet. This proportion depends on the species of fish and on the type of packing to be used for the fillet. It may also depend on the quality of the raw material.

(5) The yield of the machine representing the heading, the filleting and the skinning operations: The yield depends mainly on the fish species, but may also depend on the size of the fish.

(6) The number of machines for heading, filleting and skinning operations for species-1. The base model has three such machines available, of which one machine may only be used for species-2. For species-1, the user has the option of specifying the use of either one or two machines.

(7) The yield of trimming stations : This yield also depends on the type of species.

(8) The average number and standard deviation of number of fishes in a box of raw material : These numbers

may be different for each species, and also for each fishing trip.

(9) Number of packages of each type of fish that fit into one pan : Because the fish is frozen in a plate freezer, the packages of fish have to be put into pans before being frozen. The packages are of different sizes so the number of packages that fit into one pan depends on the kind of packages being used. Therefore the number of packages of each type that fit into one pan, is read in next.

(10) The number of boxes of raw material of each species that are waiting to be put into the system, and the average weight of these boxes.

(11) Breakdown and repair times for filleting machines. Although the headers and the skinning machines rarely brake down, the filleting machines may break down several times during a work day. The primary reason for the breakdown is fish getting stuck in the machines; a secondary cause that may cause machine downtime is breakage of machine-knives. Based on the operations at "Ishusfelag Bolungarvikur", a triangular distribution is used for machine break-downs and a uniform distribution for the repair times. The system displays the default parameters for these distributions, and

prompts the user for changing any of these default parameters.

After all the values have been read in or defaulted to the built in values, the program calculates parameters for the distribution of the number of fillets in a 20 kg tray. Finally, all the values are written out to a data file that may later be read by a user function called by the network model. A listing of the parameters to be read in and the default values is given in Appendix 5. An example of a user-system dialog is given in Appendix 6.

IV. RESULTS

To give some idea of the information that may be obtained using the simulation model presented in this thesis, a few runs of the model were made. However, it should be noted that the objective here is not to solve a unique problem using simulation, but rather to supply a tool that may be used as a decision aid in production planning as well as in facilities design in the fish processing industry. The simulation model also serves as an excellent tool for training production managers, thus resulting in cost and time savings, and increasing the efficiency of the operation.

The output from the simulation model consists of statistics for various measures. Histograms may also be obtained for these measures. The measures include:

1) The number of 60 kilogram boxes put into processing.
2) Inventory of 20 kilogram trays of fillets waiting to be trimmed.
3) The number of trays of trimmed fillets, napes and block of each type or species waiting to be packed.
4) Kilograms of fillets napes and block at packing stations.

5) Number of pans of fillets, napes and block produced during the simulated time.
6) The waiting time of pans waiting to be stored in the quickfreezer.
7) The throughput time, that is the time duration from the moment fish is taken out of cooler to start processing until it comes out of the quickfreezer.
8) Average utilization, standard deviation, maximum utilization, minimum utilization, current utilization and current capacity for all resources defined in the model.
9) For every file used (recall that files are used for entites waiting for a resource) the average number of entities in the file to be processed, the standard deviation of the number of entities, maximum number in the file, current number in the file and the average waiting time for an entity in a file.

A sample of the output from one run of the model is given in Appendix 7.

Discussion of results

Before discussing the results given in Appendix 7, the input to the simulation model for that run will be explained briefly. In Appendix 6, a listing of the user-computer dialog using the "Front - End" program is given where all the input values to the program for the example run are listed.

Input

The example run processes two species of fish, Cod and Catfish. From the Cod, the following products are made : Fillets that are packed into 5 lbs. packings; fillets that are packed into 8 lbs. packings; napes; and block. From the Catfish there are only two types of product being produced : Fillets that are packed into 5 lbs. packings and block.

Values of some major input variables are given below in Table 4.

Table 4. Number of workers for some tasks.

Activity	Species	type	Number of workers
Trimming	1	1	25
Trimming	1	2	10
Trimming	2	1	15
Packing	1	1 fillets	6
Packing	1	2 fillets	2
Packing	1	1 & 2 napes	1
Packing	1	1 & 2 block	1
Packing	2	1 fillets	3
Packing	2	1 napes	0
Packing	2	1 block	1

There is one set of machines performing the heading, filleting and skinning operations for each species. The time elapse between startup of system and start of trimming is 60 minutes. If the number of 20 kilogram trays of untrimmed fillets falls below 40, more fish is brought into the system by sending the forklift to the cooler to get 8-60 kilogram boxes of raw material. The number of boxes of species-1 is assumed to be 1000, and that of species-2 to be 500. All other input values assume default values, as shown in Appendix 6. The statistics in the output are taken after 300 minutes of simulated time.

Output

The first set of output obtained from the execution of the SLAM model are statistics for variables based on observation, that is, variables that are based on simple attribute averages. Among these variables are the number of 20 kilogram trays of each species waiting to be trimmed, the number of entities of each product waiting to be packed, waiting time for pans placed in the quickfreezer and the throughput time. The summary statistics for these variables are shown in Table 5. Histograms for these variables are also obtained as part of the output report.

Table 5. Statistics for variables based on observation

SP1 BEFORE TRIM : Number of 20 kilogram trays of species 1 waiting to be trimmed.
SP2 BEFORE TRIM : Number of 20 kilogram trays of species 2 waiting to be trimmed.
FI11 WAITFORPACK : Number of entities of fillets, species-1, type-1 waiting to be packed.
FI12 WAITFORPACK : Number of entities of fillets, species-1, type-2 waiting to be packed.
FL11 WAITFORPACK : Number of entities of napes, species-1 waiting to be packed.
BL11 WAITFORPACK : Number of entities of block, species-1 waiting to be packed.
FI21 WAITFORPACK : Number of entities of fillets, species-2 waiting to be packed.
FL21 WAITFORPACK : Number of entities of napes of species-2 waiting to be packed.
BL21 WAITFORPACK : Number of entities of block of species-2 waiting to be packed.
WAIT BEF. QUICKF : Number of pans waiting to be stored in quickfreezer.
PROCESS TIME : Time interval between the time, fish is taken out of cooler as raw material until it is taken out of quickfreezer as a finished product.

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
SP1 BEFORE TRIM	.3919E+02	.1339E+02	.3417E+00	.1000E+01	.6000E+02	228
SP2 BEFORE TRIM	.3553E+02	.1765E+02	.4932E+00	.1000E+01	.5400E+02	123
FI11 WAITFORPACK	.9410E+01	.4215E+01	.4491E+00	.5000E+00	.1600E+02	117
FI12 WAITFORPACK	• .9500E+01	.5561E+01	.5853E+00	.0000E+00	.1900E+02	15
FL11 WAITFORPACK	.5864E+00	.8800E+00	.1495E+01	.0000E+00	.4000E+01	162
BL11 WAITFORPACK	.1173E+00	.3415E+00	.2911E+01	.0000E+00	.2000E+01	162
FI21 WAITFORPACK	• .7000E+00	.1035E+01	.1479E+01	.0000E+00	.3000E+01	50
FL21 WAITFORPACK	.2450E+02	.1458E+02	.5950E+00	.0000E+00	.4900E+02	50
BL21 WAITFORPACK	.1600E+00	.5841E+00	.3651E+01	.0000E+00	.3000E+01	50
WAIT BEF. QUICKF		NO VALUES RECORDED				
PROCESS TIME		NO VALUES RECORDED				

Waiting time for pans to be placed in the quickfreezer may be due to two reasons. Either a quickfreezer unit may not be available; or since 30 pans need to be accumulated before loading into the quickfreezer, the number of pans waiting to be loaded is less than 30. The throughput or the process time is the time duration from the moment the fish is taken out of the cooler as raw material, until it is removed from the quickfreezer and put into the freezer. The histograms for waiting time in front of quickfreezers and for processing time are shown in Figure 24 and 25.

The next group of statistics obtained from the simulation model, are statistics for time - persistent variables or variables that are a function of time, and are summarized in Table 6. Among these variables are the number of boxes of raw material of each species in the cooler; kilograms of each product type at packing station, (that is the number of kilograms waiting to be packed plus the number of kilograms already packed, but not enough to fill one pan),and number of pans of each product produced. The last mentioned statistic may enable the user to find out the throughput capacity for different situations. This output facility might be of great importance when time is a critical factor, in the sense that raw material gets spoiled because of age. Other variables of interest to the user may be the completion times for trimming and packing. For instance, there might be a certain amount of raw material that has to be finished by the end of a given day because it may get spoiled if not consumed. The user may then run the model for different kinds of

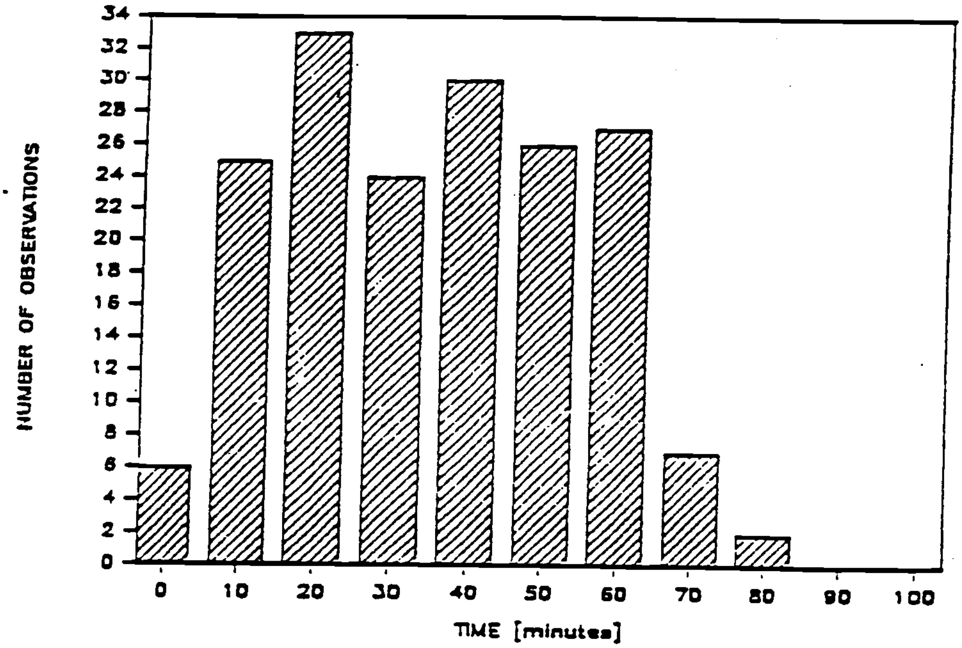


Figure 24. Waiting time in front of quickfreezers.

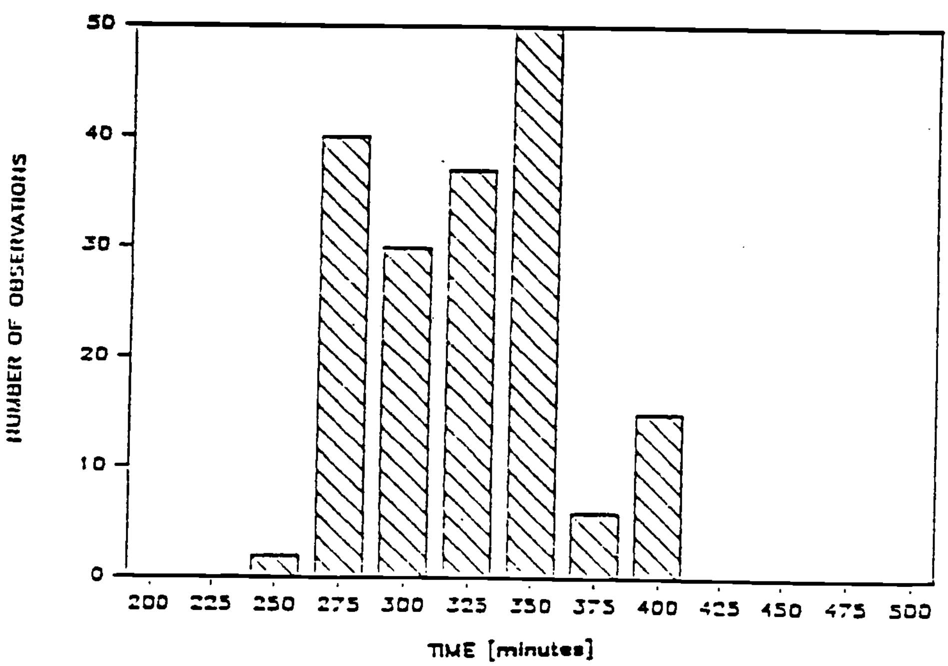


Figure 25. Processing time.

packings for that raw material, and compare the times required to process it, which may in turn dictate the overtime required to complete processing. Because in the example run statistics are taken after 300 minutes, the values of those two variables just show the last time within the 300 minutes a tray came out of a trimming station or a pan out of a packing station.

Table 6. Statistics for time-persistent variables

SPEC 1 IN COOLER : Number of 60 kilogram boxes of species 1 in cooler.
SPEC 2 IN COOLER : Number of 60 kilogram boxes of species 2 in cooler.
INV TRAY TYPE 1 : Number of 20 kilogram trays of species-1 in inventory.
INV TRAY TYPE 2 : Number of 20 kilogram trays of species-2 in inventory.
KG FILL1 AT PACK : Kilograms of fillets of species-1, type-1 located at packing stations.
KG FILL2 AT PACK : Kilograms of fillets of species-1 type-2 located at packing stations.
KG FLAP1 AT PACK : Kilograms of napes of species-1 located at packing stations.
KG BLOC1 AT PACK : Kilograms of block of species-1 located at packing stations.
KG FILL3 AT PACK : Kilograms of fillets of species-2 located at packing stations.
KG FLAP2 AT PACK : Kilograms of napes of species-2 located at packing stations.
KG BLOC2 AT PACK : Kilograms of block of species-2 located at packing stations.
PAN FILLET S1T1 : Number of pans of fillets of species-1 produced so far.
PAN FLAPS SPEC1 : Number of pans of napes of species-1 produced so far.
PAN BLOCK SPEC1 : Number of pans of block species-1 produced so far.
PAN FILLET S1T2 : Number of pans of fillets species-1, type-2 produced so far.

(Continued on next page)

Table 6. (Continued)

PAN FILLET SPE2 : Number of pans of fillets species-2 produced so far.
PAN FLAPS SPEC2 : Number of pans of napes of species-2 produced.
PAN BLOCK SPEC2 : Number of pans of block of species-2 produced.
TIME FINISH TRIM : Time when trimming is finished.
TIME FIN PACKING : Time when packing is finished.
KILOS FROZEN FISH : Total weight of production so far, in kilograms.

	MEAN VALUE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	TIME INTERVAL	CURRENT VALUE
SPEC 1 IN COOLER	.8720E+03	.5199E+02	.0000E+00	.9920E+03	.3000E+03	.7920E+03
SPEC 2 IN COOLER	.4143E+03	.3144E+02	.0000E+00	.4920E+03	.3000E+03	.3720E+03
INV TRAY TYPE 1	.3807E+02	.1442E+02	.0000E+00	.6000E+02	.3000E+03	.3000E+02
INV TRAY TYPE 2	.3665E+02	.1938E+02	.0000E+00	.6400E+02	.3000E+03	.6100E+02
KG FILL1 AT PACK	.1094E+02	.1153E+02	.0000E+00	.3394E+02	.3000E+03	.2117E+01
KG FILL2 AT PACK	.1021E+02	.1109E+02	.0000E+00	.3165E+02	.3000E+03	.2903E+02
KG FLAP1 AT PACK	.1048E+02	.1011E+02	.0000E+00	.2992E+02	.3000E+03	.2764E+02
KG BLOC1 AT PACK	.1118E+02	.1065E+02	.0000E+00	.3342E+02	.3000E+03	.1576E+02
KG FILL3 AT PACK	.1066E+02	.1133E+02	.0000E+00	.3402E+02	.3000E+03	.1456E+02
KG FLAP2 AT PACK	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.3000E+03	.0000E+00
KG BLOC2 AT PACK	.9290E+01	.9709E+01	.0000E+00	.2372E+02	.3000E+03	.1135E+02
#PAN FILLET S1T1	.1273E+02	.1297E+02	.0000E+00	.3900E+02	.3000E+03	.3900E+02
#PAN FLAPS SPEC1	.3557E+01	.3494E+01	.0000E+00	.1000E+02	.3000E+03	.1000E+02
#PAN BLOCK SPEC1	.3486E+01	.3414E+01	.0000E+00	.1000E+02	.3000E+03	.1000E+02
#PAN FILLET S1T2	.3077E+01	.3410E+01	.0000E+00	.1000E+02	.3000E+03	.1000E+02
#PAN FILLET SPE2	.5827E+01	.6205E+01	.0000E+00	.1900E+02	.3000E+03	.1900E+02
#PAN FLAPS SPEC2	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.3000E+03	.0000E+00
#PAN BLOCK SPEC2	.1572E+01	.1657E+01	.0000E+00	.5000E+01	.3000E+03	.5000E+01
TIME FINISH TRIM	.1351E+03	.1030E+03	.0000E+00	.2993E+03	.3000E+03	.2993E+03
TIME FIN PACKING	.1301E+03	.1064E+03	.0000E+00	.2375E+03	.3000E+03	.2375E+03
KILOS FROZEN FIS	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.3000E+03	.0000E+00

The output summary report also contains statistics on the queues or files used in the model for storing entities waiting to be processed. For instance, it may be seen that an 8 box load of species-1 is put into the system approximately every 11 minutes, while an 8 box load of species-2 is put into the system approximately every 17 minutes. From the files used to keep entities waiting for packing workers to become available, it can be seen that the average waiting time for fillets of species-1 and type-1 is approximately 18 minutes, and for fillets of species-1 and type-2 is approximately 45 minutes. The summary file statistics is shown in Table 7.

Table 7. Summary file statistics for average number of entities waiting and average waiting time

File for	File number	Number waiting	Waiting time [minutes]
Box emptying-station	5	2.15	15.39
Elevator	9	0.019	0.1368
Machine 1 for species-1	13	17.1	27.9
Machine 2 for species-2	14	11.56	27.1
Trimming			
species-1 type-1	22	16.8	33.3
species-1 type-2	23	19.8	80.26
species-2	24	35.8	83.9
Weighing station	25	1.02	0.48
Packing species-1			
fillets type-1	27	7.2	18.47
fillets type-2	26	7.01	45.71
napes	29	0.51	0.95
block	31	0.1855	0.34
Packing species-2			
fillets	28	0.70	0.4
napes	30	no napes from species-2	
block	32	0.06	0.35

Statistics for resources are produced for all resources that are defined in the simulation model. These statistics show that the utilization of the header, filleting and skinning machine is about 78 percent for species-1, and 70 percent for species-2; thus one set of machines for each species is sufficient to handle the specified input rate. Before considering the utilization of trimming and packing stations it should be pointed out that the average utilization of a resource reported in the output is computed from the start of the simulation until the time the statistics are collected, regardless of the capacity of the resource. Because the capacity of both trimming and packing workers is zero for the first hour of simulated time, the actual utilization has to be adjusted accordingly. In the example run, statistics were taken after 300 minutes, so the trimming and packing workers have been at work for only 240 minutes. Furthermore, if there are two or more parallel workstations, then the utilization reported in the output is for all the workstations. The utilization per workstation is the figure reported in the summary report divided by the number of parallel workstations. The utilization for some of the resources, recalculated where necessary, is shown in Table 8.

Table 8. Resource Utilization

Resource name	Average utilization per station	Maximum utilization	Current capacity
Machine for:			
species-1	0.7751	1	1
species-2	0.6917	1	1
Trimming			
species-1 type-1	1.0	25	25
species-1 type-2	1.0	10	10
species-2	1.0	15	15
Packing			
species-1 fillet type-1	0.85	6	6
species-1 fillet type-2	0.81	2	2
species-2 fillets	0.80	3	3
species-1 napes	0.6546	1	1
species-1 block	0.5384	1	1
species-2 block	0.3174	1	1

From the table above it is clear that the trimming workers are fully utilized. The workers at the packing stations are not as well utilized. According to the table, one worker should be able to handle all packing of block, as the utilization of the worker packing block from species-1 is only 0.54 and the utilization of the worker packing block from species 2 is only 0.32; these figures when combined represent only 86 percent utilization.

One of the things that is of concern to a designer of a fish processing plant is the number of different types of working stations needed to have a "good" balance between the work stations. Also, the number of machines needed for each species, is of interest. There are a number of factors that can affect that balance. Among them are the species of the fish being processed and the size of fish being processed.

The production manager faces a similar problem. After deciding on the species to be processed, the production manager has to decide on the product to be produced from the fish, then, given the product, the number of work stations of each type to be used, the number of workers required and the production schedule. The summary statistics discussed above provide an invaluable tool for both the designer and the production manager.

Sensitivity analysis

Sensitivity analysis consists of changing one or more parameters at a time, and observing the change in the behaviour of the system. To illustrate sensitivity analysis, some of the more critical system parameters were varied, and their effect on the model output investigated.

To make the effects of changes more clear, assumptions are made that only one species is being worked on at a time, and that only one type of fillets from that species is being produced at any given time. Consequently, only one type of trimming worker is used, and three types of packing workers for packing fillets napes and block. Statistics for utilization of machines (header, filleting machine and skinner), trimming workers and packing workers, were taken after 300 minutes of simulated time. The results will now be described. Three runs were made for each given set of parameters, using different random number seeds for each run.

Size of fish

In a first series of runs, the effect of the size of the fish being processed on the balance between filleting, trimming and packing workstations was investigated. Three runs of the model were made for each of the following average number of fishes in a box. The mean value of 30 is based on the distribution for the number of fishes in a box; the values of 18 and 42 represent the range when the mean is 30.

1) Average number of fishes in a box = 18, standard deviation = 2.34
2) Average number of fishes in a box = 30, standard deviation = 3.9
3) Average number of fishes in a box = 42, standard deviation = 5.46

The coefficient of variation (mean/standard deviation) for the number of fishes in a box is a constant, 0.13, in the above data. It is assumed that cod fillets are being produced, and packed in to 5 lbs. packings; the side products, napes and block are also produced. The number of trimming workers is assumed to be 50 and the number of workers packing fillets is 11.

The results are shown graphically in Figure 26. From the figure it can be seen that as the number of fishes in a box increases (that is, the fish get smaller), utilization of machine for heading, filleting and skinning goes up while the utilization for trimming and packing workers decreases. The utilization for machines increases because as the fish size decreases, the number of fishes to be processed to fill the constant volume of trays increases. However, it takes longer to fill each tray due to the smaller weight of the fish. The result is a decrease in the utilization of the trimming and packing workers as it takes longer for the trays to be filled at the filleting machines and hence greater time lag before they can reach the trimming stations. This results in the trimming and packing stations being idle for a greater proportion of the time. It appears from the figure that the "best" results (that is, balance in utilization's and minimum inventories) under the conditions specified are obtained when the number of fishes in a box of raw material is 30.

Different Types of Packings

It has been mentioned earlier that processing time of various species of fish is different, and so is the processing time of the various packings of a given species. Figure 27 shows utilization of machines, trimming workers and packing workers for the following species and types of packings.

1) Cod processed for a five pound packing.
2) Catfish processed for a five pound packing
3) Cod processed for a 12 pound packing

As before the number of trimming workers is 50 and the number of workers packing fillets is 11. The average number of fishes in each 60 kilogram box is 30, and the standard deviation of these is 3.9.

For a five pound packing of cod the balance between machines and trimming workers seems to be quite good. The utilization of packing workers is somewhat lower which suggests that fewer workers than 11 are needed to keep up with the trimming speed.

For the five pound packing of catfish there is quite an imbalance between the utilization of heading, filleting and skinning machine and utilization of trimming workers. A likely reason is that when catfish is being processed the probabilty of a breakdown of the filleting machines is much more than it is when cod is being processed. In the model, the breakdown time of a machine counts as utilization, although there is no flow of fish through the machine during a breakdown. This is done because during a breakdown the machine is not available for processing, hence the breakdown is taking up some of the capacity of the machine. Thus the utilization of the machines goes up at the same time as utilization of both trimming and packing workers goes down.

For the 12 pound cod packing, utilization of machines is higer than for the five pound packing, and the utilization of trimming and packing workers goes down as compared to the utilization of these when a five pound packing of cod is being produced. The reason is

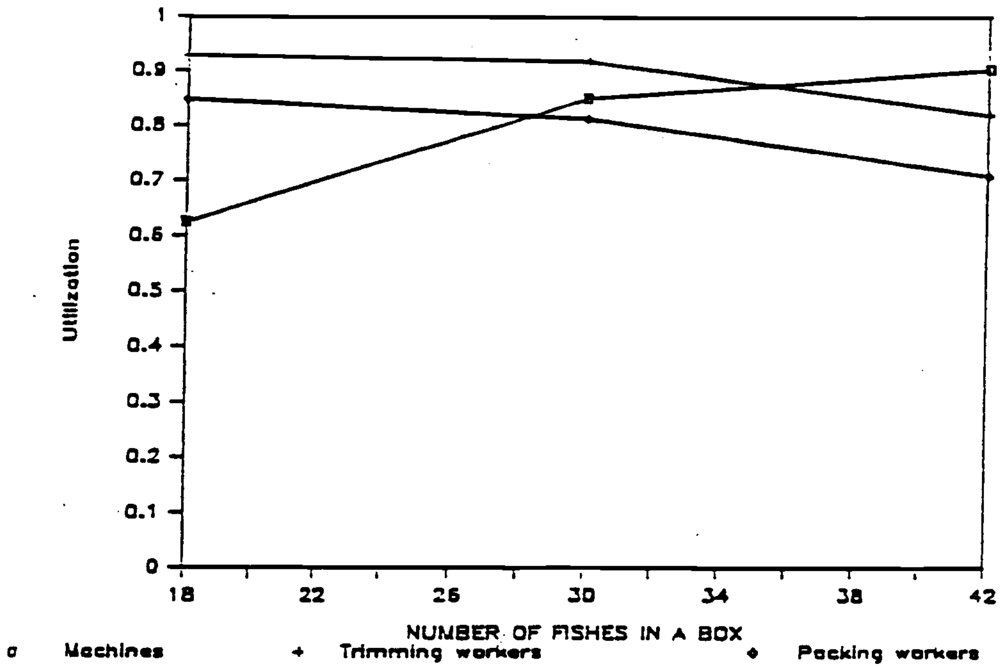


Figure 26. Different sizes of fish.

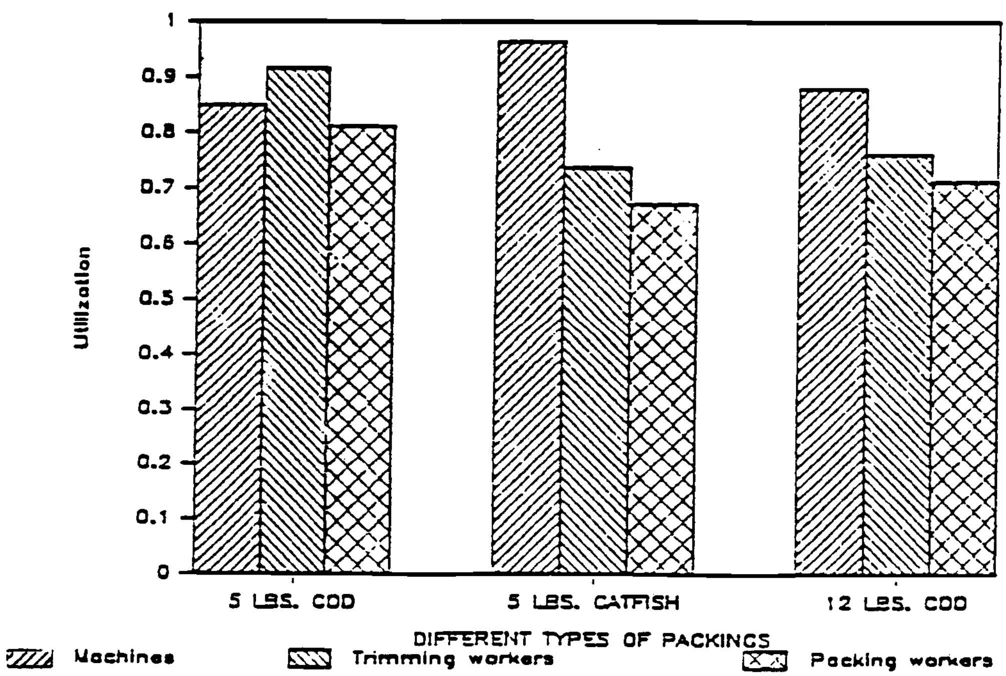


Figure 27. Different types of packings.

that the trimming time of the fillets is less for a 12 pound packing than for a five pound packing.

In the cases of five pound catfish and 12 pound cod, the utilization of machines is much more than the utilization of trimming or packing workers. This represents a bottleneck which may be fixed by adding a new set of machines (header, filleting machine and a skinner) to the system.

Number of trimming workers

The effect of changing the number of trimming workers on utilization is shown in Figure 28. The number of workers packing fillets is constant at 15 and there is only one set of header, filleting and skinning machine. It is assumed that the fish being processed is cod, and the fillets are being put in to a five pound packing. The average number of fishes in a 60 kilogram box of raw material is 30 and the standard deviation of number of fishes is 3.9.

The utilization of the machines increases as trimming workers are increased. Even though the raw material input to the system is constant, the machines operate only as long as the in-process inventory of fillets after the machines is below a certain level. As the trimming workers are increased, the inventory is consumed at a much faster rate resulting in higher utilization of machines. As would be expected utilization of the trimming workers decreases as the number of workers is increased. However, this results in a greater number of fishes to be packed resulting in higher utilization of the packing workers.

One or Two Machines

The effect of adding a new set of heading filleting and skinning machine is shown in Figure 29. There are 65 trimming workers used, and 15 fillet packing workers. When one set of machines is used, the machine utilization is almost 90 percent, and the trimming worker and packing worker utilization is only approximately 65 percent. When another set of machines is added, the utilization of each of the machines is just above 65 percent, and the utilization of the trimming workers rises to 90 percent. The utilization of workers packing fillets is somewhat less, but also rises to around 80 percent.

Lead time

In Figure 30, the effects of different time intervals between the start of the system and start of trimming and packing are illustrated. The results are based on the use of 50 trimming workers, 11 workers packing fillets and 2 machine sets. When trimming workers arrive only 30 minutes after the simulation is started, utilization of those workers is 90 percent, while the utilization of each of the machines is approximately 60 percent, and the utilization of packing workers is about 75 percent. When 60 minutes are allowed to pass before trimming and packing workers start working, the trimming workers are fully utilized, the utilization of packing workers rises to about 83 percent, while the utilization of the machines stays the same as before. This shows that with 50 trimming workers, a startup time between 30 and 60 minutes appears to provide a satisfactory balance.

The above sensitivity analysis is by no means comprehensive, and is intended to serve only as an example of the applications of the simulation model.

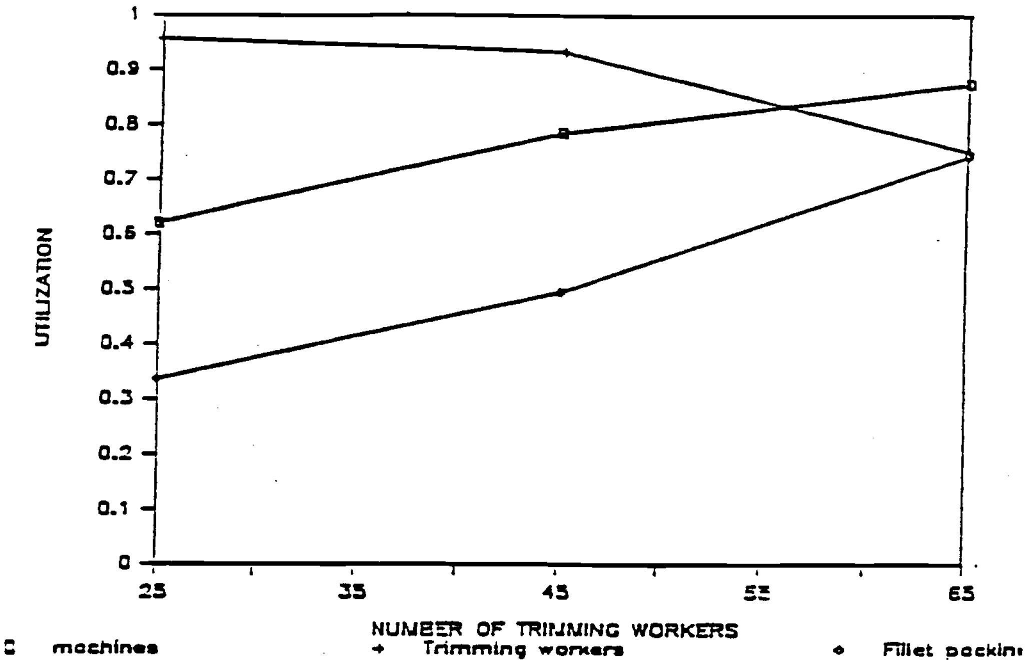


Figure 28. Different number of trimming workers.

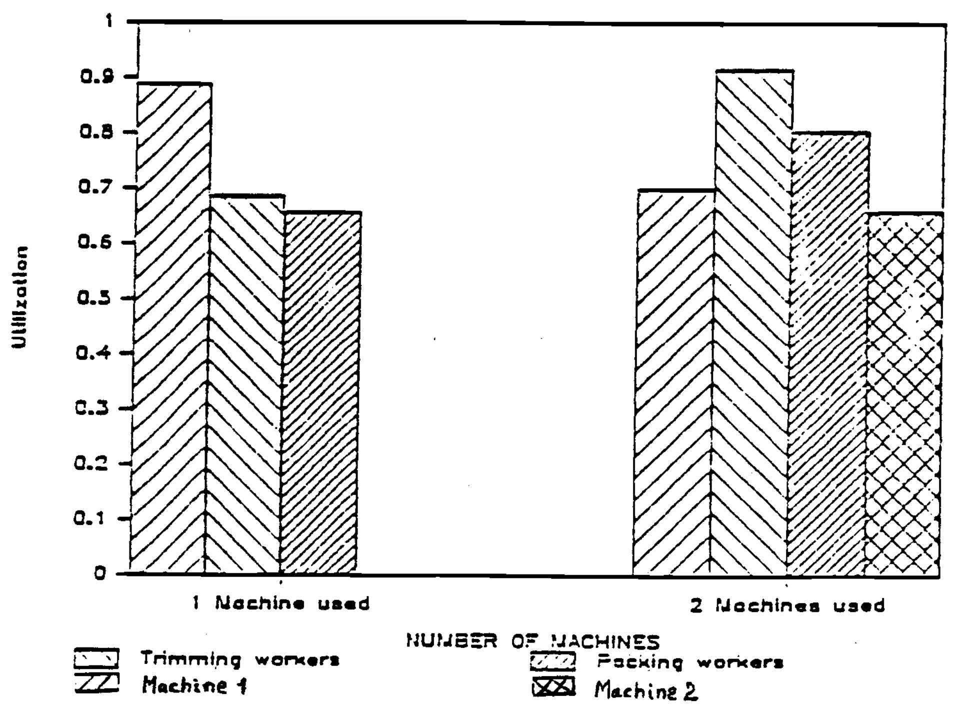


Figure 29. Different number of machines.

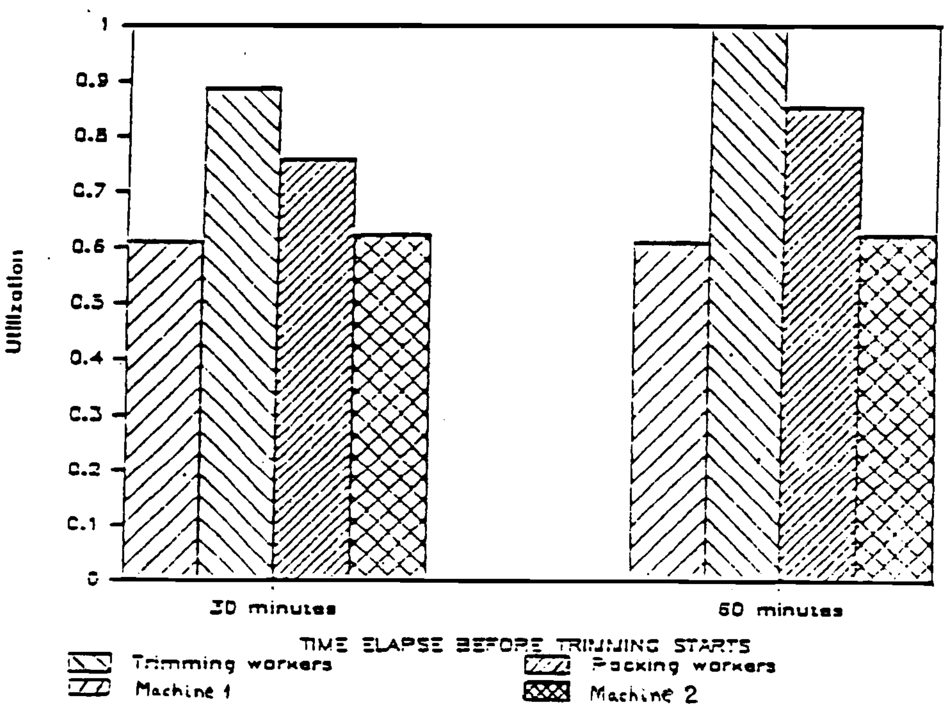


Figure 30. Different time intervals.

V. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The objective of this study was to design a simulation model of a fish processing plant that might be used as an aid in decision making for a production manager, and also as an aid in designing a fish processing facility.

Conclusions

In this research some of the potential applications of a simulation model of a fish processing plant are illustrated. An example of output statistics that can be obtained from the model is given and discussed, and sensitivity analysis performed on some of the major factors of the model is illustrated. It is shown that there is a number of factors that can affect the performance of the system. For example, the species of fish, the type of product being made and the size of the fish may effect the performance of the system. Allocation of workers to the different types of work stations is also a major factor concerning the efficiency of the system. The fact that many of the system parameters can easily be changed gives the model great flexibility to examine a wide variety of situations.

The network design of the simulation model renders it easy to adapt to different fish processing facilities. Furthermore, effects of changes in technology to the process should be easy to model and test before actually implementing any changes in the process. An example of such change might be the automation of trimming or packing, or a different quickfreezing method. Similarily, the effect of adding a new product or a production line may be easily investigated with the model. An example of such an addition would be production of a new product such as fish sticks.

Suggestions for Future Research

One possible way of enhancing the current model would be to develop output subroutines that would explain each variable as it is written out, thus making the output of the model more user friendly. Another enhancement might be to show dynamically some of the output on the screen at certain time intervals as the simulation progresses. The user may then be allowed to change certain parameters of the model based on the dynamic output of the model.

A Final Perspective

A simulation model was developed in this research to analyze a fish processing plant. The model was used to illustrate the potential use of such a model in serving as a decission-making aid in the fish processing environment. It is conceived that such a simulation model can greatly enhance the effectiveness and efficiency of the production operation, and may form the basis for a management decision support system.

BIBLIOGRAPHY

[1] Asgeirsson, Larus L., "Profun a Linulegu Bestunarlikani vid Framleidsluskipulagningu i Frystihusi", Thesis, Uneversity of Iceland (1981) (Unpublished).

[2] Chatfield, Christopher, Statistics for Technology A course in Applied Statistics, Second edition, Chapman and Hall Ltd. London (1978).

[3] Einarsson, Oskar, "Framleidsluskipulagning i Frystihusum", Thesis, University of Iceland (1980) (Unpublished).

[4] Giffin, Walter C., Introduction to Operations Engineering, Richard D. Irwin, Inc. (1971).

[5] Gudmundsson, Einar, Supervisor at "Ishusfelag Bolungarvikur" (The Bolungarvik Freezing plant).

[6] Harris, Thomas R. and Khoshnevis, Behrokh, "A Simulation Model of a Wheat Elevator System Using Slam" 1981 Winter Simulation Conference Proceedings, 705-712 (1981).

[7] Hilderbrand, Kenneth S., "Parasites in marine fishes Questions and answers for seafood retailers", Oregon State University Extension Service SG 79 (September 1984).

[8] Jakobsson, Asgeir, "Einars Saga Gudfinnssonar", Skuggsja, Reykjavik, Iceland (1978).

[9] Jensson, Pall and Maack, Petur, "Dagleg Framleidsluskipulagning Frystihuss", Report, Computer Center University of Iceland (March 1983) (Unpublished).

[10] Levins, Richard A. and Parker, Murl Wayne, "Modeling a Genetic Control Program for the Tobacco Budworm with SLAM" 1981 Winter Simulation Conference Proceedings, 713-719 (1981).

[11] Lorange, Peter Corporate Planning an Executive Viewpoint, Prentice-Hall, Inc., Englewood Cliffs, N.J. (1980).

[12] Olafsson, Gudjon B. "Fresh Frozen Fish: U.S. is the Major Market" 1984 Iceland Fisheries Yearbook. Iceland Review, Reykjavik, Iceland (1984).

[13] Olafsson, Rognvaldur "Tolvur og Rafeindataekni i Frystihusum" Fiskvinnslan Fagblad Fiskidnadarins, no.1 18-22, Reykjavik, Iceland (1985).

[14] Pritsker, A. Alan B. and Pegden, Claude Dennis Introduction to Simulation and SLAM, Halsted Press, a Division of John Wiley & Sons, Inc., New York (1979).

[15] Pritsker, A. Alan B. "Discrete simulation: methods and applications" 1983 Summer Computer Simulation Conference, 1120-1131 (1983).

[16] Pritsker, A. Alan B. "SLAM II and applications" 1983 Summer Computer Simulation Conference Proceedings, 911-917 (1983).

[17] "The Seafood Handbook", Seafood Business Report (1984).

[18] "Seafoods future", Seafood Business Report, vol.4, no.1, 7-16 (January/February 1985).

[19] Skyrsla stjornar Solumidstodvar Hradfrystihusanna, fyrir starfsarid 1983-1984 (1984).

[20] Tryggvason, Skuli "Afkastageta Frystihusa" Thesis, University of Iceland (1982) (Unpublished).

[21] Verklysingar, Leidbeiningar og Stadlar fyrir akvaedisvinnu i frystihusum, Solumidstod Hradfrystihusanna ofl., Reykjavik (December 1980).

[22] Walpole, Ronald E. and Myers, Raymond H., Probability and Statistics for Engineers and Scientists. 2-nd edition, Macmillan Publishing Co., Inc. New York (1978).

APPENDICES

APPENDIX 1

VARIABLE DEFINITION

Atrib (.) = Entity attributes
[The same attribute may represent different properties at different points in the network]

XX (.) = Global variables

ATTRIBUTE	DEFINITION
ATRIB(1) :	Weight of fish in one box of raw material, [kilograms].
ATRIB(1) :	Weight of fillets in one tray, 20 kilograms.
ATRIB(1) :	Weight of fish that's left after trimming of one 20 kilogram tray of fillets.
ATRIB(1) :	Waiting time of pans in front of quick-freezer units.
ATRIB(2) :	Species of fish.
ATRIB(2) :	Type of product; fillets, napes or block.
ATRIB(3) :	Number of boxes of fish going in to the system.
ATRIB(3) :	Time when fish is removed from cooler.
ATRIB(4) :	Number of fishes in one box of rawmaterial.
ATRIB(4) :	Number of fillets in a 20 kilogram tray.
ATRIB(4) :	Time to head, fillet and skin, fish from one box of raw material.
ATRIB(4) :	Time to trim fish from one 20 kilogram tray.
ATRIB(4) :	Time to pack one kilogram of fish.

VARIABLE	DEFINITION
XX(1) :	Inventory of raw material species-1.
XX(2) :	Total number of 8 box loads of species-1 put into system.
XX(3) :	Number of filleting machines species-1.
XX(4) :	A counter.
XX(5) :	Inventory of species-2 in cooler.
XX(6) :	A counter.
XX(7) :	Total number of fishes processed.
XX(8) :	Total weight of fillets after machines, species-1.
XX(9) :	Counter.
XX(10) :	Total weight of fillets of species-2,after machines.
XX(11) :	Total number of 8 box loads put into system, species-2.
XX(12) :	Plotting variable for utilization of extra machine-set (header, filleting machine and skinner) for spceies 1, resource HEFISK1B.
XX(13) :	Plotting variable for utilization of machine-set (header, filleting machine and skinner) for species-1, resource HEFISK1.
XX(14) :	Counter.
XX(15) :	Minimum time between breakdowns of machine HEFISK1. Also, minimum time between breakdowns of machine HEFISK1B.
XX(16) :	Most common time between breakdowns of machine HEFISK1. Also, most common time between breakdowns of machine HEFISK1B.
XX(17) :	Maximum time between breakdowns of machine HEFISK1. Also maximum time between breakdowns of machine HEFISK1B.

XX(18) : Minimum repair time for machine HEFISK1, or minimum repair time for machine HEFISK1B.

XX(19) : Maximum repair time for machine HEFISK1, or maximum repair time for maxhine HEFISK1B.

XX(20) : Minimum time between breakdowns of machine HEFISK2.

XX(21) : Most common time between breakdowns of machine HEFISK2.

XX(22) : Maximum time between breakdowns of machine HEFISK2.

XX(23) : Inventory of 20 kilogram fillet trays, species-1.

XX(24) : Inventory of 20 kilogram fillet trays, species-2.

XX(25) : Kilograms of fillets at packing station, species-1, type-1.

XX(26) : Kilograms of fillets at packing station, species-1, type-2.

XX(27) : Kilograms of flaps at flap packing station, species-1.

XX(28) : Minimum repair time for machine HEFISK2.

XX(29) : Kilograms of block at block packing station, species-1.

XX(30) : Kilograms of fillets at packing station, species-2.

XX(31) : Counts number of "pans" of fillets type-1, species-1.

XX(32) : Kilograms of flaps species-2 at packing station.

XX(33) : Number of "pans" of flaps species-1 produced.

XX(34) : Kilograms of block at block packing station species-1.

XX(35) : Number of "pans" of block, species-1 produced.

XX(36) : Number of pans of fillets, species-1 type-2 produced.

XX(37) : Counter for "pans" going into quickfreezer.

XX(38) : Number of pans of fillets, species-2 produced.

XX(39) : Maximum repair time for machine HEFISK2.

XX(40) : Number of pans of flaps, species-2 produced.

XX(41) : Time when Fork lifters should stop taking fish from cooler.

XX(42) : Number of pans of block, species-2 produced.

XX(43) : Plotting variable for utilization of resource HEFISK2.

XX(44) : Average number of fillets in a tray, species-1.

XX(45) : Standard deviation of number of fillets in a tray, species-1.

XX(46) : Average number of fillets in a tray, species-2.

XX(47) : Standard deviation of number of fillets in a tray, species-2.

XX(48) : Time (TNOW) when entities come out of trimming stations.

XX(49) : Time (TNOW) when entities come out of packing stations.

XX(50) : Kilograms of fish frozen.

XX(51) : Kilograms per pan, fillets species-1, type-1.

XX(52) : Kilograms per pan, fillets species-1, type-2.

XX(53) : Kilograms per pan, napes species-1.

XX(54) : Kilograms per pan, block species-1.

XX(55) : Kilograms per pan, fillets species-2.

XX(56) : Kilograms per pan, napes species-2.

XX(57) : Kilograms per pan, block species-2.

XX(58) : Number of boxes species-1 initially in cooler.

XX(59) : Number of boxes species-2, initially in cooler.

XX(60) : Number of trim workers species-1, type-1.

XX(61) : Number of trim workers species-1, type-2.

XX(62) : Number of trim workers species-2.

XX(63) : Number of packing workers species-1, fillet type-1.

XX(64) : Number of packing workers species-1, fillet type-2.

XX(65) : Number of packing workers species-1, flap type-1 & 2.

XX(66) : Number of packing workers species-1, block type-1 & 2.

XX(67) : Number of packing workers species-2, fillets.

XX(68) : Number of packing workers species-2, flaps.

XX(69) : Number of packing workers species-2, block.

XX(70) : Trimming time, species-1 type-1, coefficient Ca.

XX(71) : Trimming time, species-1 type-1, coefficient Cb.

XX(72) : Trimming time, species-1 type-2, coefficient Ca.

XX(73) : Trimming time, species-1 type-2, coefficient Cb.

XX(74) : Trimming time, species-2, coefficient Ca.

XX(75) : Trimming time, species-2, coefficient Cb.

XX(76) : Packing speed species-1, fillet type-1.

XX(77) : Packing speed species-1, fillet type-2.

XX(78) : Packing speed species-1, flaps.

XX(79) : Packing speed species-1, block.

XX(80) : Packing speed species-2, fillets.

XX(81) : Packing speed species-2, flaps.

XX(82) : Packing speed species-2, block.

XX(83) : After trimming species-1, type-1, fillets percentage.

XX(84) : After trimming species-1, type-1, flaps percentage.

XX(85) : After trimming species-1, type-2, fillets percentage.

XX(86) : After trimming species-1 type-2, flaps percentage.

XX(87) : After trimming species-2, fillets percentage.

XX(88) : After trimming species-2, flaps percentage.

XX(89) : Yield of Head- filleting- and skinning machine 1.

XX(90) : Yield of Head- filleting- and skinning machine 2.

XX(91) : Yield when trimming species-1, type-1.

XX(92) : Yield when trimming species-1, type-2.

XX(93) : Yield when trimming species-2.

XX(94) : Average number of fishes of species-1 in a 60 kilogram box.

XX(95) : Standard deviation of number of fishes species-1 in a 60 kilogram box.

XX(96) : Average number of fishes of species-2 in a 60 kilogram box.

XX(97) : Standard deviation of number of fishes species-1 in a 60 kilogram box.

XX(98) : Average weight in a "60 kilogram" box, species-1.

XX(99) : Average weight in a "60 kilogram" box, species-2.

APPENDIX 2

LISTING FOR THE SLAM NETWORK MODEL

```
C     ----------------------------------------------------------------
C     :                                                              :
C     :     OREGON STATE UNIVERSITY        MAY 1985                  :
C     :                                                              :
C     :                                                              :
C     :     This is the program :   FREEZE                           :
C     :                                                              :
C     :     It calls the SLAM executive program                      :
C     :                                                              :
C     :     ------------------------------------                     :
C     :                                                              :
C     :     Designed by :   Elias Jonatensson                        :
C     :                                                              :
C     ----------------------------------------------------------------
C
C
C
      PROGRAM FREEZE(TAPE5,TAPE6,TAPE7)
      DIMENSION NSET(9500)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MJA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(9500)
      CHARACTER *8 NAME1
      EQUIVALENCE (NSET(1),QSET(1))
      WRITE (*,3)
3     FORMAT (//////////10X,
     1' What is the name of the data file the input values '/10X,
     2' are written in ?  .  [DATAIN]')
      READ (*,4) NAME1
4     FORMAT(A)
      IF (NAME1 .EQ. ' ') NAME1='DATAIN'
      OPEN (UNIT=1,FILE=NAME1,STATUS='OLD')
      NNSET=9500
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL SLAM
      STOP
      END
```

```
;  ------------------------------------------------------------
;  !                                                          !
;  !   OREGON STATE UNIVERSITY       MAY 1985                 !
;  !                                                          !
;  !                                                          !
;  !   A SIMULATION MODEL OF A FISH PROCESSING PLANT          !
;  !   ----------------------------------------------         !
;  !                                                          !
;  !      Designed                 Under the supervision      !
;  !         by                            of                 !
;  !                                                          !
;  !   Elias Jonatansson            Dr. Sabah Randhawa        !
;  !   -----------------            ------------------        !
;  !        Student                Assistant Professor        !
;  !          at                           at                 !
;  !   Oregon State University.  Oregon State University      !
;  !                                                          !
;  ------------------------------------------------------------
;
;
GEN,ELIAS JONATANSSON,FREEZING PLANT,5/23/1985,1,YES,,,,;
LIMITS,35,4,550;     LIMITS,MFIL,MATR,MNTRY
;
;
TIMST,XX(1),SPEC 1 IN COOLER;    # OF 60 KG BOXES (SPECIES 1) IN COOLER
TIMST,XX(5),SPEC 2 IN COOLER;    # OF 60 KG BOXES (SPECIES 2) IN COOLER
TIMST,XX(23),INV TRAY TYPE 1;     # OF 20 KG TRAYS (TYPE 1) AFTER SKIN
TIMST,XX(24),INV TRAY TYPE 2;     # OF 20 KG TRAYS (TYPE 2) AFTER SKIN
TIMST,XX(25),KG FILL1 AT PACK;     KG OF FILLETS SPEC.1 TYPE 1 AT PACK
TIMST,XX(26),KG FILL2 AT PACK;     KG OF FILLETS SPEC.1 TYPE 2 AT PACK
TIMST,XX(27),KG FLAP1 AT PACK;     KG OF FLAPS SPEC.1 AT PACK. STATION
TIMST,XX(29),KG BLOC1 AT PACK;     KG OF BLOCK SPEC.1 AT PACK STATION
TIMST,XX(30),KG FILL3 AT PACK;     KG OF FILLETS SPEC.2 AT PACK STATION
TIMST,XX(32),KG FLAP2 AT PACK;     KG OF FLAPS SPECIES 2 AT PACK STATION
TIMST,XX(34),KG BLOC2 AT PACK;     KG OF BLOCK SPECIES 2 AT PACK STATION
TIMST,XX(31),#PAN FILLET S1T1;     # OF PANS OF FILLETS SPEC.1 TYPE 1
TIMST,XX(33),#PAN FLAPS SPEC1;     # OF PANS OF FLAPS SPEC.1 PRODUCED
TIMST,XX(35),#PAN BLOCK SPEC1;     # OF PANS OF BLOCK SPEC.1 PRODUCED
TIMST,XX(36),#PAN FILLET S1T2;     # OF PANS OF FILLETS SPEC.1 TYPE 2
TIMST,XX(38),#PAN FILLET SPE2;     # OF PANS OF FILLETS SPEC.2 PRODUCED
TIMST,XX(40),#PAN FLAPS SPEC2;     # OF PANS OF FLAPS SPEC.2 PRODUCED
TIMST,XX(42),#PAN BLOCK SPEC2;     # OF PANS OF BLOCK SPEC.2 PRODUCED
TIMST,XX(48),TIME FINISH TRIM;     TIME WHEN TRIMMING WAS FINISHED
TIMST,XX(49),TIME FIN PACKING;     TIME WHEN PACKING WAS FINISHED
TIMST,XX(50),KILOS FROZEN FISH;     # OF KILOS OF FROZEN FISH PRODUCED
;
;
NETWORK;
;
;       RESOURCES USED
;
        RESOURCE/COOLER1(5000),1;      RAW MATERIAL BEFORE PROCESSING
        RESOURCE/FORK1(1),3;           FORK LIFTER FOR SPECIES 1
        RESOURCE/FORK2(1),4;           FORK LIFTER FOR SPECIES 2
        RESOURCE/BOXEM(1),5;           BOX EMPTYING STATION
        RESOURCE/ELEV(2),9;            ELEVATOR TO SECOND FLOOR
        RESOURCE/HEFISK1(1),11,13;     HEAD, FILLET- AND SKIN- MACH (1)
        RESOURCE/HEFISK2(1),12,14;     HEAD FILLET- AND SKIN MACH (2)
        RESOURCE/HEFISK1B(1),10,15;    HEAD, FILLET- AND SKIN- MACH (1B)
        RESOURCE/TRIM11(65),22;        TRIMMING STATIONS  SPECIES 1 TYPE 1
```

```
        RESOURCE/TRIM12(65),23;      TRIMMING STATIONS, SPECIES 1 TYPE 2
        RESOURCE/TRIM21(65),24;      TRIMMING STATIONS, SPECIES 2
        RESOURCE/WEIGH2(1),25;       WEIGHING STATION
        RESOURCE/FILLP11(30),27;     FILLET PACKING STATIONS (SP 2,TYPE 1)
        RESOURCE/FILLP12(30),26;     FILLET PACKING STATIONS (SP 1,TYPE 2)
        RESOURCE/FILLP21(30),28;     FILLET PACKING STATIONS (SP 2)
        RESOURCE/FLAP11(30),29;      FLAPPACKING STATIONS (SP 1)
        RESOURCE/FLAP21(30),30;      FLAPPACKING STATIONS (SP 2)
        RESOURCE/BLOCK11(30),31;     BLOCKPACKING STATIONS (SP 1)
        RESOURCE/BLOCK21(30),32;     BLOCKPACKING STATIONS (SP 2)
        RESOURCE/QUICKF(5),35;       QUICKFREEZER UNITS
;
;       GATES USED
;
        GATE/GMACHOUT,OPEN,19;     GATE AFTER SKINNER
        GATE/GWEIGH,OPEN,21;     WEIGHING STATION BEFORE TRIMMING STATIONS
        GATE/GQUICK,CLOSED,33;     QUICK FREEZERS
;
;       ================================================
;       THIS IS THE FIRST NETWORK !
;       --------------------------
;
;       ALTER AVAILABLE RESOURCES UNTIL STARTUP INVENT. HAS BEEN BUILT UP.
;       TRIMMING WORKERS AND PACKING WORKERS START ONE HALF HOUR LATER THAN
;       MACHINE WORKERS.
        CREATE,,0,,1,1;
             ACTIVITY,USERF(1);      CALL A USER-FUNCTION TO ASSIGN
        ALTER,TRIM11/-65,1;          INITIAL VALUES TO SOME VARIABLES.
        ALTER,TRIM12/-65,1;          THE VARIABLES ARE READ IN BY THE
        ALTER,TRIM21/-65,1;          USERFUNCTION, FROM A FILE CREATED
        ALTER,WEIGH2/-1,1;           BY THE FRONT END PROGRAM : READIN
        ALTER,FILLP11/-30,1;
        ALTER,FILLP12/-30,1;     PUTTING THE CAPACITY OF THE TRIMMING-
        ALTER,FILLP21/-30,1;     PACKING- AND THE QUICKFREEZER RESOURCES
        ALTER,FLAP11/-30,1;      TO ZERO UNTIL "WORK" STARTS AT THOSE
        ALTER,FLAP21/-30,1;      STATION, WHICH IS LATER THAN IT STARTS
        ALTER,BLOCK11/-30,1;     AT THE MACHINES.  THE CAPACITY OF
        ALTER,BLOCK21/-30,1;     HEFISK18 IS ALSO PUT TO ZERO BECAUSE IT
        ALTER,QUICKF/-5,1;       MIGHT NOT BE USED AT ALL.
        ALTER,HEFISK18/-1,2;
             ACTIVITY,30,,AL11;
             ACTIVITY,,,AL12;
AL11    ALTER,TRIM11/XX(60),1;
        ALTER,TRIM12/XX(61),1;
        ALTER,TRIM21/XX(62),1;
        ALTER,WEIGH2/1,1;            HERE THE CAPACITY OF THE RESOURCES
        ALTER,FILLP11/XX(63),1;      IS SET TO VALUES SPECIFIED BY
        ALTER,FILLP12/XX(64),1;      THE DATAFILE CREATED BY THE PROGRAM
        ALTER,FLAP11/XX(65),1;       READIN .
        ALTER,BLOCK11/XX(66),1;
        ALTER,FILLP21/XX(67),1;
        ALTER,FLAP21/XX(68),1;
        ALTER,BLOCK21/XX(69),1;
        ALTER,QUICKF/5,;
        TERMINATE;
;
AL12    ALTER,HEFISK18/XX(3),1;      THE RESOURCE HEFISK18 HAS TO BE
        ASSIGN,XX(41)=300,1;         ALTERED BACK TO THE VALUE READ IN
        TERMINATE;                   BY THE USERFUNCTION   AND
;                                    XX(41) IS SET TO THE TIME THE
```

```
;                                        FORKS SHOULD STOP TAKING FISH OUT
;                                        OF COOLER
;
;
;
;
;          ------------------------------------------------
;          THIS IS THE SECOND NETWORK !
;          --------------------------
;
;
           CREATE,,300,,1,1;          STOP TAKING FISH OUT OF COOLER
           ALTER,FORK1/-1,1;          AFTER 5 HOURS OF WORK
           ALTER,FORK2/-1,1;
           TERMINATE;
;
;
;
;          ------------------------------------------------
;          THIS IS THE THIRD NETWORK !
;          --------------------------
;
;
;          THE FOLLOWING NETWORK MODELS BREAKDOWNS AND REPAIR
;          OF THE FILLETING   MACHINES.
;
           CREATE,,0.5,,1,2;
           ASSIGN,ATRIB(2)=5,3;     TAKE THREE BRANCHES
                ACTIVITY,TRIAG(XX(15),XX(16),XX(17),7),,PRM1;
                ACTIVITY,TRIAG(XX(15),XX(16),XX(17),4),,PRM2;
                ACTIVITY,TRIAG(XX(20),XX(21),XX(22),2),,PRM3;
;
;          PREEMPTING MACHINE 1      FOR SPECIES 1
;
PRM1       PREEMPT(10)/HIGH(2),HEFISK18,,4,1;                  <! ENDLESS
                ACTIVITY,UNFRM(XX(18),XX(19),8),,FPM1;           !
FPM1       FREE,HEFISK18/1,1;                                  !
                ACTIVITY,TRIAG(XX(15),XX(16),XX(17),5),,PRM1;  >! LOOP
;
;          PREEMPTING MACHINE 2     FOR SPECIES 1
;
PRM2       PREEMPT(11)/HIGH(2),HEFISK1,,4,1;                     <! ENDLESS
                ACTIVITY,UNFRM(XX(18),XX(19),6),,FPM2;             !
FPM2       FREE,HEFISK1/1,1;                                     !
                ACTIVITY,TRIAG(XX(15),XX(16),XX(17),3),,PRM2;     >! LOOP
;
;          PREEMPTING MACHINE 3     FOR SPECIES 2
;
PRM3       PREEMPT(12)/HIGH(2),HEFISK2,,4,1;                   <! ENDLESS
                ACTIVITY,UNFRM(XX(28),XX(39),1),,FPM3;           !
FPM3       FREE,HEFISK2/1,1;                                   !
                ACTIVITY,TRIAG(XX(20),XX(21),XX(22),9),,PRM3;  >! LOOP
;
;
;
;          ------------------------------------------------
;          THIS IS THE FOURTH NETWORK !
;          --------------------------
;
;
;          THIS NETWORK KEEPS TRACK OF UTILIZATION OF THE HEADING-
;          FILLETING- AND SKINNING MACHINES.  A USERFUNCTION THAT
```

```
;       WRITES THE UTILIZATION OF THE MACHINES IS CALLED EVERY
;       10 MINUETS.
;
        CREATE,10,0.5,,100,1;
        ASSIGN,XX(12)=NNRSC(HEFISK1B),
               XX(13)=NNRSC(HEFISK1),
               XX(43)=NNRSC(HEFISK2),1;
             ACTIVITY,USERF(2);
        TERMINATE;
;
;
;
;       ------------------------------------------------
;       THIS IS THE MAIN NETWORK !  (THE FIFTH NETWORK)
;       ------------------------------------------------
;
;
;       PUT AN ENTITY INTO THE SYSTEM TO INITATE THE PROCESS
;
;
CRE1    CREATE,,0.5,,1,2;    TBC=INFINITE MIN, TF=0.5, MA=0, MC=1, M=2
;
             ACTIVITY,,,AS01;
             ACTIVITY,,,AS02;
;
AS01    ASSIGN,ATRIB(2)=1.,
               ATRIB(3)=XX(58),1;    ATRIB (2) = TYPE OF FISH
;                                    ATRIB(3) = # OF BOXES IN SHIPMENT
             ACTIVITY,,,RC01;
;
AS02    ASSIGN,ATRIB(2)=2,
               ATRIB(3)=XX(59),1;
;
             ACTIVITY,,,RC01;
;
RC01    AWAIT(1),COOLER1/ATRIB(3),1;             COOLER FOR RAW MATERIAL
             ACTIVITY,,ATRIB(2) .EQ. 1,AS03;
             ACTIVITY,,ATRIB(2) .EQ. 2,AS04;
;
AS03    ASSIGN,XX(1)=XX(1)+ATRIB(3),
               ATRIB(3)=ATRIB(3)/8,
               XX(2)=XX(2)+ATRIB(3),1;   FOR SPECIES 1
;                                        XX(1)=INVENTORY OF RAW MATERIAL
;                                        XX(2)=NUMBER OF 8 BOXES LOADS
;
RFK1    AWAIT(3),FORK1/1,1;
AS05    ASSIGN,XX(4)=XX(4)+1,2;                  TAKE TWO BRANCHES
             ACTIVITY,,XX(4) .LT. XX(2),RFK1;
             ACTIVITY,,,GO03;
             ACTIVITY,,,TE05;
;
TE05     TERMINATE;
;
GO03    GOON,2;
             ACTIVITY,,,FC01;
             ACTIVITY,UNFRM(2,4,1),,AS09;  TRANSPORT TIME FROM COOLER
;
AS04    ASSIGN,XX(5)=XX(5)+ATRIB(3),
               ATRIB(3)=ATRIB(3)/8,
               XX(11)=XX(11)+ATRIB(3),1;   FOR SPECIES 2
```

```
;                                       XX(5)=INVENTORY OF RAW MATERIAL
;                                       XX(11)=NUMBER OF 8 BOXES LOADS
;
RFK2    AWAIT(4),FORK2/1,1;
AS06    ASSIGN,XX(6)=XX(6)+1,2;
             ACTIVITY,,XX(6) .LT. XX(11),RFK2;
             ACTIVITY,,,G004;
             ACTIVITY,,,TE06;
;
TE06     TERMINATE;
;
G004    GOON,2;
             ACTIVITY,,,FC01;
             ACTIVITY,UNFRM(2,4,2),,AS09;  TRANSPORT TIME FROM COOLER
;
;
FC01    FREE,COOLER1/8,1;
             ACTIVITY,,ATRIB(2) .EQ. 1,AS07;
             ACTIVITY,,ATRIB(2) .EQ. 2,AS08;
AS07    ASSIGN,XX(1)=XX(1)-8,1;         REDUCE INVENTORY OF SPECIES 1
             ACTIVITY,,,TE08;
AS08    ASSIGN,XX(5)=XX(5)-8,1;         REDUCE INVENTORY OF SPECIES 2
             ACTIVITY,,,TE08;
TE08    TERMINATE;
;
AS09    ASSIGN,ATRIB(3)=TNOW,1;
;
RBXM    AWAIT(5),BOXEM/1,1;                 BOXEMPTYING STATION
             ACTIVITY,UNFRM(2,4,3),,FBXM;    TIME TO EMPTY 8 BOXES
FBXM    FREE,BOXEM/1,1;
;
;
RELE    AWAIT(9),ELEV/1,1;                  ELEVATOR
             ACTIVITY,UNFRM(3,7,4),,FELE;    TIME FOR ONE ELEVATOR
FELE    FREE,ELEV/1,1;                      ROUNDTRIP
;
;
             ACTIVITY,,,AS15;
;
AS15    ASSIGN,XX(9)=XX(9)+1,2;
;
        ACTIVITY,,XX(9) .LT. 8,AS15;
        ACTIVITY,,ATRIB(2) .EQ. 1,AS17;
        ACTIVITY,,ATRIB(2) .EQ. 2,AS18;
        ACTIVITY,,XX(9) .EQ.8,AS19;
;
AS19    ASSIGN,XX(9)=0;
        TERMINATE;
;
;
AS17    ASSIGN,ATRIB(4)=RNORM (XX(94),XX(95),3),
            XX(7)=XX(7)+ATRIB(4);              ATRIB(4)=# OF FISHES IN
             ACTIVITY,,,AS31;                  A 60 KG BOX
;
AS18    ASSIGN,ATRIB(4)=RNORM (XX(96),XX(97),1),
            XX(7)=XX(7)+ATRIB(4);
             ACTIVITY,,,AS31;
;
AS31    ASSIGN,ATRIB(4)=ATRIB(4)+0.038,1;      ATRIB(4)=TIME TO FILLET
;                                              FISH FROM A 60 KG BOX
```

```
             ACTIVITY,,ATRIB(2) .EQ. 1,GO48;
             ACTIVITY,,ATRIB(2) .EQ. 2,RMA2;
;
;
GO48    GOON,1;
             ACTIVITY,,NNQ(15) .LT. NNQ(13) .AND.
                       XX(3) .GT. 0,RMB1;
             ACTIVITY,,,RMA1;
;
RMB1    AWAIT(15),HEFISK1B/1,1;          HEADER,FILLETING MACHINE
             ACTIVITY,ATRIB(4),,FMB1;    AND SKINNER FOR
FMB1    FREE,HEFISK1B/1,2;               SPECIES 1   (EXTRA MACHINE)
             ACTIVITY,,TONOW .LE. 30 .AND. XX(23) .LE. 40,FFKA;
             ACTIVITY,,,GMOU;
             TERMINATE;
;
;
RMA1    AWAIT(13),HEFISK1/1,1;           HEADER,FILLETING MACHINE
             ACTIVITY,ATRIB(4),,FMA1;    AND SKINNER FOR
FMA1    FREE,HEFISK1/1,2;                SPECIES 1
             ACTIVITY,,TNOW .LE. 30 .AND. XX(23) .LE. 40,FFKA;
             ACTIVITY,,,GMOU;
             TERMINATE;
;
;
RMA2    AWAIT(14),HEFISK2/1,1;           HEADER,FILLETING MACHINE
             ACTIVITY,ATRIB(4),,FMA2;    AND SKINNER  FOR
FMA2    FREE,HEFISK2/1,1;                SPECIES 2
             ACTIVITY,,TNOW .LE. 30 .AND. XX(24) .LE. 40,FFKB;
             ACTIVITY,,,GMOU;
             TERMINATE;
;
;
FFKA    FREE,FORK1/1,1;
        TERMINATE;                       THE FORK IS FREED TO BUILD
;                                        UP INVENTORY OF TRAYS BEFORE
FFKB    FREE,FORK2/1,1;                  WORK STARTS IN TRIMMING
        TERMINATE;
;
GMOU    AWAIT(19),GMACHOUT,1;
;
CMOU    CLOSE,GMACHOUT,1;
;
;
;
AS32    ASSIGN,XX(14)=XX(14)+1,1;
             ACTIVITY,,XX(14) .EQ. 1,GO05;
             ACTIVITY,,,GMOU;
;
GO05    GOON,1;
             ACTIVITY,,ATRIB(2) .EQ. 1,AS33;
             ACTIVITY,,ATRIB(2) .EQ. 2,AS34;
;
AS33    ASSIGN,ATRIB(1)=XX(98),
               ATRIB(1)=ATRIB(1)*XX(89),
               XX(8)=XX(8)+ATRIB(1);     FOR SPECIES 1
             ACTIVITY,,,GWEI;            ATRIB(1)=WEIGHT OF FISH FROM
;                                        ONE 20 KG TRAY, AFTER MACHINING
AS34    ASSIGN,ATRIB(1)=XX(99),
               ATRIB(1)=ATRIB(1)*XX(90),
```

```
          XX(10)=XX(10)+ATRIB(1);    FOR SPECIES 2 :
        ACTIVITY,,,GWEI;             ATRIB(1)=WEIGHT OF FISH FROM
;                                    ONE 20 KG TRAY, AFTER MACHINING
;
GWEI    AWAIT(21),GWEIGH,1;          THE WEIGHING STATION
        ACTIVITY,,XX(8) .GE. 20 .OR. XX(10) .GE. 20,G006;
        ACTIVITY,,,OMOU;
;
G006    GOON,1;
        ACTIVITY,,ATRIB(2) .EQ. 1,AS37;
        ACTIVITY,,ATRIB(2) .EQ. 2,AS38;
;
AS37    ASSIGN,XX(8)=XX(8)-20,2;     PUTTING FILLETS, SPECIES ONE INTO
        ACTIVITY,,,CWEI;             20 KG TRAYS
        ACTIVITY,,,AS39;
;
AS38    ASSIGN,XX(10)=XX(10)-20,2;   PUTTING FILLETS, SPECIES TWO INTO
        ACTIVITY,,,CWEI;             20 KG TRAYS
        ACTIVITY,,,AS40;
;
CWEI    CLOSE,GWEIGH,1;
        ACTIVITY,,,GWEI;     BACKWARDS JUMP
;
;
;
OMOU    OPEN,GMACHOUT,1;
AS41    ASSIGN,XX(14)=0;
        TERMINATE;
;
;
AS39    ASSIGN,ATRIB(4)=RNORM(XX(44),XX(45),7),
          ATRIB(1)=20.,1;                     FOR SPECIES 1 :
        ACTIVITY,,,OWE1;                      ATRIB(4)=# OF FILLETS
;                                             IN A 20 KG TRAY
AS40    ASSIGN,ATRIB(4)=RNORM(XX(46),XX(47),8),
          ATRIB(1)=20,1;                      FOR SPECIES 2 :
        ACTIVITY,,,OWE1;                      ATRIB(4)=# OF FILLETS
;                                             IN A 20 KG TRAY
OWE1    OPEN,GWEIGH,1;
;
        ACTIVITY,,ATRIB(2) .EQ. 1,AS45;
        ACTIVITY,,ATRIB(2) .EQ. 2,A245;
;
AS45    ASSIGN,XX(23)=XX(23)+1,1;                 FOR SPECIES 1 :
        COLCT,XX(23),SP1 BEFORE TRIM,20/0/5,1;    XX(23)=INVENTORY OF
        ACTIVITY,2,NNQ(22) .LE. NNQ(23) .AND.
                  XX(60) .GT. 0 .OR.
                  XX(61) .EQ. 0 ,RTR1;            20 KG FILLET TRAYS
        ACTIVITY,2,,RTR2;
;
A245    ASSIGN,XX(24)=XX(24)+1,1;                 FOR SPECIES 2 :
        COLCT,XX(24),SP2 BEFORE TRIM,20/0/5,1;    XX(24)=INVENTORY OF
        ACTIVITY,2,,RTR3;                         20 KG FILLET TRAYS
;
RTR1    AWAIT(22),TRIM11/1,1;      TRIMMING STATIONS  SPECIES 1  TYPE 1
;
        ACTIVITY,,XX(23) .GT. 20.0 .OR. NNRSC(FORK1) .GE. 1 .OR.
                NNQ(5) .GT. 0 .OR. NNQ(13) .GT. 8 .OR.
                TNOW .GE. XX(41) .OR.
                NNQ(15) .GT. 8 .OR. NNQ(9) .GE. 1,G009;
```

```
          ACTIVITY,,,FFK1;
;
FFK1      FREE,FORK1/1,1;
          ACTIVITY,,,G009;
;
G009      GOON,1;
AS46      ASSIGN,XX(23)=XX(23)-1,
                 ATRIB(1)=ATRIB(1)*XX(91),
                 ATRIB(4)=ATRIB(4)/20,
                 ATRIB(4)=ATRIB(4)*XX(71),
                 ATRIB(4)=ATRIB(4)+XX(70),
                 ATRIB(4)=ATRIB(4)*20,
                 ATRIB(4)=ATRIB(4)*UNFRM(0.7,1.4,2),1;  ATRIB(1)=KG'S OF
;                                      TRIMMED FISH OUT OF ONE 20 KG TRAY
;                                      ATRIB(4)=TIME TO TRIM FISH FROM
;                                      ONE 20 KG TRAY
;
          ACTIVITY,ATRIB(4),,FTR1;
;
FTR1      FREE,TRIM11/1,3;
;
          ACTIVITY,,,AS47;
          ACTIVITY,,,AS49;
          ACTIVITY,,,AS51;
;
RTR2      AWAIT(23),TRIM12/1,1;
;
          ACTIVITY,,XX(23) .GT. 20.0 .OR. NNRSC(FORK1) .GE. 1 .OR.
                    NNQ(5) .GT. 0 .OR. NNQ(13) .GT. 8 .OR.
                    TNOW .GE. XX(41) .OR.
                    NNQ(15) .GT. 8 .OR. NNQ(9) .GE. 1,G010;
          ACTIVITY,,,FF12;
;
FF12      FREE,FORK1/1,1;
          ACTIVITY,,,G010;
G010      GOON,1;
AS48      ASSIGN,XX(23)=XX(23)-1,
                 ATRIB(1)=ATRIB(1)*XX(92),
                 ATRIB(4)=ATRIB(4)/20,
                 ATRIB(4)=ATRIB(4)*XX(71),
                 ATRIB(4)=ATRIB(4)+XX(70),
                 ATRIB(4)=ATRIB(4)*20,
                 ATRIB(4)=ATRIB(4)*UNFRM(0.7,1.4,1),1;  ATRIB(1)=KG'S OF
;                                      TRIMMED FISH OUT OF ONE 20 KG TRAY
;                                      ATRIB(4)=TIME TO TRIM FISH FROM
;                                      ONE 20 KG TRAY
;
          ACTIVITY,ATRIB(4),,FTR2;
;
FTR2      FREE,TRIM12/1,3;
;
          ACTIVITY,,,A147;
          ACTIVITY,,,A149;
          ACTIVITY,,,A151;
;
RTR3      AWAIT(24),TRIM21/1,1;
;
          ACTIVITY,,XX(24) .GT. 20 .OR. NNRSC(FORK2) .GE. 1 .OR.
                    NNQ(5) .GT. 0 .OR. NNQ(14) .GT. 8 .OR.
                    TNOW .GE. XX(41) .OR.
```

```
                    NNQ(9) .GE. 1,GO12;
               ACTIVITY,,,FFK2;
;
FFK2    FREE,FORK2/1,1;
             ACTIVITY,,,GO12;
GO12    GOON,1;
AS50    ASSIGN,XX(24)=XX(24)-1,
              ATRIB(1)=ATRIB(1)*XX(93),
              ATRIB(4)=ATRIB(4)/20,
              ATRIB(4)=ATRIB(4)*XX(73),
              ATRIB(4)=ATRIB(4)+XX(72),
              ATRIB(4)=ATRIB(4)*20,
              ATRIB(4)=ATRIB(4)*UNFRM(0.7,1.4,4),1;  ATRIB(1)=KG'S OF
;                                        TRIMMED FISH OUT OF ONE 20 KG TRAY
;                                        ATRIB(4)=TIME TO TRIM FISH FROM
;                                        ONE 20 KG TRAY
          ACTIVITY,ATRIB(4),,FTR3;
;
FTR3    FREE,TRIM21/1,3;
;
          ACTIVITY,,,A247;
          ACTIVITY,,,A249;
          ACTIVITY,,,A251;
;
;
;
AS47    ASSIGN,ATRIB(1)=ATRIB(1)*XX(83),
              ATRIB(2)=11,
              XX(48)=TNOW,1;            ATRIB(2)=TYPE OF CUT OF FISH
          ACTIVITY,0.1,,RWE2;           FILLETS (SPECIES 1, TYPE 1)
;                                        ATRIB(1)=KG OF FILLETS FROM A
;                                        20 KG TRAY
A147    ASSIGN,ATRIB(1)=ATRIB(1)*XX(85),
              ATRIB(2)=12,
              XX(48)=TNOW,1;            ATRIB(2)=TYPE OF CUT OF FISH
          ACTIVITY,0.1,,RWE2;           FILLETS (SPECIES 1,TYPE 2)
;                                        ATRIB(1)=KG OF FILLETS FROM A
;                                        20 KG TRAY
AS49    ASSIGN,ATRIB(1)=ATRIB(1)*XX(84),
              ATRIB(2)=13,
              XX(48)=TNOW,1;            ATRIB(2)=TYPE OF CUT OF FISH
          ACTIVITY,0.2,,RWE2;           FLAPS (SPECIES 1, TYPE 1)
;                                        ATRIB(1)=KG OF NAPES FROM A
;                                        20 KG TRAY
A149    ASSIGN,ATRIB(1)=ATRIB(1)*XX(86),
              ATRIB(2)=13,
              XX(48)=TNOW,1;             ATRIB(2)=TYPE OF CUT OF FISH
          ACTIVITY,0.3,,RWE2;            FLAPS (SPECIES 1, TYPE 2)
;                                         ATRIB(1)=KG OF NAPES FROM A
;                                         20 KG TRAY
AS51    ASSIGN,ATRIB(4)=1,
              ATRIB(4)=ATRIB(4)-XX(83),
              ATRIB(4)=ATRIB(4)-XX(84),
              ATRIB(1)=ATRIB(1)*ATRIB(4),
              ATRIB(2)=14,
              XX(48)=TNOW,1;             BLOCK (SPECIES 1 TYPE 1)
          ACTIVITY,0.3,,RWE2;            ATRIB(2)=TYPE OF CUT OF FISH
;                              ATRIB(4)=% OF BLOCK FROM A 20 KG TRAY
;                              ATRIB(1)=KG OF BLAOCK FROM A 20 KG TRAY
A151    ASSIGN,ATRIB(4)=1,
```

```
              ATRIB(4)=ATRIB(4)-XX(85),
              ATRIB(4)=ATRIB(4)-XX(86),
              ATRIB(1)=ATRIB(1)*ATRIB(4),
              ATRIB(2)=14,
              XX(48)=TNOW,1;              ATRIB(2)=TYPE OF CUT OF FISH
            ACTIVITY,0.3,,RWE2;           BLOCK (SPECIES 1 TYPE 2)
;                          ATRIB(4)=% OF BLOCK FROM A 20 KG TRAY
;                          ATRIB(1)=KG OF BLAOCK FROM A 20 KG TRAY
A247    ASSIGN,ATRIB(1)=ATRIB(1)*XX(87),
              ATRIB(2)=21,
              XX(48)=TNOW,1;              ATRIB(2)=TYPE OF CUT OF FISH
            ACTIVITY,0.3,,RWE2;           FILLETS (SPECIES 2)
;                                         ATRIB(1)=KG OF FILLETS FROM A
;                                         20 KG TRAY
A249    ASSIGN,ATRIB(1)=ATRIB(1)*XX(88),
              ATRIB(2)=22,
              XX(48)=TNOW,1;              ATRIB(2)=TYPE OF CUT OF FISH
            ACTIVITY,0.3,,RWE2;           FLAP (SPECIES 2)
;                                         ATRIB(1)=KG OF NAPES FROM A
;                                         20 KG TRAY
A251    ASSIGN,ATRIB(4)=1,
              ATRIB(4)=ATRIB(4)-XX(87),
              ATRIB(4)=ATRIB(4)-XX(88),
              ATRIB(1)=ATRIB(1)*ATRIB(4),
              ATRIB(2)=23,
              XX(48)=TNOW,1;              ATRIB(2)=TYPE OF CUT OF FISH
            ACTIVITY,0.3,,RWE2;           BLOCK (SPECIES 2)
;                                         ATRIB(1)=KG OF BLOCK FROM A
;                                         20 KG TRAY
;
RWE2    AWAIT(25),WEIGH2/1,1;             WEIGHING STATION FOR FISH
;                                         COMING OUT OF TRIMMING
            ACTIVITY,0.2,,FWE2;
;
FWE2    FREE,WEIGH2/1,1;
;
            ACTIVITY,,ATRIB(2) .EQ. 11.0,AS53;
            ACTIVITY,,ATRIB(2) .EQ. 12.0,A153;
            ACTIVITY,,ATRIB(2) .EQ. 13.0,AS55;
            ACTIVITY,,ATRIB(2) .EQ. 14.0,AS57;
            ACTIVITY,,ATRIB(2) .EQ. 21.0,A253;
            ACTIVITY,,ATRIB(2) .EQ. 22.0,A255;
            ACTIVITY,,ATRIB(2) .EQ. 23.0,A257;
;
;
AS53    ASSIGN,ATRIB(4)=UNFRM(0.7,1.4,5)*XX(76),
              ATRIB(4)=ATRIB(1)/ATRIB(4),1;        ATRIB(4)=TIME TO PACK
        COLCT,NNQ(27),FI11 WAITFORPACK,20/0/5,1;   TRIMMED FILLETS
;                                                  FROM ONE 20 KG TRAY
RFP1    AWAIT(27),FILLP11/1,1;                  PACKING STATION FOR FILLETS
;
            ACTIVITY,ATRIB(4),,FFP1;
;
FFP1    FREE,FILLP11/1;
AS59    ASSIGN,XX(25)=XX(25)+ATRIB(1),1;   XX(25)=KG'S AT PACKING STATION
;
            ACTIVITY,,XX(25) .GE. XX(51),AS65;
        TERMINATE;
;
AS65    ASSIGN,XX(25)=XX(25)-XX(51),
```

```
              XX(31)=XX(31)+1,
              XX(49)=TNOW,.
              ATRIB(1)=XX(51),1;          ATRIB(1)=WEIGHT OF ONE PAN
;
           ACTIVITY,,,6011;
;
A153    ASSIGN,ATRIB(4)=UNFRM(0.7,1.4,7)*XX(77),
             ATRIB(4)=ATRIB(1)/ATRIB(4),1;         ATRIB(4)=TIME TO PACK
        COLCT,NNQ(26),FI12 WAITFORPACK,20/0/5,1;   TRIMMED FILLETS
;                                                  FROM ONE 20 KG TRAY
RFP2    AWAIT(26),FILLP12/1,1;                PACKING STATION FOR FILLETS
;
            ACTIVITY,ATRIB(4),,FFP2;
;
FFP2    FREE,FILLP12/1;
A159    ASSIGN,XX(26)=XX(26)+ATRIB(1),1;    XX(26)=KG'S AT PACKING STATION
;
            ACTIVITY,,XX(26) .GE. XX(52),A165;
        TERMINATE;
;
A165    ASSIGN,XX(26)=XX(26)-XX(52),
              ATRIB(1)=XX(52),
              XX(49)=TNOW,
              XX(36)=XX(36)+1,1;          ATRIB(1)=WEIGHT OF ONE PAN
;
            ACTIVITY,,,6011;
;
AS55    ASSIGN,ATRIB(4)=UNFRM(0.7,1.4,8)*XX(78),
              ATRIB(4)=ATRIB(1)/ATRIB(4),1;        ATRIB(4)=TIME TO PACK
        COLCT,NNQ(29),FL11 WAITFORPACK,20/0/5,1;   NAPES
;                                                  FROM ONE 20 KG TRAY
RFL1    AWAIT(29),FLAP11/1,1;                 PACKING STATION FOR NAPES
;
           ACTIVITY,ATRIB(4),,FFL1;
;
FFL1    FREE,FLAP11/1,1;
AS61    ASSIGN,XX(27)=XX(27)+ATRIB(1),1;    XX(27)=KG'S AT PACKING STATION
;
           ACTIVITY,,XX(27) .GE. XX(53),AS67;
        TERMINATE;
;
AS67    ASSIGN,XX(27)=XX(27)-XX(53),
        XX(33)=XX(33)+1,
        XX(49)=TNOW,
        ATRIB(1)=XX(53),1;                  ATRIB(1)=WEIGHT OF ONE PAN
;
            ACTIVITY,,,6011;
;
;
AS57    ASSIGN,ATRIB(4)=UNFRM(0.7,1.4,9)*XX(79),
              ATRIB(4)=ATRIB(1)/ATRIB(4),1;        ATRIB(4)=TIME TO PACK
        COLCT,NNQ(31),BL11 WAITFORPACK,20/0/5,1;   BLOCK
;                                                  FROM ONE 20 KG TRAY
RBP1    AWAIT(31),BLOCK11/1,1;                PACKING STATION FOR BLOCK
;
            ACTIVITY,ATRIB(4),,FBP1;
;
FBP1    FREE,BLOCK11/1,1;
AS63    ASSIGN,XX(29)=XX(29)+ATRIB(1),1;    XX(29)=KG'S AT PACKING STATION
;
```

```
             ACTIVITY,,XX(29) .GE. XX(54),AS69;
        TERMINATE;
;
AS69    ASSIGN,XX(29)=XX(29)-XX(54),
               XX(35)=XX(35)+1,
               XX(49)=TNOW,
               ATRIB(1)=XX(54),1;          ATRIB(1)=WEIGHT OF ONE PAN
;
             ACTIVITY,,,GO11;
;
;
A253    ASSIGN,ATRIB(4)=UNFRM(0.7,1.4,5)*XX(80),
               ATRIB(4)=ATRIB(1)/ATRIB(4),1;        ATRIB(4)=TIME TO PACK
        COLCT,NNQ(28),FI21 WAITFORPACK,20/0/5,1;   TRIMMED FILLETS
;                                                   FROM ONE 20 KG TRAY
RFP3    AWAIT(28),FILLP21/1,1;                 PACKING STATION FOR FILLETS
;
             ACTIVITY,ATRIB(4),,FFP3;
;
FFP3    FREE,FILLP21/1,1;
A259    ASSIGN,XX(30)=XX(30)+ATRIB(1),1;   XX(30)=KG'S AT PACKING STATION
;
             ACTIVITY,,XX(30) .GE. XX(55),A265;
        TERMINATE;
;
A265    ASSIGN,XX(30)=XX(30)-XX(55),
               ATRIB(1)=XX(55),
               XX(49)=TNOW,
               XX(38)=XX(38)+1,1;          ATRIB(1)=WEIGHT OF ONE PAN
;
             ACTIVITY,,,GO11;
;
;
A255    ASSIGN,ATRIB(4)=UNFRM(0.7,1.4,6)*XX(81),
               ATRIB(4)=ATRIB(1)/ATRIB(4),1;        ATRIB(4)=TIME TO PACK
        COLCT,NNQ(30),FL21 WAITFORPACK,20/0/5,1;   NAPES
;                                                   FROM ONE 20 KG TRAY
RFL2    AWAIT(30),FLAP21/1,1;                  PACINKG STATION FOR NAPES
;
             ACTIVITY,ATRIB(4),,FFL2;
;
FFL2    FREE,FLAP21/1,1;
A261    ASSIGN,XX(32)=XX(32)+ATRIB(1),1;   XX(32)=KG'S AT PACKING STATION
;
             ACTIVITY,,XX(32) .GE. XX(56),A267;
        TERMINATE;
;
A267    ASSIGN,XX(32)=XX(32)-XX(56),
               ATRIB(1)=XX(56),
               XX(49)=TNOW,
               XX(40)=XX(40)+1,1;          ATRIB(1)=WEIGHT OF ONE PAN
;
             ACTIVITY,,,GO11;
;
;
A257    ASSIGN,ATRIB(4)=UNFRM(0.7,1.4,3)*XX(82),
               ATRIB(4)=ATRIB(1)/ATRIB(4),1;        ATRIB(4)=TIME TO PACK
        COLCT,NNQ(32),BL21 WAITFORPACK,20/0/5,1;   BLOCK
;                                                   FROM ONE 20 KG TRAY
RBP2    AWAIT(32),BLOCK21/1,1;                 PACKING STATION FOR BLOCK
```

```
;
          ACTIVITY,ATRIB(4),,FBP2:
;
FBP2    FREE,BLOCK21/1,1;
A263    ASSIGN,XX(34)=XX(34)+ATRIB(1),1;   XX(34)=KG'S AT PACKING STATION
;
          ACTIVITY,,XX(34) .GT. XX(57),A269;
        TERMINATE;
;
A269    ASSIGN,XX(34)=XX(34)-XX(57),
            ATRIB(1)=XX(57),
            XX(49)=TNOW,
            XX(42)=XX(42)+1,1;          ATRIB(1)=WEIGHT OF ONE PAN
;
          ACTIVITY,,,GO11;
;
GO11    GOON,2;
;
          ACTIVITY,,,ACPA;
          ACTIVITY,,,AS70;
;
;                              30 PANS ARE NEEDED
ACPA    ACCUMULATE,30,30,,1;   TO FILL ONE FREEZER UNIT
;
ROF1    AWAIT(35),QUICKF/1,1;          QUICKFREEZER STATION
;
          ACTIVITY,150,,FQF1;     IT TAKES 150 MINUETS TO
;                                 FREEZE THE FISH
FQF1    FREE,QUICKF/1,1;
AS73    ASSIGN,XX(37)=0,1;
OQCK    OPEN,GQUICK,1;
        TERMINATE;
;
;
AS70    ASSIGN,ATRIB(1)=TNOW,1;
GQCK    AWAIT(33),GQUICK,1;
AS71    ASSIGN,XX(37)=XX(37)+1,1
;
          ACTIVITY,,XX(37) .LT. 30.0,AS74;
          ACTIVITY,,XX(37) .EQ. 30.0,CQCK;
          ACTIVITY,,,GQCK;        BACKWARDS JUMP
;
CQCK    CLOSE,GQUICK,1;
          ACTIVITY,,,AS74;
;
AS74    ASSIGN,ATRIB(1)=TNOW-ATRIB(1),
             ATRIB(1)=ATRIB(1)-150,1;
LCWQ    COLCT,ATRIB(1),WAIT BEF. QUICKF,10/0/10,1;
GO13    GOON,1;
;
          ACTIVITY,1,,AS75;
;
AS75    ASSIGN,ATRIB(3)=TNOW-ATRIB(3),
             XX(50)=XX(50)+ATRIB(1),1;   XX(50)=KILOS OF FROZEN
;                                         FISH PRODUCED
LCPT    COLCT,ATRIB(3),PROCESS TIME,10/200/25,1;
;
        TERMINATE;
;
;
```

```
;
;
;
;
        ENDNETWORK;
INITIALIZE,0,10;
FIN;
```

APPENDIX 3

COMPUTER LISTING FOR 'SLAM' USERFUNCTIONS

```
C     ---------------------------------------------------------
C     :                                                       :
C     :      OREGON STATE UNIVERSITY       MAY 1985           :
C     :                                                       :
C     :                                                       :
C     :      This is the  USERFUNCTION                        :
C     :                                                       :
C     :                                                       :
C     :      ---------------------------------------          :
C     :                                                       :
C     :      Designed by :   Elias Jonatansson                :
C     :                                                       :
C     ---------------------------------------------------------
C
C
C
      FUNCTION USERF(IX)
C
C       The function routine reads in variables for the network
C
      CHARACTER DUMMY*5
C
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MJA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C
C
      GO TO (10,20) IX
10    CONTINUE
      USERF=0
C
C
C      Now  the values that have previously been read
C      in to a file by the program READIN, will be read in to
C      the network
C
C
      READ (1,3000) XX(3)
3000  FORMAT (F5.2)
C
      DO  3500 I=15,22
         READ (1,3000) XX(I)
3500     CONTINUE
      READ (1,3000) XX(28)
      READ (1,3000) XX(39)
C
      DO 3600 J=44,47
         READ (1,3000) XX(J)
3600    CONTINUE
C
      DO 3700 K=51,99
         READ (1,3000) XX(K)
3700     CONTINUE
C
C
      RETURN
C
C
C
C
20    CONTINUE
```

```
C
      WRITE (2,5000) TNOW,XX(12),XX(13),XX43)
5000  FORMAT (5X,F7.2,1X,F8.2,1X,F8.2,1X,F8.2)
C
C
      RETURN
C
      END
```

APPENDIX 4

COMPUTER LISTING FOR FRONT-END PROGRAM READIN

```
C     ---------------------------------------------------------
C     !                                                       !
C     !      OREGON STATE UNIVERSITY       MAY 1985           !
C     !                                                       !
C     !                                                       !
C     !      This is the program :   READIN                   !
C     !                                                       !
C     !      The program uses one subroutine :                !
C     !                                                       !
C     !           - Subroutine ASK                            !
C     !                                                       !
C     !      ----------------------------------------         !
C     !                                                       !
C     !      Designed by :   Elias Jonetensson                !
C     !                                                       !
C     ---------------------------------------------------------
C
C
C
      PROGRAM READIN
C     PROGRAM MAIN(TAPES,TAPE6,TAPE7)
      DIMENSION NSET(9500)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MJA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(9500)
      CHARACTER*8  NAME1,NAME2
      EQUIVALENCE (NSET(1),QSET(1))
      WRITE (*,5)
5     FORMAT (////////10X,
     1' What do you want to call the output data file that later'/10X,
     2' will be read by the USERFUNCTION called by the'/10X,
     3' Freezing Plant Network ?   [DATAIN]')
      READ (*,6) NAME1
6     FORMAT (A)
      IF (NAME1 .EQ. ' ') NAME1='DATAIN'
      WRITE (*,7)
7     FORMAT (//////10X,
     1' What do you want to call the output file that s written'/10X,
     2' out only for the user to be able to see which values were'/10X,
     3' given to the variables ?   [RECORD]')
      READ (*,8) NAME2
8     FORMAT (A)
      IF (NAME2 .EQ. ' ') NAME2='RECORD'
      OPEN (1,FILE=NAME1,STATUS='NEW')
      OPEN (2,FILE=NAME2,STATUS='NEW')
      NNSET=9500
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL ASK
      STOP
      END
C
C
C
C
C
      SUBROUTINE ASK
C
C       The subroutine reads in variables for the Freezing Plant
```

```
C         network.  It writes them into a file that later will be
C         read by a USERFUNCTION called from within the network.
C
      CHARACTER DUMMY*5
C
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MJA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C
C
C
C
C         First we'll read in the number of workers of each 'type'
C
C
      WRITE (*,100)
      WRITE (2,100)
100   FORMAT ('1'////5X,
     1' The model can handle 2 species at a time.  One species can'/5X,
     2' be cut into either one of 2 different types of fillets,'/5X,
     3' but the other one can be cut into only one type of fillet.'/5X,
     4' Both species can have two side products, which are the'/5X,
     5' napes and the block.  The napes and the block are the same'/5X,
     6' from fillets of the same species regardless of the cut.'//15X,
     7' DEFAULT VALUES ARE GIVEN IN [   ] '//5X,
     8' IF YOU DON T WANT TO USE A RESOURCE, ENTER'/5X,
     9' -1. (a minus one point zero)'/5X,
     0' Remember the   DECIMAL POINT for all entries  !!!'/5X,
     1' To use default values, hit the SPACE BAR and'/5X,
     2' then HIT RETURN or ENTER '/////5X,
     3' First we will read in the number of workers : '//5X,
     4' # of Trimming workers, SPECIES 1, TYPE 1 ?  [25]')
C
      READ (*,110) XX(60)
110   FORMAT (F8.3)
      IF (XX(60) .EQ. 0) XX(60)=25
      IF (XX(60) .EQ. -1) XX(60)=0
      WRITE (2,110) XX(60)
C
      WRITE (*,120)
      WRITE (2,120)
120   FORMAT (//5X,
     1' # of Trimming workers, SPECIES 1, TYPE 2 ?  [10]')
      READ (*,130) XX(61)
130   FORMAT (F8.3)
      IF (XX(61) .EQ. 0) XX(61)=10
      IF (XX(61) .EQ. -1) XX(61)=0
      WRITE (2,130) XX(61)
C
      WRITE (*,140)
      WRITE (2,140)
140   FORMAT (//5X,
     1' # of Trimming workers, SPECIES 2 ?  [15]')
      READ(*,150) XX(62)
150   FORMAT (F8.3)
      IF (XX(62) .EQ. 0) XX(62)=15
      IF (XX(62) .EQ. -1) XX(62)=0
      WRITE (2,150) XX(62)
C
      WRITE (*,160)
      WRITE (2,160)
```

```
160   FORMAT (//5X,
     1' # of Packing workers SPECIES 1, FILLET TYPE 1 ?   [6]')
      READ (*,170) XX(63)
170   FORMAT (F8.3)
      IF (XX(63) .EQ. 0) XX(63)=6
      IF (XX(63) .EQ. -1) XX(63)=0
      WRITE (2,170) XX(63)
C
      WRITE (*,180)
      WRITE (2,180)
180   FORMAT (//5X,
     1' # of Packing workers SPECIES 1, FILLET TYPE 2 ?   [2]')
      READ (*,190) XX(64)
190   FORMAT (F8.3)
      IF (XX(64) .EQ. 0) XX(64)=2
      IF (XX(64) .EQ. -1) XX(64)=0
      WRITE (2,190) XX(64)
C
      WRITE (*,200)
      WRITE (2,200)
200   FORMAT (//5X,
     1' # of Packing workers SPECIES 1, NAPES (TYPE 1&2) ?  [1]')
      READ (*,210) XX(65)
210   FORMAT (F8.3)
      IF (XX(65) .EQ. 0) XX(65)=1
      IF (XX(65) .EQ. -1) XX(65)=0
      WRITE (2,210) XX(65)
C
      WRITE (*,220)
      WRITE (2,220)
220   FORMAT (//5X,
     1' # of Packing workers SPECIES 1, BLOCK (TYPE 1&2) ?   [1]')
      READ (*,230) XX(66)
230   FORMAT (F8.3)
      IF (XX(66) .EQ. 0) XX(66)=1
      IF (XX(66) .EQ. -1) XX(66)=0
      WRITE (2,230) XX(66)
C
      WRITE (*,240)
      WRITE (2,240)
240   FORMAT (//5X,
     1' # of Packing workers SPECIES 2, FILLETS ?   [3]')
      READ (*,250) XX(67)
250   FORMAT (F8.3)
      IF (XX(67) .EQ. 0) XX(67)=3
      IF (XX(67) .EQ. -1) XX(67)=0
      WRITE (2,250) XX(67)
C
      WRITE (*,260)
      WRITE (2,260)
260   FORMAT (//5X,
     1' # of Packing workers SPECIES 2, NAPES ?   [0]')
      READ (*,270) XX(68)
270   FORMAT (F8.3)
      IF (XX(68) .EQ. 0) XX(68)=0
      IF (XX(68) .EQ. -1) XX(68)=0
      WRITE (2,270) XX(68)
C
      WRITE (*,280)
      WRITE (2,280)
```

```
280   FORMAT (//5X,
     1' # of Packing workers SPECIES 2, BLOCK ?   [1]')
      READ (*,290) XX(69)
290   FORMAT (F8.3)
      IF (XX(69) .EQ. 0) XX(69)=1
      IF (XX(69) .EQ. -1) XX(69)=0
      WRITE (2,290) XX(69)
C
C     ----------------------------------------------------
C
C     STANDARD TIMES FOR DIFFERENT TASKS
C
      WRITE (*,300)
      WRITE (2,300)
300   FORMAT (//////5X,' Next we will read in parameters for'/5X,
     1' calculating standard times for different tasks.  We do'/5X,
     2' the following assumptions :'/10X,
     3' Number of parasites = Conctant pr. kg.'/10X,
     4' Number of filleting defects = Constant pr. kg.'/10X,
     5' The standard times are calculated according to formulas'/10X,
     6' given in "VERKLYSINGAR, LEIDBEININGAR OG STADLAR FYRIR'/10X,
     7' AKVAEDISVINNU I FRYSTIHUSUM" (Working Methods, Guide'/10X,
     8' and Standards for Wage Incentives in Freezing Plants)'/10X,
     9' Reykjavik, Iceland, December 1980.'///)
      WRITE (*,305)
305   FORMAT (15X,' HIT RETURN TO CONTINUE')
      READ (*,306) DUMMY
306   FORMAT (A)
      WRITE (*,307)
      WRITE (2,307)
307   FORMAT (//////5X,
     1' To calculate standard time for trimming we actually need'/5X,
     2' four parameters :'///5X,
     3' c1 + c2 * [# fillets/kg] + c3 * [# parasites/kg] +'/5X,
     4' c4 * [# defects/kg]'//5X,
     5' But because of our assumptions we only need to read in'//5X,
     6' Ca and Cb, Ca = c1 + c3 * (# parasites) +'/5X,
     7' c4 * (# of filleting defects)   and   Cb = c2'//////5X,
     8' Let s start with parameters for trimming times'///5X,
     9' For SPECIES 1, TYPE 1 :   Coefficient  Ca = ?  [1.249]')
C
      READ (*,310) XX(70)
310   FORMAT (F8.3)
      IF (XX(70) .EQ. 0) XX(70)=1.249
      IF (XX(70) .EQ. -1) XX(70)=0
      WRITE (2,310) XX(70)
C
      WRITE (*,320)
      WRITE (2,320)
320   FORMAT (30X,' Coefficient  Cb = ?  [0.457]')
      READ (*,330) XX(71)
330   FORMAT (F8.3)
      IF (XX(71) .EQ. 0) XX(71)=0.457
      IF (XX(71) .EQ. -1) XX(71)=0
      WRITE (2,330) XX(71)
C
C
      WRITE (*,340)
      WRITE (2,340)
340   FORMAT (//5X,
```

```
     1' For SPECIES 1, TYPE 2 :  Coefficient Ca = ? [1.479]')
      READ (*,350) XX(72)
350   FORMAT (F8.3)
      IF (XX(72) .EQ. 0) XX(72)=1.479
      IF (XX(72) .EQ. -1) XX(72)=0
      WRITE (2,350) XX(72)
      WRITE (*,360)
      WRITE (2,360)
360   FORMAT (30X,' Coefficient   Cb = ? [0.457]')
      READ (*,370) XX(73)
370   FORMAT (F8.3)
      IF (XX(73) .EQ. 0) XX(73)=0.457
      IF (XX(73) .EQ. -1) XX(73)=0
      WRITE (2,370) XX(73)
C
      WRITE (*,380)
      WRITE (2,380)
380   FORMAT (//5X,
     1' For SPECIES 2 :  Coefficient Ca = ? [1.324]')
      READ (*,390) XX(74)
390   FORMAT (F8.3)
      IF (XX(74) .EQ. 0) XX(74)=1.324
      IF (XX(74) .EQ. -1) XX(74)=0
      WRITE (2,390) XX(74)
      WRITE (*,400)
      WRITE (2,400)
400   FORMAT (22X,' Coefficient   Cb = ? [0.450]')
      READ (*,410) XX(75)
410   FORMAT (F8.3)
      IF (XX(75) .EQ. 0) XX(75)=0.45
      IF (XX(75) .EQ. -1) XX(75)=0
      WRITE (2,410) XX(75)
C
C     ___________________________
C
      WRITE (*,420)
      WRITE (2,420)
420   FORMAT (//////5X,' Now standard times for PACKING !'///5X,
     1' Packing, SPECIES 1 FILLET TYPE 1  (kg. pr. min.) ?  [1.15]')
      READ (*,430) XX(76)
430   FORMAT (F8.3)
      IF (XX(76) .EQ. 0) XX(76) =1.15
      IF (XX(76) .EQ. -1) XX(76)=0
      WRITE (2,430) XX(76)
C
      WRITE (*,440)
      WRITE (2,440)
440   FORMAT (//5X,
     1' Packing, SPECIES 1. FILLET TYPE 2  (kg. pr. min.) ?  [0.96]')
      READ (*,450) XX(77)
450   FORMAT (F8.3)
      IF (XX(77) .EQ. 0) XX(77) =0.96
      IF (XX(77) .EQ. 0) XX(77)=0
      WRITE (2,450) XX(77)
C
      WRITE (*,460)
      WRITE (2.460)
460   FORMAT (//5X,
     1' Packing, SPECIES 1, NAPES  (kg. pr. min.) ?  [2.07]')
      READ (*,470) XX(78)
```

```
470   FORMAT (F8.3)
      IF (XX(78) .EQ. 0) XX(78)=2.07
      IF (XX(78) .EQ. -1) XX(78)=0
      WRITE (2,470) XX(78)
C
      WRITE (*,480)
      WRITE (2,480)
480   FORMAT (//5X,
     1' Packing, SPECIES 1, BLOCK  (kg. pr. min) ?  [2.72]')
      READ (*,490) XX(79)
490   FORMAT (F8.3)
      IF (XX(79) .EQ. 0) XX(79)=2.72
      IF (XX(79) .EQ. -1) XX(79)=0
      WRITE (2,490) XX(79)
C
      WRITE (*,500)
      WRITE (2,500)
500   FORMAT (//5X,
     1' Packing, SPECIES 2, FILLETS (kg. pr. min) ? [1.15]')
      READ (*,510) XX(80)
510   FORMAT (F8.3)
      IF (XX(80) .EQ. 0) XX(80)=1.15
      IF (XX(80) .EQ.-1) XX(80)=0
      WRITE (2,510) XX(80)
C
      WRITE (*,520)
      WRITE (2,520)
520   FORMAT (//5X,
     1' Packing, SPECIES 2, NAPES (kg. pr. min) ? [2.72]')
      READ (*,530) XX(81)
530   FORMAT (F8.3)
      IF (XX(81) .EQ. 0) XX(81)=2.72
      IF (XX(81) .EQ. -1) XX(81)=0
      WRITE (2,530) XX(81)
C
      WRITE (*,540)
      WRITE (2,540)
540   FORMAT (//5X,
     1' Packing, SPECIES 2, BLOCK (kg. pr. min) ? [2.08]')
      READ (*,550) XX(82)
550   FORMAT (F8.3)
      IF (XX(82) .EQ. 0) XX(82)=2.08
      IF (XX(82) .EQ. -1) XX(82)=0
      WRITE (2,550) XX(82)
C
C     -----------------------------------------------
C
C     Next we read in the division of each species and type
C     between the final products, FILLETS, NAPES and BLOCK
C
C
      WRITE (*,560)
      WRITE (2,560)
560   FORMAT (////5X,' How much of the final product is : '//15X,
     1' - Fillets '/15X,' - Napes '/15X,' - Block '////5X,
     2' SPECIES 1, RATIO OF FILLETS TYPE 1 ?  [0.77]  ')
      READ (*,570) XX(83)
570   FORMAT (F8.3)
      IF (XX(83) .EQ. 0) XX(83)=0.77
      IF (XX(83) .EQ. -1) XX(83)=0
```

```
      WRITE (2,570) XX(83)
C
      WRITE (*,580)
      WRITE (2,580)
580   FORMAT (//5X,' SPECIES 1, RATIO OF NAPES TYPE 1 ?  [0.11]')
      READ (*,590) XX(84)
590   FORMAT (F8.3)
      IF (XX(84) .EQ. 0) XX(84)=0.11
      IF (XX(84) .EQ. -1) XX(84)=0
      WRITE (2,590) XX(84)
C
      WRITE (*,600)
      WRITE (2,600)
600   FORMAT (//5X,' SPECIES 1, RATIO OF FILLETS TYPE 2 ? [0.76]')
      READ (*,610) XX(85)
610   FORMAT (F8.3)
      IF (XX(85) .EQ. 0) XX(85)=0.76
      IF (XX(85) .EQ. -1) XX(85)=0
      WRITE (2,610) XX(85)
C
      WRITE (*,620)
      WRITE (2,620)
620   FORMAT (//5X,' SPECIES 1, RATIO OF NAPES TYPE 2 ?  [0.11]')
      READ (*,630) XX(86)
630   FORMAT (F8.3)
      IF (XX(86) .EQ. 0) XX(86)=0.11
      IF (XX(86) .EQ. -1) XX(86)=0
      WRITE (2,630) XX(86)
C
      WRITE (*,640)
      WRITE (2,640)
640   FORMAT (//5X,' SPECIES 2, RATIO OF FILLETS ?  [0.81]')
      READ (*,650) XX(87)
650   FORMAT (F8.3)
      IF (XX(87) .EQ. 0) XX(87)=0.81
      IF (XX(87) .EQ. -1) XX(87)=0
      WRITE (2,650) XX(87)
C
      WRITE (*,660)
      WRITE (2,660)
660   FORMAT (//5X,' SPECIES 2, RATIO OF NAPES ?  [0.00]')
      READ (*,670) XX(88)
670   FORMAT (F8.3)
      IF (XX(88) .EQ. 0) XX(88)=0
      IF (XX(88) .EQ. -1) XX(88)=0
      WRITE (2,670) XX(88)
C
C     ---------------------------------------------------------
C
C     Now we'll read in the yield for the machines
C     header, filleting machine and the skinning machine as
C     a whole, and then the yield at the trimming stations
C     for the different types of species and types of fillets
C
C     We will also read in the number of machines for species 1
C     which can be either 1 or 2.
C
      WRITE (*,680)
      WRITE (2,680)
680   FORMAT (//////5X,
```

```
     1' What is the YIELD for the :  /SX,
     2' Heeder, the Filleting macnine and the Skinner.'/SX,
     3' as a whole  ?'///SX,
     4' Yield of machines for species 1,         YIELD ?    [0.45]')
      READ (*,690) XX(89)
 690  FORMAT (F8.3)
      IF (XX(89) .EQ. 0) XX(89)=0.45
      IF (XX(89) .EQ. -1) XX(89)=0
      WRITE (2,690) XX(89)
C
C     The manipulating of XX(3) after it's read in, may need
C     some explanation, which is given below.
C
      WRITE (*,692)
      WRITE (2,692)
 692  FORMAT (//SX,
     1' How many filleting machines are there'/SX,
     2' for species 1, (either one or two) ?  [1]')
      READ (*,694) XX(3)
 694  FORMAT (F8.3)
      IF (XX(3) .EQ. 1) XX(3)=0
      IF (XX(3) .EQ. -1) XX(3)=0
      IF (XX(3) .EQ. 2) XX(3)=1
C     TO KEEP THE RECORD RIGHT WE WRITE THE NUMBER OF MACHINES
      XX(3)=XX(3)+1
      WRITE (2,694) XX(3)
      XX(3)=XX(3)-1
C     (HEFISK1+HEFISK18)-TO THE RECORD FILE
C
C      XX(3) is the units of RESOURCE HEFISK18 used.  Therefore
C      if there are two filleting machines for species 1, it means
C      that HEFISK18 needs to be used and XX(3) is set to 1.  If only
C      one filleting machine is needed for species 1, XX(3) is set
C      to 0, indicating that HEFISK18 will not be used.
C
C
      WRITE (*,700)
      WRITE (2,700)
 700  FORMAT (//SX,
     1' Yield of machines for species 2,         YIELD ?    [0.39]')
      READ (*,710) XX(90)
 710  FORMAT (F8.3)
      IF (XX(90) .EQ. 0) XX(90)=0.39
      IF (XX(90) .EQ. -1) XX(90)=0
      WRITE (2,710) XX(90)
C
      WRITE (*,720)
      WRITE (2,720)
 720  FORMAT (//////SX,
     1' What is the trimming-yield for different species'/SX,
     2' and different types of cuts of fillets  ?'//SX,
     3' Trimming yield for Species 1, Type 1 ?   [0.918]')
      READ (*,730) XX(91)
 730  FORMAT (F8.3)
      IF (XX(91) .EQ. 0) XX(91)=0.918
      IF (XX(91) .EQ. -1) XX(91)=0
      WRITE (2,730) XX(91)
C
      WRITE (*,740)
      WRITE (2,740)
```

```
740   FORMAT (//5X,' Trimming yield for Species 1, Type 2 ?   [0.935]')
      READ (*,750) XX(92)
750   FORMAT (F8.3)
      IF (XX(92) .EQ. 0) XX(92)=0.936
      IF (XX(92) .EQ. -1) XX(92)=0
      WRITE (2,750) XX(92)
C
      WRITE (*,760)
      WRITE (2,760)
760   FORMAT (//5X,' Trimming yield for Species 2 ?   [0.850]')
      READ (*,770) XX(93)
770   FORMAT (F8.3)
      IF (XX(93) .EQ. 0) XX(93)=0.850
      IF (XX(93) .EQ. -1) XX(93)=0
      WRITE (2,770) XX(93)
C
C     ---------------------------------------------------
C
C     Now we will read in the average $ of fishes in a "60" kg box
C     for both species.  We will also read in the standard deviation.
C
      WRITE (*,780)
      WRITE (2,780)
780   FORMAT (/////5X,' Now we need to know the MEAN value and the'/5X,
     1' STDEV of the $ of fishes in a box '///5X,
     2' $ of fishes in a box,  Species 1,    MEAN  ?   [30]')
      READ (*,790) XX(94)
790   FORMAT (F8.3)
      IF (XX(94) .EQ. 0) XX(94)=30
      IF (XX(94) .EQ. -1) XX(94)=0
      WRITE (2,790) XX(94)
C
      WRITE (*,800)
      WRITE (2,800)
800   FORMAT (//5X,
     1' $ of fishes in a box, Species 1,    STDEV?   [3.9]')
      READ (*,810) XX(95)
810   FORMAT (F8.3)
      IF (XX(95) .EQ. 0) XX(95)=3.9
      IF (XX(95) .EQ.-1) XX(95)=0
      WRITE (2,810) XX(95)
C
      WRITE (*,820)
      WRITE (2,820)
820   FORMAT (//5X,
     1' $ of fishes in a box, Species 2,    MEAN ?  [32]')
      READ (*,830) XX(96)
830   FORMAT (F8.3)
      IF (XX(96) .EQ. 0) XX(96)=32
      IF (XX(96) .EQ. -1) XX(96)=0
      WRITE (2,830) XX(96)
C
      WRITE (*,840)
      WRITE (2,840)
840   FORMAT (//5X;
     1' $ of fishes in a box, Species 2,    STDEV ?  [4.2]')
      READ (*,850) XX(97)
850   FORMAT (F8.3)
      IF (XX(97) .EQ. 0) XX(97)=4.2
      IF (XX(97) .EQ. -1) XX(97)=0
```

```
      WRITE (2,950) XX(97)
C
C     ---------------------------------------------------
C
C     Now we need to know the quantity of product that goes
C     into one 'frame' or 'pan' .
C
      WRITE (*,860)
      WRITE (2,860)
860   FORMAT (//////5X,
     1' What is the quantity of different products that '/5X,
     2' goes into one 'Frame' or 'Pan'  (in kg s)  ? '///5X,
     3' Quantity of fillets, species 1, type 1 in a pan ?    [34.02]')
      READ (*,870) XX(51)
870   FORMAT (F8.3)
      IF (XX(51) .EQ. 0) XX(51)=34.02
      IF (XX(51) .EQ. -1) XX(51)=0
      WRITE (2,870) XX(51)
C
      WRITE (*,880)
      WRITE (2,880)
880   FORMAT (/5X,
     1' Quantity of fillets, species 1, type 2 in a pan ?    [32.66]')
      READ (*,890) XX(52)
890   FORMAT (F8.3)
      IF (XX(52) .EQ. 0) XX(52)=32.66
      IF (XX(52) .EQ. -1) XX(52)=0
      WRITE (2,890) XX(52)
C
      WRITE (*,900)
      WRITE (2,900)
900   FORMAT (/5X,
     1' Quantity of napes, species 1 in a pan ?    [29.93]')
      READ (*,910) XX(53)
910   FORMAT (F8.3)
      IF (XX(53) .EQ. 0) XX(53)=29.93
      IF (XX(53) .EQ. -1) XX(53)=0
      WRITE (2,910) XX(53)
C
      WRITE (*,920)
      WRITE (2,920)
920   FORMAT (/5X,
     1' Quantity of block, species 1 in a pan ?    [33.57]')
      READ (*,930) XX(54)
930   FORMAT (F8.3)
      IF (XX(54) .EQ. 0) XX(54)=33.57
      IF (XX(54) .EQ. -1) XX(54)=0
      WRITE (2,930) XX(54)
C
      WRITE (*,940)
      WRITE (2,940)
940   FORMAT (/5X,
     1' Quantity of fillets, species 2 in a pan ?    [34.02]')
      READ (*,950) XX(55)
950   FORMAT (F8.3)
      IF (XX(55) .EQ. 0) XX(55)=34.02
      IF (XX(55) .EQ. -1) XX(55)=0
      WRITE (2,950) XX(55)
C
      WRITE (*,960)
```

```
      WRITE (2,960)
960   FORMAT (/5X,
     1' Quantity of napes, species 2 in a pan ?    [29.93]')
      READ (*,970) XX(56)
970   FORMAT (F8.3)
      IF (XX(56) .EQ. 0) XX(56)=29.93
      IF (XX(56) .EQ. -1) XX(56)=0
      WRITE (2,970) XX(56)
C
      WRITE (*,980)
      WRITE (2,980)
980   FORMAT (/5X,
     1' Quantity of block, species 2 in a pen ?    [29.93]')
      READ (*,990) XX(57)
990   FORMAT (F8.3)
      IF (XX(57) .EQ. 0) XX(57)=29.93
      IF (XX(57) .EQ. -1) XX(57)=0
      WRITE (2,990) XX(57)
C
C
C
C     ________________________________________________________
C
C     Next we will read in the number of boxes of fish of
C     each species, and the average weight of boxes of each
C     type.
C
      WRITE (*,1000)
      WRITE (2,1000)
1000   FORMAT (//////5X,
     1' What is the number of "60" kg boxes, of each'/5X,
     2'  species, going into the system  ?'///5X,
     3' Number of boxes of species 1, is ?    [250]')
      READ (*,1010) XX(58)
1010   FORMAT (F8.3)
      IF (XX(58) .EQ. 0) XX(58)=250
      IF (XX(58) .EQ. -1) XX(58)=0
      WRITE (2,1010) XX(58)
C
      WRITE (*,1020)
      WRITE (2,1020)
1020   FORMAT (//5X,' Number of boxes of species 2 is ?    [100]')
      READ (*,1030) XX(59)
1030   FORMAT (F8.3)
      IF (XX(59) .EQ. 0) XX(59)=100
      IF (XX(59) .EQ. -1) XX(59)=0
      WRITE (2,1030) XX(59)
C
      WRITE (*,1040)
      WRITE (2,1040)
1040  FORMAT (//////5X,
     1' What is the average weight of boxes of raw'/5X,
     2' material, of each species, going into the systen  ?'///5X,
     3' Average weight of boxes of species 1 is  ?      [62.0]')
      READ (*,1050) XX(98)
1050  FORMAT (F8.3)
      IF (XX(98) .EQ. 0) XX(98)=62
      IF (XX(98) .EQ. -1) XX(98)=0
      WRITE (2,1050) XX(98)
C
```

```
      WRITE (*,1060)
      WRITE (2,1060)
1060  FORMAT (//5X,
     1' Average weight of boxes of species 2 is  ?      [64.0]')
      READ (*,1070) XX(99)
1070  FORMAT (F8.3)
      IF (XX(99) .EQ. 0) XX(99)=64
      IF (XX(99) .EQ. -1) XX(99)=0
      WRITE (2,1070) XX(99)
C
C     ----------------------------------------------------------
C
C       Finally we will read in distribution parameters for machine
C       breakdowns and for the repair time of the machines.
C
C
C
      WRITE (*,1080)
      WRITE (2,1080)
1080  FORMAT (//////5X,
     1' Finally, we will read in distribution parameters for'/5X,
     2' 1) machine breakdowns,  and   2) for machine repair time'///5X,
     3' First for the machines for species 1'//5X,
     4' Minimum time between breakdowns  (minuets) ?   [15]')
      READ (*,1090) XX(15)
1090  FORMAT (F8.3)
      IF (XX(15) .EQ. 0) XX(15)=15
      IF (XX(15) .EQ. -1) XX(15)=0
      WRITE (2,1090) XX(15)
C
      WRITE (*,1100)
      WRITE (2,1100)
1100  FORMAT (//5X,
     1' Most common time between breakdowns (minuets) ?   [60]')
      READ (*,1110) XX(16)
1110  FORMAT (F8.3)
      IF (XX(16) .EQ. 0) XX(16)=60
      IF (XX(16) .EQ. -1) XX(16)=0
      WRITE (2,1110) XX(16)
C
      WRITE (*,1120)
      WRITE (2,1120)
1120  FORMAT (//5X,
     1' Maximum time between breakdowns (minuets) ?   [120]')
      READ (*,1130) XX(17)
1130  FORMAT (F8.3)
      IF (XX(17) .EQ. 0) XX(17)=120
      IF (XX(17) .EQ. -1) XX(17)=0
      WRITE (2,1130) XX(17)
C
      WRITE (*,1140)
      WRITE (2,1140)
1140  FORMAT(////5X,
     1' What is the repair time for machine 1 ?'//5X,
     2' Minimum repair time (min) ?    [2]')
      READ (*,1150) XX(18)
1150  FORMAT (F8.3)
      IF (XX(18) .EQ. 0) XX(18)=2
      IF (XX(18) .EQ. -1) XX(18)=0
      WRITE (2,1150) XX(18)
```

```
C
C
      WRITE (*,1160)
      WRITE (2,1160)
1160  FORMAT (//5X,
     1' Maximum repair time (min) ?    [15]')
      READ (*,1170) XX(19)
1170  FORMAT (F8.3)
      IF (XX(19) .EQ. 0) XX(19)=15
      IF (XX(19) .EQ. -1) XX(19)=0
      WRITE (2,1170) XX(19)
C
C     ---------------------
C
      WRITE (*,1180)
      WRITE (2,1180)
1180  FORMAT (//////5X,
     1' Now the parameters for the machine for species 2, for  '/5X,
     2' 1) machine breakdowns,  and   2) for machine repair time'///5X,
     3' Minimum time between breakdowns  (minuets) ?   [10]')
      READ (*,1190) XX(20)
1190  FORMAT (F8.3)
      IF (XX(20) .EQ. 0) XX(20)=10
      IF (XX(20) .EQ. -1) XX(20)=0
      WRITE (2,1190) XX(20)
C
      WRITE (*,1200)
      WRITE (2,1200)
1200  FORMAT (//5X,
     1' Most common time between breakdowns (minuets) ?   [20]')
      READ (*,1210) XX(21)
1210  FORMAT (F8.3)
      IF (XX(21) .EQ. 0) XX(21)=20
      IF (XX(21) .EQ. -1) XX(21)=0
      WRITE (2,1210) XX(21)
C
      WRITE (*,1220)
      WRITE (2,1220)
1220  FORMAT (//5X,
     1' Maximum time between breakdowns (minuets) ?   [60]')
      READ (*,1230) XX(22)
1230  FORMAT (F8.3)
      IF (XX(22) .EQ. 0) XX(22)=60
      IF (XX(22) .EQ. -1) XX(22)=0
      WRITE (2,1230) XX(22)
C
      WRITE (*,1240)
      WRITE (2,1240)
1240  FORMAT(////5X,
     1' What is the repair time for machine 2 ?'//5X,
     2' Minimum repair time (min) ?    [4]')
      READ (*,1250) XX(28)
1250  FORMAT (F8.3)
      IF (XX(28) .EQ. 0) XX(28)=4
      IF (XX(28) .EQ. -1) XX(28)=0
      WRITE (2,1250) XX(28)
C
C
      WRITE (*,1260)
      WRITE (2,1260)
```

```
1250  FORMAT (//5X,
     1' Maximum repair time (min) ?    [20]')
      READ (*,1270) XX(39)
1270  FORMAT (F8.3)
      IF (XX(39) .EQ. 0) XX(39)=20
      IF (XX(39) .EQ. -1) XX(39)=0
      WRITE (2,1270) XX(39)
C
C
C     ----------------------------------------------------
C
C       Now we will calculate parameters for the distribution of
C       number of fishes in a TRAY, based on the given distribution
C       of number of fishes in a '60 kg' box.
C
C       First the AVERAGE number of fillets of species 1 in a tray
C
        XX(44)=(XX(94)*2*20)/(XX(89)*60)
C
C       then the STD.DEV.
C
        XX(45)=(((XX(44)/XX(94))**2)*(XX(95))**2)**0.5
C
C
C       The AVERAGE number of fillets of species 2 in a tray
C
        XX(46)=(XX(96)*2*20)/(XX(90)*60)
C
C       and the STD.DEV.
C
        XX(47)=(((XX(46)/XX(96))**2)*(XX(97))**2)**0.5
C
C       Read the data that was read in into a DATA file
C
      WRITE (1,3000) XX(3)
3000  FORMAT (F8.3)
C
      DO  3500 I=15,22
         WRITE (1,3000) XX(I)
3500     CONTINUE
      WRITE (1,3000) XX(28)
      WRITE (1,3000) XX(39)
C
      DO 3600 J=44,47
         WRITE (1,3000) XX(J)
3600    CONTINUE
C
      DO 3700 K=51,99
         WRITE (1,3000) XX(K)
3700     CONTINUE
C
C
      RETURN
      END
```

APPENDIX 5

LIST OF PARAMETERS THAT MAY BE CHANGED BY THE USER USING THE FRONT END PROGRAM.

PARAMETER	DEFAULT VALUE
Number of workers :	
- Trimming species 1, fillet type 1	20
- Trimming species 1, fillet type 2	10
- Trimming species 2, fillet type 1	15
- Packing species 1, fillets, type 1	6
- Packing species 1, fillets, type 2	2
- Packing species 1, napes	1
- Packing species 1, block	1
- Packing species 2, fillets	3
- Packing species 2, napes	0
- Packing species 2, block	1
Standard times for trimming	[minutes/kilogram]
- For trimming species 1, type 1 :	
Coefficient Ca	1.249
Coefficient Cb	0.457
- For trimming species 1, type 2	
Coefficient Ca	1.479
Coefficient Cb	0.457
- For trimming species 2	
Coefficient Ca	1.324
Coefficient Cb	0.450
Standard speed for packing	[kilograms/minute]
For species 1, fillet type 1	1.15
For species 1, fillet type 2	0.96
For species 1, napes	2.07
For species 1, block	2.72
For species 2. fillets	1.15
For species 2, napes	2.72
For species 2, block	2.08
Proportion of each type of final product	
Fillets species 1, type 1	0.77
Napes species 1 (from type 1 fillets)	0.11
Fillets species 1, type 2	0.76
Napes species 1 (from type 2 fillets)	0.11
Fillets species 2	0.81
Napes species 2	0.00

Yield of Heading- Filleting- and Skinning machines

For species 1	0.45
For species 2	0.39

Number of machines for species 1 — 1

Yield of trimming stations

Species 1, type 1	0.918
Species 1, type 2	0.935
Species 2	0.850

Average number of fishes in a "60" kilogram box

Mean number of fishes in one box of species 1	30
Standard deviation	3.9
Mean number of fishes in one box of species 2	32
Standard deviation	4.2

Quantity of product that goes into one pan for the quickfreezer

	[Kilograms]
Fillets, species 1, type 1	34.02
Fillets, species 1, type 2	32.66
Napes, species 1	33.57
Block, species 1	29.93
Fillets, species 2	34.02
Napes, species 2	29.93
Block, species 2	29.93

Number of "60" kilogram boxes availabele in cooler

Species 1, boxes of raw material	250
Species 2, boxes of raw material	100

Average weight of boxes of raw material

Species 1	62.00
Species 2	64.00

<u>Parameters for distribution of time between machine breakdowns, Triangular distribution</u> [Minutes]

Machines for species 1,	
- Minimum time between breakdowns	15
- Most common time between breakdowns	60
- Maximum time between breakdowns	120
Machine for species 2,	
- Minimum time between breakdowns	10
- Most common time between breakdowns	20
- Maximum time between breakdowns	60

<u>Parameters for distribution of machine repair time, Uniform distribution</u>

Machines for species 1,	
- Minimum repair time	2
- Maximum repair time	15
Machines for species 2,	
- Minimum repair time	4
- Maximum repair time	20

APPENDIX 6

LISTING OF USER - COMPUTER DIALOG USING THE FRONT-END PROGRAM.

```
The model can handle 2 species at a time.  One species can
be cut into either one of 2 different types of fillets,
but the other one can be cut into only one type of fillet.
Both species can have two side products, which are the
napes and the block.  The napes and the block are the same
from fillets of the same species regardless of the cut.

          DEFAULT VALUES ARE GIVEN IN [  ]

IF YOU DON T WANT TO USE A RESOURCE, ENTER
-1. (a minus one point zero)
Remember the   DECIMAL POINT for all entries  !!!
To use default values, hit the SPACE BAR and
then HIT RETURN or ENTER



First we will read in the number of workers :

    # of Trimming workers, SPECIES 1, TYPE 1 ?  [25]
25.000

    # of Trimming workers, SPECIES 1, TYPE 2 ?  [10]
10.000

    # of Trimming workers, SPECIES 2 ?  [15]
15.000

    # of Packing workers SPECIES 1, FILLET TYPE 1 ?   [6]
 6.000

    # of Packing workers SPECIES 1, FILLET TYPE 2 ?   [2]
 2.000

    # of Packing workers SPECIES 1, NAPES (TYPE 1&2) ?  [1]
 1.000

    # of Packing workers SPECIES 1, BLOCK (TYPE 1&2) ?   [1]
 1.000

    # of Packing workers SPECIES 2, FILLETS ?   [3]
 3.000

    # of Packing workers SPECIES 2, NAPES ?   [0]
  .000
```

```
  # of Packing workers SPECIES 2, BLOCK ?   [1]
1.000
```

```
  Next we will read in parameters for
  calculating standard times for different tasks.  We do
  the following assumptions :
       Number of parasites = Conctant pr. kg.
       Number of filleting defects = Constant pr. kg.
       The standard times are calculated according to formulas
       given in "VERKLYSINGAR, LEIDBEININGAR OG STADLAR FYRIR
       AKVAEDISVINNU I FRYSTIHUSUM" (Working Methods, Guide
       and Standards for Wage Incentives in Freezing Plants)
       Reykjavik, Iceland, December 1980.
```

```
  To calculate standard time for trimming we actually need
  four parameters :

  c1 + c2 * [# fillets/kg] + c3 * [# parasites/kg] +
  c4 * [# defects/kg]

  But because of our assumptions we only need to read in

  Ca and Cb, Ca = c1 + c3 * (# parasites) +
  c4 * (# of filleting defects)   and   Cb = c2
```

```
  Let s start with parameters for trimming times

  For SPECIES 1, TYPE 1 :  Coefficient  Ca = ?  [1.249]
1.249
                           Coefficient  Cb = ?  [0.457]
 .457

  For SPECIES 1, TYPE 2 :  Coefficient Ca = ? [1.479]
1.479
                           Coefficient   Cb = ? [0.457]
 .457

  For SPECIES 2 :  Coefficient Ca = ? [1.224]
```

```
1.324
                     Coefficient   Cb = ? [0.450]
 .450



  Now standard times for PACKING !


  Packing, SPECIES 1 FILLET TYPE 1  (kg. pr. min.) ?  [1.15]
1.150


  Packing, SPECIES 1, FILLET TYPE 2  (kg. pr. min.) ?  [0.96]
 .960


  Packing, SPECIES 1, NAPES  (kg. pr. min.) ?  [2.07]
2.070


  Packing, SPECIES 1, BLOCK  (kg. pr. min) ?  [2.72]
2.720


  Packing, SPECIES 2, FILLETS (kg. pr. min) ? [1.15]
1.150


  Packing, SPECIES 2, NAPES (kg. pr. min) ? [2.72]
2.720


  Packing, SPECIES 2, BLOCK (kg. pr. min) ? [2.08]
2.080



  How much of the final product is :

           - Fillets
           - Napes
           - Block


  SPECIES 1, RATIO OF FILLETS TYPE 1 ?  [0.77]
 .770


  SPECIES 1. RATIO OF NAPES TYPE 1 ?  [0.11]
 .110


  SPECIES 1. RATIO OF FILLETS TYPE 2 ? [0.76]
 .760
```

```
  SPECIES 1, RATIO OF NAPES TYPE 2 ?  [0.11]
.110

  SPECIES 2, RATIO OF FILLETS ?  [0.81]
.810

  SPECIES 2, RATIO OF NAPES ?  [0.00]
.000


  What is the YIELD for the :
  Header, the Filleting machine and the Skinner,
  as a whole  ?

  Yield of machines for species 1,        YIELD ?    [0.45]
.450

  How many filleting machines are there
  for species 1, (either one or two) ?  [1]
1.000

  Yield of machines for species 2,        YIELD ?    [0.39]
.390


  What is the trimming-yield for different species
  and different types of cuts of fillets  ?

  Trimming yield for Species 1, Type 1 ?   [0.918]
.918

  Trimming yield for Species 1, Type 2 ?   [0.936]
.936

  Trimming yield for Species 2 ?   [0.850]
.850


  Now we need to know the MEAN value and the
  STDEV of the # of fishes in a box
```

```
    # of fishes in a box,  Species 1,    MEAN  ?  [30]
30.000

    # of fishes in a box, Species 1,    STDEV?  [3.9]
 3.900

    # of fishes in a box, Species 2,    MEAN ?  [32]
32.000

    # of fishes in a box, Species 2,    STDEV ?  [4.2]
 4.200



    What is the quantity of different products that
    goes into one "Frame" or "Pen"  (in kg s)  ?

    Quantity of fillets, species 1, type 1 in a pen ?    [34.02]
34.020

    Quantity of fillets, species 1, type 2 in a pan ?    [32.66]
32.660

    Quantity of nepes, species 1 in a pen ?    [29.93]
29.930

    Quantity of block, species 1 in a pen ?    [33.57]
33.570

    Quantity of fillets, species 2 in a pen ?    [34.02]
34.020

    Quantity of nepes, species 2 in a pen ?    [29.93]
29.930

    Quantity of block, species 2 in a pen ?     [29.93]
29.930



    What is the number of "60" kg boxes, of each
     species, going into the system  ?

    Number of boxes of species 1, is ?    [250]
1000.000
```

Number of boxes of species 2 is ?   [100]
500.000

What is the average weight of boxes of raw
material, of each species, going into the system ?

Average weight of boxes of species 1 is ?   [62.0]
62.000

Average weight of boxes of species 2 is ?   [64.0]
64.000

Finally, we will read in distribution parameters for
1) machine breakdowns, and   2) for machine repair time

First for the machines for species 1

Minimum time between breakdowns (minuets) ?   [15]
15.000

Most common time between breakdowns (minuets) ?   [60]
60.000

Maximum time between breakdowns (minuets) ?   [120]
120.000

What is the repair time for machine 1 ?

Minimum repair time (min) ?   [2]
2.000

Maximum repair time (min) ?   [15]
15.000

Now the parameters for the machine for species 2, for
1) machine breakdowns, and   2) for machine repair time

```
    Minimum time between breakdowns  (minuets) ?   [10]
10.000

    Most common time between breakdowns (minuets) ?   [20]
20.000

    Maximum time between breakdowns (minuets) ?   [60]
60.000


    What is the repair time for machine 2 ?

    Minimum repair time (min) ?    [4]
 4.000

    Maximum repair time (min) ?    [20]
20.000
```

APPENDIX 7

EXAMPLE OUTPUT

```
SLAM II VERSION 2.0
```


PRITSKER AND ASSOCIATES, INC.
P.O. BOX 2413
WEST LAFAYETTE, INDIANA 47906
(317)463-5557

```
1  GEN,ELIAS JONATANSSON,FREEZING PLANT,5/31/1985,3,NO,NO,,,;
                                        **INTERMEDIATE RESULTS**

                    S L A M   S U M M A R Y   R E P O R T

              SIMULATION PROJECT FREEZING PLANT          BY ELIAS JONATANSSON

              DATE  5/31/1985                            RUN NUMBER    1 OF    3

              CURRENT TIME     .3000E+03
              STATISTICAL ARRAYS CLEARED AT TIME    .0000E+00
```

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
SP1 BEFORE TRIM	.3919E+02	.1339E+02	.3417E+00	.1000E+01	.6000E+02	220
SP2 BEFORE TRIM	.3653E+02	.1765E+02	.4832E+00	.1000E+01	.6400E+02	128
FT11 WAITFORPACK	.9410E+01	.4216E+01	.4481E+00	.0000E+00	.1600E+02	117
FT12 WAITFORPACK	.9500E+01	.5561E+01	.5853E+00	.0000E+00	.1900E+02	46
FL11 WAITFORPACK	.5864E+00	.8680E+00	.1480E+01	.0000E+00	.4000E+01	162
BL11 WAITFORPACK	.1173E+00	.3415E+00	.2911E+01	.0000E+00	.2000E+01	162
FT21 WAITFORPACK	.7000E+00	.1035E+01	.1479E+01	.0000E+00	.3000E+01	50
FL21 WAITFORPACK	.2450E+02	.1458E+02	.5950E+00	.0000E+00	.1900E+02	50
BL21 WAITFORPACK	.1600E+00	.5841E+00	.3651E+01	.0000E+00	.3000E+01	50
WAIT BEF. QUICKF		NO VALUES RECORDED				
PROCESS TIME		NO VALUES RECORDED				

STATISTICS FOR TIME-PERSISTENT VARIABLES

	MEAN VALUE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	TIME INTERVAL	CURRENT VALUE
SPEC 1 IN COOLER	.8720E+03	.5109E+02	.0000E+00	.9920E+03	.3000E+03	.7920E+03
SPEC 2 IN COOLER	.4143E+03	.3144E+02	.0000E+00	.4920E+03	.3000E+03	.3720E+03
INV TRAY TYPE 1	.3007E+02	.1442E+02	.0000E+00	.6000E+02	.3000E+03	.3000E+02
INV TRAY TYPE 2	.3665E+02	.1930E+02	.0000E+00	.6400E+02	.3000E+03	.6100E+02
KG FILL1 AT PACK	.1084E+02	.1153E+02	.0000E+00	.3394E+02	.3000E+03	.2117E+01
KG FILL2 AT PACK	.1021E+02	.1108E+02	.0000E+00	.3168E+02	.3000E+03	.2900E+02
KG FLAP1 AT PACK	.1040E+02	.1011E+02	.0000E+00	.2592E+02	.3000E+03	.2764E+02
KG BLOC1 AT PACK	.1110E+02	.1006E+02	.0000E+00	.3392E+02	.3000E+03	.1876E+02
KG FILL3 AT PACK	.1006E+02	.1133E+02	.0000E+00	.3402E+02	.3000E+03	.1458E+02
KG FLAP2 AT PACK	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.3000E+03	.0000E+00
KG BLOC2 AT PACK	.5290E+01	.9789E+01	.0000E+00	.2972E+02	.3000E+03	.1105E+02
SPAN FILLET S1T1	.1273E+02	.1297E+02	.0000E+00	.3900E+02	.3000E+03	.3900E+02
SPAN FLAPS SPEC1	.3557E+01	.3494E+01	.0000E+00	.1000E+02	.3000E+03	.1000E+02
SPAN BLOCK SPEC1	.3406E+01	.3414E+01	.0000E+00	.1000E+02	.3000E+03	.1000E+02
SPAN FILLET S1T2	.3077E+01	.3410E+01	.0000E+00	.1000E+02	.3000E+03	.1000E+02
SPAN FILLET SPC2	.5827E+01	.6205E+01	.0000E+00	.1900E+02	.3000E+03	.1900E+02
SPAN FLAPS SPEC2	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.3000E+03	.0000E+00
SPAN BLOCK SPEC2	.1572E+01	.1657E+01	.0000E+00	.5000E+01	.3000E+03	.5000E+01
TIME FINISH TRIM	.1351E+03	.1030E+03	.0000E+00	.2593E+03	.3000E+03	.2593E+03
TIME FIN PACKING	.1301E+03	.1064E+03	.0000E+00	.2575E+03	.3000E+03	.2575E+03
KILOS FROZEN FIS	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.3000E+03	.0000E+00

FILE STATISTICS

FILE NUMBER	ASSOCIATED NODE TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1	AWAIT	.0000	.0000	1	0	.0000
2		.0000	.0000	0	0	.0000
3	AWAIT	.9983	.0408	1	1	11.0926
4	AWAIT	.9983	.0408	1	1	17.6176
5	AWAIT	2.1546	4.3309	17	1	15.3897
6		.0000	.0000	0	0	.0000
7		.0000	.0000	0	0	.0000
8		.0000	.0000	0	0	.0000
9	AWAIT	.0182	.1338	1	0	.1368
10	PREEMPT	.8563	.3508	1	1	256.8760
11	PREEMPT	.0000	.0000	1	0	.0000
12	PREEMPT	.0000	.0000	1	0	.0000
13	AWAIT	17.0954	17.3534	68	19	27.8729
14	AWAIT	11.5615	12.7655	42	16	27.0972
15	AWAIT	.0000	.0000	0	0	.0000
16		.0000	.0000	0	0	.0000
17		.0000	.0000	0	0	.0000
18		.0000	.0000	0	0	.0000
19	AWAIT	.0000	.0000	0	0	.0000
20		.0000	.0000	0	0	.0000
21	AWAIT	.0000	.0000	1	0	.0000
22	AWAIT	16.7658	7.5075	38	9	33.3088
23	AWAIT	19.7978	7.4962	38	18	80.2612
24	AWAIT	35.8006	19.3981	64	61	83.9077
25	AWAIT	1.0238	1.9341	13	7	.4762
26	AWAIT	7.0890	6.6145	28	19	45.7112
27	AWAIT	7.2028	5.7368	17	17	18.4688
28	AWAIT	.7074	1.1078	4	0	4.2447
29	AWAIT	.5124	.8969	5	0	.9489
30	AWAIT	17.7069	16.9716	58	58	106.7215
31	AWAIT	.1855	.4351	3	1	.3435
32	AWAIT	.0506	.3622	4	0	.3514
33	AWAIT	38.2442	31.0766	93	93	97.5628
34		.0000	.0000-	0	0	.0000
35	AWAIT	.0000	.0000	1	0	.0000
36	CALENDAR	59.3801	23.9862	92	75	1:1762

RESOURCE STATISTICS

RESOURCE NUMBER	RESOURCE LABEL	CURRENT CAPACITY	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTILIZATION	CURRENT UTILIZATION
1	COOLER1	5000	1206.3022	81.8897	1492	1164
2	FORK1	0	.9983	.0408	1	1
3	FORK2	0	.9983	.0408	1	1
4	BOXCM	1	.4060	.4911	1	1
5	ELEV	2	.6469	.8167	2	1
6	HEFTSK1	1	.7751	.4175	1	1
7	HEFTSK2	1	.6917	.4618	1	1
8	HEFTSK10	0	.0000	.0000	0	0
9	TRIM11	25	19.9767	9.9904	25	25
10	TRIM12	10	8.0000	4.0000	10	10
11	TRIM21	15	12.0000	6.0000	15	15
12	WEIGH2	1	.4248	.4943	1	1
13	FILLP11	6	4.1034	2.7738	6	6
14	FILLP12	2	1.2882	.9522	2	2
15	FILLP21	3	1.9298	1.3787	3	2
16	FLAP11	1	.5237	.4994	1	1
17	FLAP21	0	.0000	.0000	0	0
18	BLOCK11	1	.4307	.4952	1	1
19	BLOCK21	1	.2539	.4353	1	0
20	QUICKF	5	.7143	.9034	3	3

RESOURCE NUMBER	RESOURCE LABEL	CURRENT AVAILABLE	AVERAGE AVAILABLE	MINIMUM AVAILABLE	MAXIMUM AVAILABLE
1	COOLER1	3836	3713.6178	3508	5000
2	FORK1	-1	.0017	-1	1
3	FORK2	-1	.0017	-1	1
4	BOXCM	0	.5940	0	1
5	ELEV	1	1.3531	0	2
6	WEFTSK1	0	.2249	0	1
7	WEFTSK2	0	.3083	0	1
8	WEFTSK18	0	.0000	0	1
9	TRIM11	0	.0233	0	65
10	TRIM12	0	.0000	0	65
11	TRIM21	0	.0000	0	65
12	WEIGH2	0	.3752	0	1
13	FILLP11	0	.6966	0	30
14	FILLP12	0	.3110	0	30
15	FILLP21	1	.4710	0	30
16	FLAP11	0	.2763	0	30
17	FLAP21	0	.0000	0	30
18	BLOCK11	0	.3693	0	30
19	BLOCK21	1	.5461	0	30
20	QUICKT	2	3.2057	0	5

GATE STATISTICS

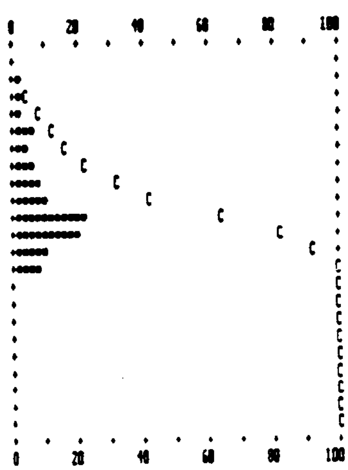
GATE NUMBER	GATE LABEL	CURRENT STATUS	PCT. OF TIME OPEN
1	GVACWAT	OPEN	1.0000
2	GWEIGH	OPEN	1.0000
3	GQUICK	CLOSED	.0000

1

HISTOGRAM NUMBER 1

SP1 BEFORE TRIM

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	.000	.000	.0000E+00
5	.022	.022	.5000E+01
5	.022	.044	.1000E+02
6	.026	.070	.1500E+02
12	.053	.123	.2000E+02
10	.044	.167	.2500E+02
14	.061	.228	.3000E+02
20	.088	.316	.3500E+02
22	.096	.412	.4000E+02
50	.219	.632	.4500E+02
45	.197	.829	.5000E+02
23	.101	.930	.5500E+02
16	.070	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
228			



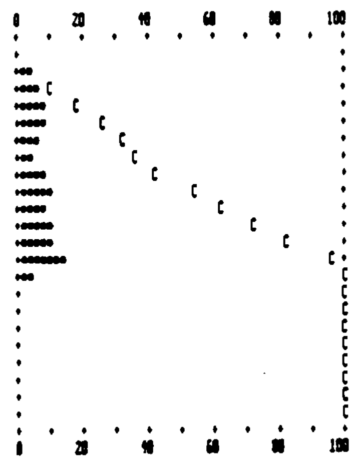
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
SP1 BEFORE TRIM	.3919E+02	.1339E+02	.3417E+00	.1000E+01	.6000E+02	228

HISTOGRAM NUMBER 2

SP2 BEFORE TRIM

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
0	.000	.000	.0000E+00
5	.039	.039	.5000E+01
7	.055	.094	.1000E+02
10	.078	.172	.1500E+02
10	.078	.250	.2000E+02
8	.063	.313	.2500E+02
5	.039	.352	.3000E+02
9	.070	.422	.3500E+02
14	.109	.531	.4000E+02
11	.086	.617	.4500E+02
13	.102	.719	.5000E+02
14	.109	.828	.5500E+02
17	.133	.961	.6000E+02
5	.039	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
128			



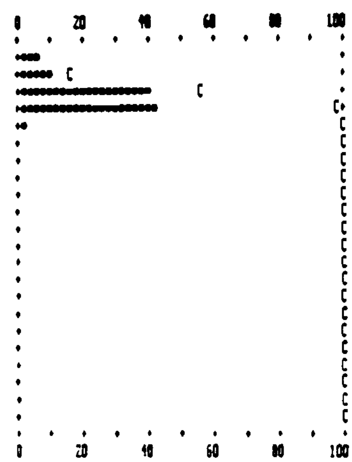
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
P2 BEFORE TRIM	.3663E+02	.1765E+02	.4822E+00	.1000E+01	.6400E+02	128

HISTOGRAM NUMBER 3

IT11 WAITFORPACK

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
7	.060	.060	.0000E+00
11	.094	.154	.5000E+01
47	.402	.556	.1000E+02
49	.419	.974	.1500E+02
3	.026	1.000	.2000E+02
0	.000	1.000	.2500E+02
0	.000	1.000	.3000E+02
0	.000	1.000	.3500E+02
0	.000	1.000	.4000E+02
0	.000	1.000	.4500E+02
0	.000	1.000	.5000E+02
0	.000	1.000	.5500E+02
0	.000	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
117			



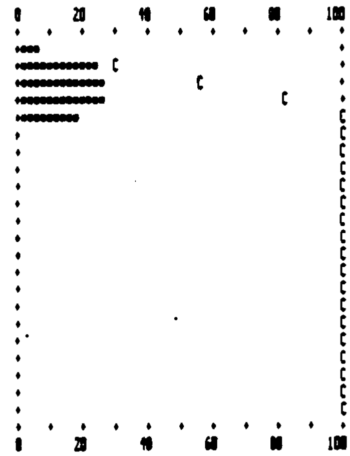
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
I11 WAITFORPACK	.9410E+01	.4216E+01	.4481E+00	.0000E+00	.1600E+02	117

HISTOGRAM NUMBER 4

FI12 WAITFORPACK

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
3	.065	.065	.0000E+00
11	.239	.304	.5000E+01
12	.261	.565	.1000E+02
12	.261	.826	.1500E+02
8	.174	1.000	.2000E+02
0	.000	1.000	.2500E+02
0	.000	1.000	.3000E+02
0	.000	1.000	.3500E+02
0	.000	1.000	.4000E+02
0	.000	1.000	.4500E+02
0	.000	1.000	.5000E+02
0	.000	1.000	.5500E+02
0	.000	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
46			



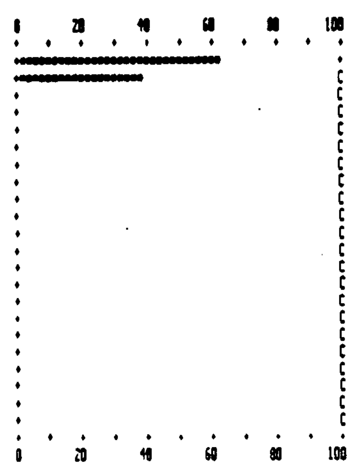
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
12 WAITFORPACK	.9500E+01	.5561E+01	.5853E+00	.0000E+00	.1900E+02	46

HISTOGRAM NUMBER 5

FL11 WAITFORPACK

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
102	.630	.630	.0000E+00
60	.370	1.000	.5000E+01
0	.000	1.000	.1000E+02
0	.000	1.000	.1500E+02
0	.000	1.000	.2000E+02
0	.000	1.000	.2500E+02
0	.000	1.000	.3000E+02
0	.000	1.000	.3500E+02
0	.000	1.000	.4000E+02
0	.000	1.000	.4500E+02
0	.000	1.000	.5000E+02
0	.000	1.000	.5500E+02
0	.000	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
162			



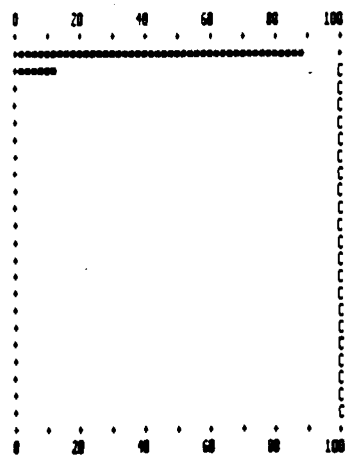
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
11 WAITFORPACK	.5864E+00	.8680E+00	.1480E+01	.0000E+00	.4000E+01	162

HISTOGRAM NUMBER 6

BL11 WAITFORPACK

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
144	.889	.889	.0000E+00
18	.111	1.000	.5000E+01
0	.000	1.000	.1000E+02
0	.000	1.000	.1500E+02
0	.000	1.000	.2000E+02
0	.000	1.000	.2500E+02
0	.000	1.000	.3000E+02
0	.000	1.000	.3500E+02
0	.000	1.000	.4000E+02
0	.000	1.000	.4500E+02
0	.000	1.000	.5000E+02
0	.000	1.000	.5500E+02
0	.000	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
162			



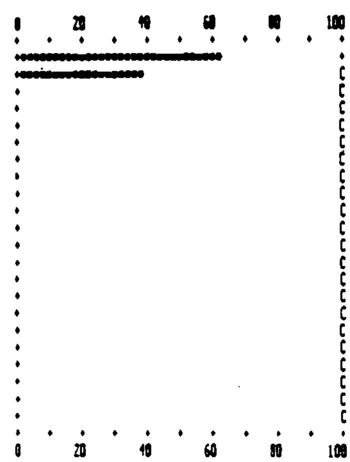
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
11 WAITFORPACK	.1173E+00	.3415E+00	.2911E+01	.0000E+00	.2000E+01	162

HISTOGRAM NUMBER 7

FI21 WAITFORPACK

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
31	.620	.620	.0000E+00
19	.380	1.000	.5000E+01
0	.000	1.000	.1000E+02
0	.000	1.000	.1500E+02
0	.000	1.000	.2000E+02
0	.000	1.000	.2500E+02
0	.000	1.000	.3000E+02
0	.000	1.000	.3500E+02
0	.000	1.000	.4000E+02
0	.000	1.000	.4500E+02
0	.000	1.000	.5000E+02
0	.000	1.000	.5500E+02
0	.000	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
50			



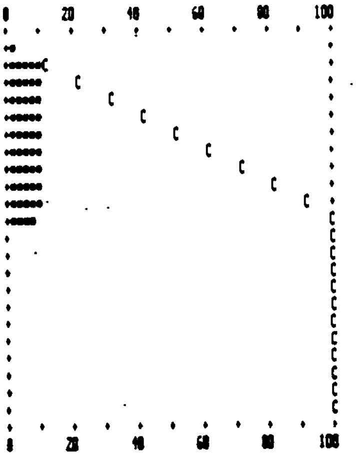
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
21 WAITFORPACK	.7000E+00	.1035E+01	.1479E+01	.0000E+00	.3000E+01	50

HISTOGRAM NUMBER 8

FL21 WAITFORPACK

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
1	.020	.020	.0000E+00
5	.100	.120	.5000E+01
5	.100	.220	.1000E+02
5	.100	.320	.1500E+02
5	.100	.420	.2000E+02
5	.100	.520	.2500E+02
5	.100	.620	.3000E+02
5	.100	.720	.3500E+02
5	.100	.820	.4000E+02
5	.100	.920	.4500E+02
4	.080	1.000	.5000E+02
0	.000	1.000	.5500E+02
0	.000	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
50			



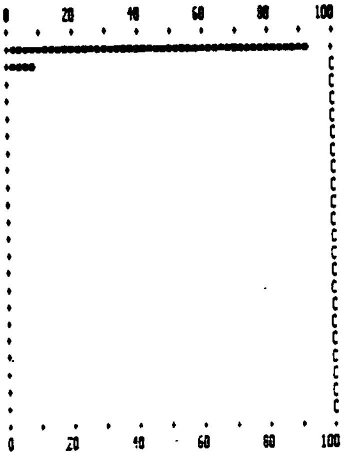
STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD-DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WAITFORPACK	.2450E+02	.1450E+02	.5950E+00	.0000E+00	.4900E+02	50

HISTOGRAM NUMBER 9

BL21 WAITFORPACK

OBSV FREQ	RELA FREQ	CUML FREQ	UPPER CELL LIMIT
46	.920	.920	.0000E+00
4	.080	1.000	.5000E+01
0	.000	1.000	.1000E+02
0	.000	1.000	.1500E+02
0	.000	1.000	.2000E+02
0	.000	1.000	.2500E+02
0	.000	1.000	.3000E+02
0	.000	1.000	.3500E+02
0	.000	1.000	.4000E+02
0	.000	1.000	.4500E+02
0	.000	1.000	.5000E+02
0	.000	1.000	.5500E+02
0	.000	1.000	.6000E+02
0	.000	1.000	.6500E+02
0	.000	1.000	.7000E+02
0	.000	1.000	.7500E+02
0	.000	1.000	.8000E+02
0	.000	1.000	.8500E+02
0	.000	1.000	.9000E+02
0	.000	1.000	.9500E+02
0	.000	1.000	.1000E+03
0	.000	1.000	INF
50			



STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WAITFORPACK	.1600E+00	.5841E+00	.3651E+01	.0000E+00	.3000E+01	50

HISTOGRAM NUMBER 10

WAIT DEF. QUICKT

```
OBSV   RELA   CUML     UPPER
FREQ   FREQ   FREQ   CELL LIMIT    0    20    40    60    80   100
                                   +  +  +  +  +  +  +  +  +  +  +
```

NO VALUES RECORDED.

STATISTICS FOR VARIABLES BASED ON OBSERVATION

```
               MEAN      STANDARD    COEFF. OF   MINIMUM    MAXIMUM    NUMBER OF
               VALUE     DEVIATION   VARIATION   VALUE      VALUE      OBSERVATIONS

WAIT DEF. QUICKT               NO VALUES RECORDED
1
```

HISTOGRAM NUMBER 11

PROCESS TIME

```
OBSV   RELA   CUML     UPPER
FREQ   FREQ   FREQ   CELL LIMIT    0    20    40    60    80   100
                                   +  +  +  +  +  +  +  +  +  +  +
```

NO VALUES RECORDED.

STATISTICS FOR VARIABLES BASED ON OBSERVATION

```
               MEAN      STANDARD    COEFF. OF   MINIMUM    MAXIMUM    NUMBER OF
               VALUE     DEVIATION   VARIATION   VALUE      VALUE      OBSERVATIONS

PROCESS TIME                   NO VALUES RECORDED
1
```

INTERMEDIATE RESULTS