IMPLEMENTATION OF JOB-SHOP SCHEDULING RULES IN TEXTILE INDUSTRY

by

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IMPLEMENTATION OF JOB-SHOP SCHEDULING RULES IN TEXTILE INDUSTRY

ABSTRACT

The work on machine scheduling problem of a large textile mill is reported in this thesis. Scheduling programs are prepared daily and present orders are taken into consideration. We can look at this problem as a static job-shop problem.

Main objectives of this research are to study the minimization of the average tardiness of orders, the variance of tardiness and the work-in-process inventory of the factory. For this purpose, Shortest-Processing-Time Rule with Truncation Process has been choosen as the best rule in meeting the main objectives, in the light of previous researches.

Series of interactive programs have been written in order to update the necessary changes in the status of orders and machines, easily. After a short education, users will be able to use this program, efficiently.

TEZGAH YÜKLEME KURALLARININ TEKSTİL ENDÜSTRİSİNE UYARLANMASI

ÖZET

Bu tezde büyük bir tekstil fabrikasinin tezgah yükleme problemi üzerinde çalişilmıştır. Yükleme programları günlük olarak ve o andaki siparişler düşünülerek yapilmaktadır. Bu özelliği ile probleme statik tezgah yükleme problemi olarak bakabiliriz.

Yapilan çalişma, işletme içindeki yarı-mamul stok miktarını, siparişlerdeki ortalama gecikmeyi ve gecikmenin variansini enküçüklemeyi hedef almiştir. Bu amaçla daha once yapilan araştirmalar da gözönünde tutularak, En Kısa İşlem Zamanı ve İşlem Başına Serbest Zaman kurallarinin kombinasyonu (SPT/T), hedefleri en iyi sağlayan kural olarak seçilmiştir.

Siparişlerin ve makinelerin durumlarindaki değişikliklerin en kolay biçimde bilgisayara girilebilmesi için etkileşimli programlar dizisi yazılmıştır. Planlama personeli kisa bir eğitim sonucu programı kullanabilmektedir.

TABLE OF CONTENTS

Page

LIST OF FIGURES

I. INTRODUCTION

Scheduling problems occur, whenever there is a choice as to the order in which a number of tasks can be performed. The accepted definition of scheduling problem is given by Conway, Maxwell and Miller (1), as the simultaneous and synchronized sequencing of jobs on several machines. Scheduling problems can be divided into two main groups:

i. Flow-shop scheduling

ii. Job-shop scheduling.

In the flow-shop case, there is a natural ordering of machines in a shop. There are two or more machines, and at least some of the jobs have a sequence of such cases the collection of machines is said to constitute a flow-shop if the machines are numbered in such a way that, for every job to be considered, operation K is performed on a higher-numbered machine than operation J, if J>K. Workflow in a flow-shop is unidirectional. The classical job-shop scheduling problem differs from the flow-shop problem in one important respect, the flow of work is not unidirectional. The elements of a problem are a set of machines and a collection of jobs to be scheduled. There is no initial machine that performs the first operation, nor a terminal machine that performs the last operation of a job, contrary to flow-shop problem.

In the following chapters, we will only deal with job-shop scheduling problem.

The jobs entering a work-shop must leave the shop as soon as possible and they are subject to due-date constraints. Dispatching procedures can be easily adopted to real life problems by considering, the aims of the firm. One main objective is to decrease the average tardiness and average flow-time of jobs.

The following chapters contain, the theory and litterature survey of dispatching procedures and possible solution techniques of job-shop scheduling problems, a consideration of a real life problem and the result of the applied algorithm to that problem.

II. JOB-SHOP SCHEDULING PROBLEM

The basic unit of the job-shop process is the operation. It has three primary attributes that are given below.

i. A symbol identifying the operation of a particular job.

ii. A symbol identifying the operation with a particular machine.

iii. A real number representing the processing time of the operation.

Each job consists of several operations with a specific precedence structure. A job may require processing by the same machine more than once in its operation sequencing. Because the workflow in a job-shop is not unidirectional, each machine in the shop can be characterized by the input and output flows of work shown in Figure 2.1.

Scheduling a job-shop process is the task of assigning each operation to a specific position on the time scale of the specified machine.

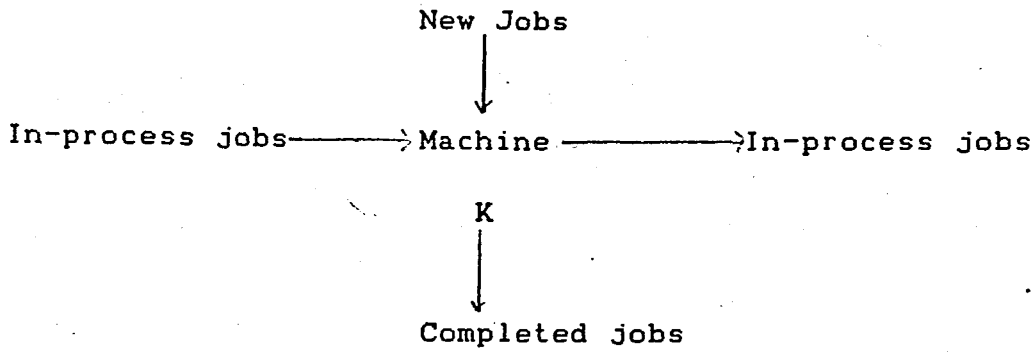

Figure 2.1 Job-Shop Process

2.1. Definition Of Shop

The job-shop process definition starts with the shop. It is described by giving the number of machines.The general function of shop could be best defined by the phrase of "m-machine shop". Existence of parallel machines and the possibility of performing an operation on the alternative one, construct the characteristics of shop.

2.2. Definition Of Job

Each job consists of g_i type of operations, and each operation is performed on a specific machine in a specific processing time. Let i show the job number and j be the operation number, then m_{ij} shows the machine number and p_{ij} shows the processing time of the j^{th} operation of the

i^{th} job. The number of data for a specific job must be $2*g_i$.

Some of the operations can be performed on an alternate machine with a different processing time according to the characteristics of the job-shop.

2.3. The Formal Definition Of The Job-Shop Scheduling Problem

A scheduling problem has several concepts that determine the characteristics of the system. The most important variables of a job are as follows:

d_i is the due-date of the i^{th} job,

r_i is the arrival date of the i^{th} job,

$a_i = d_i - r_i$, is the total allowance for the i^{th} job,

W_{ij} is the waiting time of the j^{th} operation of the i^{th} job,

S_{ij} is the set-up time for the j^{th} operation of the i^{th} job,

C_i is the completion time of the i^{th} job.

$$C_i = r_i + {}_j\, p_{ij} + \sum_j W_{ij} + \sum_j S_{ij}$$

Solution will determine an answer to our question which is "when and on what machine each operation of each job should be performed".

The result of the scheduling process introduces many other variables for compactness of notation. Some of them are as follows.

$F_i = C_i - r_i$, is the flow time of job i,

$L_i = C_i - d_i$, is the lateness of job i,

$T_i = \max(0, L_i)$, is the tardiness of job i.

In most of the cases, we use the above as measures of performance.

2.4. Dispatching or Scheduling Rules

The rule that specifies when and which job must be assigned to a specific machine is called a dispatching or a scheduling rule. The rule that will be used in scheduling, is selected according to the desired criteria of measure of performance. There are different kinds of scheduling rules that are used for different purposes. Only two of them will be explained here, because the experiments show that, in most of the cases they have the same properties. The selected two rules are most suitable rules for the desired criteria of performance in this case.

2.4.1 S/OPN Type Scheduling Rule

This is the least-slack-time-per-operation remaining rule. This rule gives the highest priority to the waiting operation corresponding to the job with the minimum ratio of slack time to remaining operations. The slack time of a job is the difference between the due-date and the total processing time of that job, at time t.

Example : Suppose that there are two jobs, X and Y, that are waiting for a specific machine. They have two and three operations respectively. The operation times are as follows.

$P_{x1} = 10$ $\qquad\qquad$ $P_{y1} = 10$

$P_{x2} = 20$ $\qquad\qquad$ $P_{y2} = 15$

$\qquad\qquad\qquad\qquad$ $P_{y3} = 11$

If total processing times of X and Y are 30 and 36 and the due-dates are 40 and 48, respectively. Therefore the slack times per remaining operations are as follows.

$$\text{S/OPN of X} = \frac{40 - 30}{2} = 5 \text{ unit,}$$

$$S/OPN \text{ of } Y = \frac{48 - 36}{3} = 4 \text{ unit.}$$

At that time, job Y has the minimum slack-time to operation remaining operation ratio and it should be processed first.

This rule shows a high performance with respect to meeting the due-dates, but, on the other hand, in minimizing the flow times of jobs, it does not give a better result like SPT and SPT/T rules.

2.4.2. Shortest Processing Time Rule With Truncation Process (SPT/T)

This rule is a combination of the shortest processing time and slack time per operation remaining rules. As it is mentioned above, S/OPN rule prevents tardiness of jobs, but, average flow time gets longer when it is compared to SPT. SPT is one of the best for minimization of:

i. Number of jobs in the shop,

ii. Average tardiness of jobs,

iii. Mean completion time of jobs,

iv. Mean waiting time of jobs in the shop,

v. Number of tardy job.

The main disadvantage of this rule is that, it generally produces a great tardiness in a job with a very long processing time, since it always gives high priority to the job with the shorter processing time. This is due to the fact that this rule never takes the due dates of jobs into consideration.

Combination of these two rule gives a better result by decreasing the deviations from the mean. SPT/T rule is defined as follows,

$$\mathrm{Min}_i^{(k)} \ \min \{ E_i + r, Q_i \} \text{ for } i \in I$$

E_i : the processing time of the next immidiate operation of job i.

Q_i : the slack-time per operation remaining for job i.

r : a parameter, from minus infinity to infinity.

I : the set of jobs waiting at a machine center.

According to SPT/T rule, for jobs waiting at a machine center, k^{th} priority is given to the job with the k^{th} minimum of min { E + r, Q }, where k=1,2,..,n and n is the number of jobs in I.

That priority rule produce the best results for job-shop scheduling with respect to:

i. percentage of tardy jobs,

ii. average tardiness,

iii. variance of tardiness,

iv. maximum tardiness.

It possibly improves

i. to decrease the level of work-in-process inventory

ii. to better utilize the machining and equipment,

iii. to avoid slow moving items,

iv. to better plan the production capacity,

2.5. Scheduling Techniques

This section is concerned with approximate solutions to the job-shop problem. Several algorithms have been developed by considering the characteristics of job-shop. Generally, they are effective for the small number of machines and jobs. If the size of the system increases, the effectiveness of the solution will decrease. For large size problems, the whole solution will take a long computer time but we need ,generally, daily solutions. If we use those analytic techniques,we have to obtain the whole solution of the system. For those solutions, too much computer time is needed, and a very small change in the status of the machines or orders, causes the solution to go away from the optimal. We need daily solutions and, if we take the whole solution for each change in the system, it will not be effective. It is not practical for our case. We need a flexible and practical solution method, in order to make it possible for application. Commonly used scheduling techniques are stated below.

2.5.1. Integer Programming Formulation

The general job-shop problem can be modeled as an integer programming problem. There are a few type of formulation. The description here will follow Manne's model

(2). For simplicity of notation we assume that each job requires processing by each machine once and only once.

p_{ik} = the processing time of job i on machine k,

r_{ijk} = 1 if the j^{th} operation of job i requires machine k,

= 0 otherwise,

T_{ik} = the starting time of job i on machine k.

From the requirement that only one job may be in process on a machine at any instant of time, we have for two jobs, I and J, either

$$T_{ik} - T_{jk} \geq p_{jk} \quad \text{or} \quad T_{jk} - T_{ik} \geq p_{jk}$$

Simply stated, either job J precedes job I or else job I precedes job J.

Let Y_{ijk} = 1 if job I precedes job J on machine K; Y_{ijk} =0 otherwise.

$$(M + p_{jk})Y_{ijk} + (T_{ik} - T_{jk}) \geq p_{jk}$$

$$(M + p_{ik})(1 - Y_{ijk}) + (T_{jk} - T_{ik}) \geq p_{ik}$$

The M is constant and is chosen sufficiently large so that only one of the above constraints are handled by noting that $\sum_K r_{i,j+1,k} T_{ik}$ is the starting time of the j^{th}.

operation of job i. For all but the last operation of a job, one must have,

$$\sum_k r_{ijk}(T_{ik} + p_{ik}) \leq \sum_k r_{i,j+1,k} T_{ik}$$

The complete formulation in order to minimize the meanflow time is:

$$\text{Min} \sum_i \sum_k r_{imk} T_{ik}$$

$$\sum_k r_{ijk}(T_{ik} + p_{ik}) \leq \sum_k r_{i,j+1,k} T_{ik}$$

$$(M + p_{jk})Y_{ijk} + (T_{ik} - T_{jk}) \geq p_{jk}$$

$$(M + p_{ik})(1 - Y_{ijk}) + (T_{jk} - T_{ik}) \geq p_{ik}$$

with variables $T_{ik} > 0$, $Y_{ijk} = 0$ or 1

Apparently the size of the resultant integer programming problem, the time consuming and often erratic behaviour of existing integer programming computer codes, and the limited availability of such codes have discouraged other investigators from employing this approach. As an example, if there are four machines and ten jobs, there will be 220 variables and 390 constraints, in the formulation

2.5.2. Branch And Bound Approach

Branch and Bound technique is a solution method for the job-shop scheduling problem. An approach has been given by Brooks and White (3).

In this approach, each node represents an active schedule for a particular subset of the operations, and a point in time at which there is more than one operation which could be scheduled next on the particular machine chosen. Selection of a particular branch is based on determining the minimum value of a lower bound on the maximum flow time for each possible branch. The power of the procedure depends heavily on the quality of the lower bounds.

1. Construct any complete schedule starting from the partial schedule in-hand using one of the simple dispatching procedures discussed in the previous sections. Take as a bound the maximum flow time for this complete schedule.

2. For each job, find the earliest time at which it could possibly start on its next unscheduled operation. Add to this sum of the processing-times of all the unscheduled operations of the job. Take as a lower bound, the maximum of these quantities. This bound is good if there are several jobs whose remaining processing time requirements are large

relative to the others.

3. For each machine find the minimum time at which an unscheduled operations which require this machine. Take as a lower bound the maximum of these quantities. This bound is reasonably good if there are a few machines whose workload is considerably higher than others.

Brooks and White (3) conclude that the procedure is computationally prohibitive for problems of practical dimension, but it could be nevertheless be an attractive alternative to integer programming for solution of small problems.

III. STATEMENT OF THE PROBLEM

3.1. Description Of The System

The factory is a textile factory that produces different kinds of fabric. The factory is composed of two parts. In the first part, there are textile machinery producing cloth from cotton. In the second part, the cloth goes through several chemical processes. The number of chemical processes varies from five to 15, following a specific order according to its type.

We will deal with the second part of the factory. The fabric comes to the second part from the first part and enters the queue of the appropriate machine.

There are almost 40 machines and 40 different types of fabric available in the system. Average number of existing orders in the system changes between 40 and 50, and if it is taken into consideration that each has to go through approximetaly 10 different processes complexity in scheduling of machines appears to be a major problem.

Another complexity is the dynamics of the system. Since the efficiency of each machine depends on the previous one, a breakdown or a problem in one of them will effect the others as well.

Generally there is no set-up time in loading operations. They attach the new fabric, to the end of the fabric whose process has just finished. That operation lasts a few minutes. Some of them need set-up time that does not take, too long. In general, the set-up times are a small percentage of the processing times.

Transfer of fabric between machines takes a few minutes. In other words, instantaneous transfer can be assumed for the items.

Some of the operations of jobs can be performed in an alternate machine if the original machine is down. The alternate machine, generally does not perform as well as the original machine. They are used for important jobs, such as exported fabric. Finishing the exported fabric by their due-dates is very important, for otherwise, indemnities are paid to the customer.

3.2. Criteria For Scheduling Of A Job-order

Job orders are scheduled according to the following rules.

i. Once an operation is started on a machine it must be finished.

ii. If the machine is not down, the job order that is waiting for that machine cannot be performed on the alternate machine, unless the job order is critical.

Schedule is prepared each morning and it is not changed unless a specific condition occurs (e.g. machine fails, defects in fabric etc.).

3.2.1. Case Of Machines Under Repair

The schedule is prepared assuming the available machines will work properly. When a machine breaks down, important job orders are performed on the alternate one, if it exists. Although more than one machine can be used for the same purpose, their performance may differ. Each can complete the same job at different time periods. That's why job orders are performed on the alternative machine if it is a very important order for the factory (i.e. exports). In preparing a new schedule, the repair time of the machine that is down must be taken into consideration.

3.2.2. Case Of Changing A Job-order

During the process of an order one of the machines may break-down. In that case, the specific process of the order is partly completed. If the order is important for the factory, the next operation of the completed part can be performed in alternative machines. In other words, the job order is divided into two parts. They move differently in the factory.

Any unordered job may be still in the production process but whenever a non-expected order comes up on that job its production will be accelerated. The opposite of that case is also possible. Whenever an order is cancelled its production will also slow-down. Those kind of events also changes schedule of the machines.

3.3. Desired Criterion of Performance

The jobs entering the work-shop under consideration are subject to due-date constraints. Currently, due to lack of scheduling policy, most of the jobs are completed after their due dates. This causes friction between the factory and work-shop leading to managerial problems. In order to alleviate these problems, the managment wants to establish a scheduling policy that will minimize the tardiness of jobs.

The tardiness is important in export. If there is a tardiness, they have to pay indemnities to the customers. This causes important problems between their planning and managment departments of the factory. The performance of the factory is measured with the amount of finish product during the day. That means, a job-order that comes into factory, must leave as soon as possible. They want to avoid slow-moving items. It is important to minimize the work-in-process inventory since it affects the amount of finished product during the day.

IV. APPLIED SOLUTION TO THE PROBLEM

The main menu is composed of two parts. Database editing and the main program. The first part is prepared for the editing of the changes in the system. The data file structures are as follows.

4.1. Data-Base Construction

There are mainly 4 files that contain the information about the state of the factory.

i. Machine master file: It contains the name of all machines that are available in the factory and their status. A machine may be either free or down for an unknown time period or down for a specific length of time. Fields are as follows:

Machine code

Time at which the machine becomes free

ii. Job master file: It contains master information about the jobs. The fields are as follows.

Job code

Job name

Specification

For each operation of that job:

Operation number

Operation name

Machine code of the operation on which the operation will be performed

Standart processing time of the operation

iii. Job-order master file: The information about the job-orders that enters the factory is written on that file. The fields are as follows:

Production order number(that is given by the planning department),

Job code

Order number(that is given by the marketting department

Pattern number

Due-date of the order

Starting time of the job-order

Ordered quantity

Number of completed operations

Total number of operations

For each operation

Operation number that is selected for that job-order

Each job-order record contains the job code field. Generally job-orders are usually passed through all the processes that belong to that job, but some customers may want an extra process or to cancel some of them. In that case, the job master file may not contain the true information for that job-order. In order to avoid such problems, all possible processes have been written on the job master file, and then, the job-order file will contain only the process numbers that are selected by the customer. This gives a flexibility in job-orders.

iv. Machine file: That file contains the information about the job-orders that are waiting for the machines. The fields are as follows.

Machine code

Production order no

Process number of the job-order

Alternative machine code

Standard processing time for the alternate machine.

4.2. Editing The Information

The scheduling program will be used by the planning department of the factory. According to the changes in position of job-orders, machines, job-types the information will be edited by them. The usage of the edit part of the program is very easy. The detailed information is given below.

4.2.1. Editing The Jobs

The menu of it, contains five choices, as seen in Figure 4.1. The first choice is about entering new job to the system. It is used only when a new type of job comes into the production process for the first time.If you use a job code that exist in the system, it will give the message "Duplicate job code", to you or if you enter a wrong machine code, it will not accept the data that you have entered. The screen that you will see is in Figure 4.2. The second choice is the update choice. Using that option, you can update the information about any job type. You can update the information by moving up or down, on the same screen, you can go to the next page or return to the previous page etc. If you press the ENTER key, the information on the screen will be permenant. The screen is on Figure 4.3.

JOB INFORMATION CF1..MENU

G:NEW JOB D:UPDATE I:DELETE L:LIST K:ALL JOBS

. Menu of Job-Type Option.

N E W J O B

100.1

CF2..CANCEL REQUEST
ENTER..NEXT PAGE
CF6..NEW JOB ADDED

ATION

P R O C E S S

NO	NAME	MACHINE-NO	ST.PROC.TIME
01			000
02			000
03			000
04			000
05			000
06			000
07			000
08			000
09			000
10			000

. New Information Screen.

JOB UPDATE

CF2..CANCEL REQUEST
ENTER..NEXT PAGE
CF6..UPDATE JOB

ODE 165.4

AME COTTON CLOTH
FICATION WHITE

PROCESS

NO	NAME	MACHINE-NO	ST.PROC.TI
01	CHEM.HARD.	STORK	165
02	EMULATION	G30-SIL	150
03	HAIRING	F.MULLER	36
04	ROLLING	S.BRUSH	70
05	EGALIZING	RAMOZ-2	100
06	ENRICHMENT	SETTI	12
07			
08			
09			
10			

4.3. Update Screen of Jobs.

LIST OF JOBS

ENTER..NEXT PAGE
CF2..CANCEL REQUEST

JOB-CODE	CLOTH-NAME	SPECIFICATION
125.3	COLLAR 2/50	WHITE
161.2	SHEET 140	REAC.PRINT
165.4	COTTON CLOTH	WHITE
181.2	FLANEL 158	PIGMENT
1125.2	ORD.COT. 140	PIGMENT
1138.0	ORD.COT. 172	REAC.PRINT

4.4. List of Jobs.

The third choice is to delete the job information from the system. If they decide not to produce a job type, anymore, then that job-type is deleted and any job-orders cannot be taken of that job type. The screen is almost the same as the update or new information screen.

The fourth choice is used to get existing information about job codes only. Any addition of new, update or delete is not accepted in this screen.

The fifth choice helps the user, in finding the job code that he or she looks for. It gives a list of jobs that exist in the system with some extra information. The screen is in Figure 4.4.

4.2.2. Editing Job-orders

The menu contains four choices. In editing job-orders, there are there are mainly two screens. The first one is master information screen, the other is operation information screen. As a first hand master information comes to screen according to the job code that is used in the first field, related fields such as operation names, name of the machines, comes into screen.

In the first and second choice (new information or update information), there is a field at the beginning of each operation information. If you enter 1 for that field, it shows that, the operation will be performed for this job-order.

The screens for new information and update information are in Figures 4.5 and 4.6. If you enter a job code that does not exist in the system, it will not be accepted.

The third one is the delete option. It is used in order to discard a job-order from the system.

Job-order editing option is used when a new job-order comes or in case of missused information. Any update in one of these three editing options will cause to edit the information in machine file. The related fields in machine file will be automaticly updated as a result of any change in one of these three editing options.

The fourth choice gives the list of job-orders that exist in the system. The screen is in Figure 4.7.

4.2.3. Editing Machine Master

The existing machines are written to the machine master file. By choosing the last option you can see the list

LE UPDATE

ENTER..UPDATE ORDER
CF2..CANCEL REQUEST

DER NO	158.0		
DE	1125.2		
NO	160		
ATION	AVUSTURYA		
N NO	4320		
ICATION	WHITE		
	DD/MM/YY		DD/MM/YY
TE	08/09/86	STARTING-TIME	05/07/86
QUANTITY	12000		
OF COMP.OPR.			
MBER OF OPR.	10		

.5. Update of Orders (Master Information).

DER NO	:	158.0	ORDER NO	:	160
	:	1125.2			
	:	ORD.COT 140			CF2..CANCEL REQUE
ATION	:	PIGMENT			ENTER..END-OF-UPD

PUT 1 IN FRONT OF THE SELECTED OPERATIONS

OCESS-NO	PROCESS-NAME	MACHINE-NAME	STD.PROCESS-TIME
01	BURNING	PAREX	100
02	CHEM.HARDEN.	STORK	85
03	DRYING	CYLINDER 30	100
04	BRUSHING	B.BRUSH	90
05	EGALIZING	E.RAMOZ	100
06	PAINTING	RAMOZ-2	100
07	PRINTING	FD/ROT	90
08	CONDENSING	ARTHOS HF2	50
09	APRE	RAMOZ-2	60
10	CHEM.PAINT TREAT.	BRIEM	48

.6. Update of Orders (Operational Information).

L I S T   O F   O R D E R S

ENTER..NEXT PAGE
CF2.. MENU

UCTION ER NO	EXPLANATION	JOB-CODE	SPECS.	DUE-DATE	ORDER QUANTITY
6.0	AD.K	1138.0		27 8 86	7500
1.0	HECK	181.2		20 8 86	27400
0.0	AD.K	161.2		22 8 86	29000
2.0	ADIK	161.2		23 8 86	14800
6.0	DIERIG	181.2		23 8 86	6000
8.0	AUSTRIA	1125.2		8 9 86	12000
5.0	AD.KAP	1125.2		27 8 86	5300
6.0	HECKIN	1125.2		27 8 86	15000
0.0	IBENA	181.2		29 8 86	10000

4.7. List of Orders.

of machines in the factory. There is a second field that is the time of machine becomes free. If it is zero that means, the machine is free. If it has the highest value (99999999); that shows the machine is under repair. If it has a value between them, that value is the repair time in minute, after the simulation is started. As an example; its value is 600, the machine will be ready ten hours later. At that time, the program can make a schedule for that machine.

Four options are available for machine editing, too. Entering a new machine, update, delete the machine and list of machines.

In the case of break-down of a machine, the update option will be selected and the field will be changed (for unknown time: 99999999, known time: repair time in minute as shown in Figure 4.8. The screen for the fourth choice is in Figure 4.9.

4.2.4. Editing The Last Positions Of Job-orders And Machines

When you enter the information about job-orders, each selected operation is placed into related machine record in the machine file. The file is sorted according to the machine code.

FILE UPDATE

ENTER...UPDATE
CF2..CANCEL REQ.

CODE : BRIEM

IE PERIOD :

SKIP THE SECOND FIELD FOR IDLE MACHINE
PUT 99999999 FOR DOWN MACHINE

ı.8. Update of Machine File.

L I S T O F M A C H I N E S

ENTER..NEXT PAG
CF2..MENU

-CODE	IDLE-TIME
HF1	
HF2	
R	
	125
	99999999
R	
.	
IC	

4.9. List of Machines.

In that option of the main menu, three choices are available. The first one gives the information about orders in front of a specific machine. That option is for the user to see the amount of work in front of the specific machine.

The second choice, includes all machines. All available operations that wait for machines are listed on the screen. The list is sorted in descending order according to the machine code.The screen of second choice is in Figure 4.10.

The last choice is used to give the last status of the factory to the computer. The changes in the system will be given to the computer by using this option.

The program that prepares the schedule of the machines, is used after that option is executed, in order to obtain the right schedule. In the factory, schedule is prepared in mornings. By entering the positions of machines and orders, using that option, the data in the files are changed with the actual data.

It is used for three purposes:

i. The alternate machine for any operation is given. There is a field at the beginning of each record, field X. Put 2 into that field then write the code of alternate

M A C H I N E   I N F O R M A T I O N

ENTER..NEXT PAGE
CF2..CANCEL REQ.

:	PROD. ORDER NO	EXPLANATION	ORDER QUANTITY	P R O C E S S NAME	NO	ALTERNATE MACHINE	STD.F TIM
HF2	142.0	ADIK	14800	CONDENSE	8		000
HF2	140.0	AD.K	29000	CONDENSE	8		000
HF2	165.0	AD.KAP	5300	CONDENSE	8		000
HF2	166.0	HECKIN	15000	CONDENSE	8		000
HF2	158.0	AUSTRIA	12000	CONDENSE	8		000
	142.0	ADIK	14800	CH.PT.TRT.	10		000
	140.0	AD.K	29000	CH.PT.TRT.	10		000
	165.0	AD.KAP	5300	CH.PT.TRT.	10		000
	166.0	HECKIN	15000	CH.PT.TRT.	10		000
	158.0	AUSTRIA	12000	CH.PT.TRT.	10		000
:	146.0	DIERIG	6000	EGALIZING	6		000
:	170.0	IBENA	10000	EGALIZING	6		000
:	131.0	HECK	27400	EGALIZING	6		000
:	165.0	AD.KAP	5300	EGALIZING	5		000
:	166.0	HECKIN	15000	EGALIZING	5		000

4.10. List of Jobs That Are Waiting for Machines.

machine and the standard processing time for that operation. So the operation will be performed on the alternate one.

ii. If any machine breaks down while an order was completed partly in that machine the next operation cannot start. But using this option you can apart the finished part from the remaining one, so the finished part may go on although the remaining part waits for the previous machine. Put 2 into field X, write the completed amount to the field then you will see that the order is divided into two part by starting from the next operation. The order number of the second part is increased by 0.1 unit. That case is shown in Figures 4.11 and 4.12.

iii. The finished operations are given to the computer by using that option. If you put 1 into the field X and leave the field amount completed as it is; it means that operation is finished. If you write anything to that field, that value is taken as the completed amount and files are updated using the remaining value as the new amount.

4.3. Scheduling

The solution for the problem is a heuristic approach using the dispatching rules that are stated in Section II.

M A C H I N E   I N F O R M A T I O N

ENTER..NEXT PAGE
CF2..END-OF-UPDATE

FOR PARTLY OR FULLY COMPLETED OPERATIONS
FOR ALTERNATE MACHINE OR PARTITION OF ORDER

C	PROD. ORDER-NO	EXPLANATION	COMP.ORD. QUANTITY	P R O C E S S NAME	NO	ALTERNATE MACHINE	STD.P TIME
RT	131.0	HECK	27400	HAIRING	4		
	131.0	HECK	10000	CHEM.HARD.	1		
	16.0	AD.K	7500	CHEM.HARD.	2		
ER 30	16.0	AD.K	7500	DRYING	10		

11. Updating Status of Machines.

M A C H I N E   I N F O R M A T I O N

ENTER..NEXT PAGE
CF2..END-OF-UPDATE

FOR PARTLY OR FULLY COMPLETED OPERATIONS
FOR ALTERNATE MACHINE OR PARTITION OF ORDER

C	PROD. ORDER-NO	EXPLANATION	COMP.ORD. QUANTITY	P R O C E S S NAME	NO	ALTERNATE MACHINE	STD.P TIME
2	131.0	HECK	17400	EMULATION	3		
2	131.0	HECK	10000	EMULATION	3		
2	131.0	HECK	10000	APRE	9		
RT	131.0	HECK	17400	HAIRING	4		
RT	131.0	HECK	10000	HAIRING	4		
	131.0	HECK	17400	CHEM.HARD.	1		
	16.0	AD.K	7500	CHEM.HARD.	2		
ER 30	16.0	AD.K	7500	DRYING	10		

12. Updating Status of Machines.

The assumptions made for the system are summarized below.

4.3.1. Assumptions For The Problem .

Some assumptions were made about the system in order to make it more clear but the real structure of it and appropriateness to the practise are protected. The assumptions are:

i. Preemption is not allowed, i.e. once an operation is started on a machine, it must be completed before another operation can begin on that machine,

ii. The processing times of successive operations of a particular job cannot be overlapped, i.e. physicaly each job moves through the job-shop as a single unit,

iii. Set-up times of machines are neglected,

iv. Instantaneous transfer to the next machine center is assumed,

v. Unavailability of machines due to break-down or electric-shortage after simulation is started, is considered (If the machine is in maintanence for a specific time or unknown time, that information can be given to the computer).

4.3.2. Algorithm Used For The Scheduling

The schedule is prepared, by selecting the option CF5 in the main menu. That program prepares the schedule for machines for the specific time that is decided by the user, as you see in Figure 4.13. It uses the shortest-processing-time with truncation as dispatching rule.

As mentioned in previous sections, the file structure and usage of this language is different from others and you can reach any record with different keyword or keylist, by using logical files. Search and sort techniques are not needed because, the logical files make those operations automatically.

Down machines are also taken into consideration, in the program. If a machine is down for a specific time, it is activated at the repair time of it.

Input for that program are given or changed by using options previously explained. After the completion of updating of data, that part can be executed to get the schedule of machines, using the information about the last positions of machines.

All the programs except, the preperation of schedule are executed interactivly. Preperation of schedule takes a

CF1..MENU

S C H E D U L I N G   T I M E

		DD MM YY	HH MM
STARTING TIME	:	26 9 86	10 30
		DD HH MM	
SIMULATION TIME	:	1 2	

13. Prompt of the Scheduling Program.

N ORDER NO : 131.0 ENTER..NEXT PAGE
ON : HECK CF2..END-OF-SESS

		DD MM YY	HH MM		DD MM YY
TIME	:	26 09 86	10 30	DUE-DATE :	20 08 86
ER QUANTITY	:	17400			

E S S	NO	MACHINE NAME	COMPLETED QUANTITY	REMAINING QUANTITY
.	1	STORK	17400	
	2	G30-SIL	17400	
	3	RAMOZ-2	17400	
	4	SCHOLAERT	17400	
	9	RAMOZ-2		17400

14. The Result According to The Orders.

long time with respect to the other programs and if we execute it interactively, the whole system slows down. That's why we execute it in batch and at the end of execution, a message comes to screen. Using the next option in menu, we can see the results of schedule in machine and order base with the collected statistics.

The program stops if the current time is greater than or equal to the simulatin time, or all orders in the system are completed.

Step 1. Initialize the data and give the simulation time,

Step 2. If there is any down-machine, change the machine code of the operations that is waiting for it with the alternative machine code,

Step 3. If the current time is greater than simulation time go to Step 12,

Step 4. Search the machine master file for a free machine, if not found go to Step 11,

Step 5. Read an operation, that is waiting for that machine, if no job in front of the machine go to Step 4; If there is no job in the system, go to Step 12, Step 6. If the previous operations of the job-order are completed then continue; otherwise go to Step 5,

Step 7. Calculate the priority for that order and write it to the file CIZELGE,

Step 8. If there are other job-orders waiting for that machine, go to Step 5,

Step 9. Chain the CIZELGE file by key priority. This order is the one that has the minimum priority. Update that record with the starting time of the operation,

Step 10. Update machine master file with the completion time of operation plus current time. Go to Step 4,

Step 11. Chain the machine master file with key time of machine becomes free. This record belongs to the machine that will be free before others. Then the current time is incremented to that time. Go to Step 3,

Step 12. End of simulation is reached. Find the completed amount of jobs, on the machines. Stop.

4.4. The Report

Last part of the program contains three choices. That part can be used after the message of the scheduling program that shows completion of it.

4.4.1. According To Orders

In the first choice, you can get a report, according to the orders. You can completed and incompleted amount of operations of the order, at the end of the simulation time. The screen is in Figure 4.14.

4.4.2. According To Machines

In the second choice, the schedule of machines are listed.The list is in machine base, it is sorted according to the machine codes and starting time of the operations. You can see the screen in the Figure 4.15.

4.4.3. Statistics

The third choice is the statistics that is collected during the simulation. Flow times and tardiness of jobs are isted for each completed order and the average of them is calculated.

MACHINE CODE	RANK NO	DAY	MONTH	YEAR	HOUR	MIN.	EXPLANATION	COMPLETED AMOUNT	PRODUCTION ORDER NO	P R O C E S S NAME	NO
ARTHOS HF2	1	11	9	86	18	48	AD.KAP	54000	165.0	CONDENSING	8
BRIEM	1	12	9	86	12	48	AD.KAP	54000	165.0	CHEM.PAINT.TREAT.	10
E.RAMOZ	1	10	9	86	9	57	BENLI TIC.	500	203.0	EGALIZING	2
E.RAMOZ	2	10	9	86	13	48	FARMA TIC.	23000	301.0	EGALIZING	6
E.RAMOZ	3	10	9	86	23	48	AD.KAP	54000	165.0	EGALIZING	5
E.RAMOZ	4	11	9	86	8	48	BAYRAKTAR TIC.	5000	201.0	EGALIZING	2
E.RAMOZ	5	12	9	86	1	28	FAMATEX	50000	300.0	EGALIZING	6
E.RAMOZ	6	12	9	86	21		YANIK MEN.	10000	200.0	EGALIZING	2
E.RAMOZ	7	14	9	86	6	20	SANCAK	10000	202.0	EGALIZING	2
FAMATEX	1	11	9	86	10	35	HECK	17000	131.0	CONDENSING	8
FD/ROT	1	11	9	86	8	48	AD.KAP	54000	165.0	PRINTING	7
FD/ROT	2	12	9	86	9	48	FAMATEX	50000	300.0	PRINTING	7
FD/ROT	3	14	9	86	20	14	AD.K	75000	16.0	PRINTING	7
L.BRUSH	1	10	9	86	8	20	FARMA TIC.	23000	301.0	ROLLING	5
L.BRUSH	2	10	9	86	13	48	AD.KAP	54000	165.0	BRUSHING	4
GERBER	1	15	9	86	8	44	AD.K	75000	16.0	VAPORIZING	8
G30-SIL	1	10	9	86	5	15	FARMA TIC.	23000	301.0	DRYING	2
G30-SIL	2	10	9	86	9	7	HECK	17000	131.0	DRYING	2
G30-SIL	3	14	9	86		5	AD.K	75000	16.0	DRYING	5
KUSTERS	1	11	9	86	13	6	FAMATEX	50000	300.0	SQUEZING	3
KUSTERS	2	12	9	86	4	20	AD.K	75000	16.0	SQUEZING	3
MAXGOLLER	1	12	9	86	16	50	AD.K	75000	16.0	MERSERIZE	4
MEZERA	1	16	9	86	21	29	AD.K	75000	16.0	WASHING	9
OSTOF	1	10	9	86			FAMATEX	50000	300.0	BURNING	1
PAREX	1	10	9	86			AD.KAP	54000	165.0	BURNING	1
RAMOZ-1	1	10	9	86	20	17	VERTA TIC.	2000	212.0	EGALAZING	3
RAMOZ-2	1	10	9	86	11	24	HECK	17000	131.0	EMULATION	3
RAMOZ-2	2	10	9	86	18	51	FARMA TIC.	23000	301.0	APRE	9
RAMOZ-2	3	11	9	86	15	49	HECK	17000	131.0	APRE	9
SCHOLAERT	1	10	9	86	18	51	HECK	17000	131.0	HAIRING	4
SETTI	1	10	9	86	11	57	YILDIRIM TIC.	600	207.0	ENRICHMENT	2
SETTI	2	10	9	86	18	37	VERTA TIC.	2000	212.0	ENRICHMENT	2
SETTI	3	14	9	86	9	40	CANER TIC.	6000	205.0	ENRICHMENT	2
SETTI	4	15	9	86	22	20	GUNAYLAR	11000	204.0	ENRICHMENT	2
SETTI	5	17	9	86	11		EGINLI TIC.	11000	206.0	ENRICHMENT	2
STORK	1	10	9	86			FARMA TIC.	23000	301.0	CHEM.HARD.	1
STORK	2	10	9	86	5	15	HECK	17000	131.0	CHEM.HARD.	1
STORK	3	10	9	86	9	7	BENLI TIC.	500	203.0	CHEM.HARD.	1
STORK	4	10	9	86	9	57	YILDIRIM TIC.	600	207.0	CHEM.HARD.	1
STORK	5	10	9	86	11	57	VERTA TIC.	2000	212.0	CHEM.HARD.	1

The most important statistics are those values because they want to minimize the flow times and tardiness of jobs. The screen is in Figure 4.16.

S T A T I S T I C S

AGE TARDINESS : 1709 ENTER..NEXT PAGE
AGE FLOW TIME : 9108 CF2..END-OF-SESSI

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8873	7433
140.0	3898	0
165.0	6403	0
210.0	13672	0
211.0	19672	0
212.0	19872	0
300.0	6612	0
301.0	3136	6016
302.0	7444	0
303.0	8345	0
304.0	7340	5900
305.0	4040	1160

re 4.16. Statistics.

V. RESULTS AND CONCLUSION

5.1. Computational Results

The experiments that are made show that SPT/T rule is better for our case, because it decreases the flow-times of orders which are related to the work-in-process inventory level. You can see below average flow times and average tardiness in SPT/T and S/OPN rules which are obtained for five different data samples. You can see the detailed result in Appendix C.

Average Tardiness		Average Flow-time	
SPT/T	S/OPN	SPT/T	S/OPN
1866	1887	7729	10354
1671	1709	7372	9108
212	254	5766	10958
1221	1202	7045	10590
1005	986	8051	13309

5.2. Implication Of Results

The characteristics of the job-orders affect the selection of priorty rule that will be used in the program.

The level of shop load, The manner in which due-dates are set, and the tightness of the due-dates, are very critical in selecting the best rule, especially if one of the performance measures is tardiness. A complete set of reliable data has not been obtained yet. However, there are many experiments based on priority rule using a lot of set of samples. General results have been obtained by Conway (1) about the effects of the priority rules to the different kinds of measure of performances. If the main objectives of the factory like minimizing work-in-process inventory and the tardiness are taken into consideration, the best rule that shows the best performance on those measure is SPT/T which is the combination of SPT and S/OPR rules. In the meanwhile, the experiments that are performed using the actual data show that SPT/T rule causes a less average flow-time and tardiness if it is compared with the S/OPR rule.

Considering the schedule of the machines is prepared daily, the real positions of the machines at the preperation time, must be represented in the computer. Two of the most important features of that program are that it can be used by anyone who has no experience and status of the system can be updated by the user in a few minutes. The information in the computer always shows the last position of the factory since it is day-to-day updated.

The program helps the planning department in following respects:

i. It enables user to update the related changes in a shorter time period,

ii. Scheduling program of the whole factory can be prepared in thirty minutes without any effort.

5.3. Extension Of Research

An extension of the research may be to apply the program to the data samples in the factory and to observe the percent usage of SPT and S/OPN rules and to decide the value of r which is a parameter that gives different performance according to the different characteristics of shop. That may also help to decide a strategy in determining due-dates.

APPENDIX A COMPUTER SYSTEM

The computer system of the factory is IBM-System/38. The only available language is the RPG III. The file usage of it makes it a very powerful language in business. The attractive properties of it are as follows:

i. There are two types of data files, physical files and logical files. Firstly, physical file is constructed with a specific key or a composite key. That physical file is sorted automatically in descending or ascending order, according to the key or keylist. If you want to reach the data with a different keyfield, then you will construct a logical file on that physical file with a different field as a key. If you take the list of that logical file, the list is sorted according to the key of logical file. You may construct as many logical files as you want, on the physical data. Logical files does not contain physical data but it contains, logical record number which is in physical file.

ii. Use of subfiles: You can enter, or update the same type of data as you use a note-book. You can go anywhere on the screen, you can see the next page , or previous page, you can update any field on the screen, then you press the ENTER key in order to make the information permenant. It brings a simplicity in editing the files.

APPENDIX B

LIST OF THE COMPUTER PROGRAM

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ...
     FSIPAR1B UF  E           K        DISK
     FSIPAR1P IF  E           K        DISK
     FSIPAR2B UF  E           K        DISK
     FKALIT2P IF  E           K        DISK
     FMACHINB UF  E           K        DISK                        A
     FMACHINL UF  E           K        DISK
     FGENMAKB UF  E           K        DISK
     FCIZELGE UF  E           K        DISK                        A
     FCIZEL1L UF  E           K        DISK                        A
     FGECIC   IF  E           K        DISK
     FISTATIS O   E           K        DISK                        A
     FGENMAKL UF  E           K        DISK
     C**    KEYLISTLERIN TANIMLANMASI
     C              KAKO      KLIST
     C                        KFLD           KAKODR
     C                        KFLD           ISNOK2
     C              PROCS     KLIST
     C                        KFLD           USINS2
     C                        KFLD           ISNOS2
     C              MACKE     KLIST
     C                        KFLD           MCHCOR
     C                        KFLD           USNOR
     C                        KFLD           ISLNOR
     C** DATALARIN INITIALIZE EDILMESI VE SIMULASYON SURESI PROMPT
     C              BASLA     TAG
     C                        MOVE 1         BB
     C              BB        CHAINGECICI              61
     C   61                   SETON                    LR
     C                        CALL 'INITIALP'
     C                        EXSR SUBR3
     C              BEGIN     TAG
     C                        Z-ADD0         SIMZAM  80
     C              G4        MULT 24        ZAMAN   80
     C                        ADD  H4        ZAMAN
     C                        MULT 60        ZAMAN
     C                        ADD  M4        ZAMAN
     C                        Z-ADD0         X       10
     C** SURE   KONTROLU
     C              YENIBA    TAG
     C              SIMZAM    COMP ZAMAN               78  78
     C   78                   GOTO LIST
     C                        MOVE *LOVAL    MCHCOR
     C              MCHCOR    SETLLGENMAKG
     C                        SETOF                    21
     C** BOS   MAKINE ARAMASI**********************************
     C              TEKRAR    TAG
     C                        READ GENMAKG                 65
     C   65N21                Z-ADD1         X
     C   65N21                GOTO LIST
     C   65                   GOTO LAB5
     C              BOZZAR    CADNEO         TTT
     C                        GOTO TTT1
     C              TTT       TAG
```

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ...
     C                    SETON                     21
     C                    GOTO TEKRAR
     C           TTT1     TAG
     C           MCHCOR   SETLLMACHING                  61
     C  N61               GOTO TEKRAR
     C                    SETON                     21
     C** MAKINEDEKI  SIPARISLERIN  OKUNMASI*****************
     C           NEXTSI   TAG
     C           MCHCOR   READEMACHING                  62
     C                    MOVE MCHCOR    MCH1    10
     C   62               GOTO LAB4
     C                    MOVE USNOR     USINS2
     C                    MOVE *LOVAL    ISNOS2
     C** ISLEMIN ILK ISLEM OLUP OLMADIGININ SAPTANMASI**************
     C           USINS2   SETLLSIPAR2G                  63
     C  N63               SETON                     58
     C  N63               GOTO LIST
     C   63               READ SIPAR2G                  41
     C   41               SETON                     58
     C   41               GOTO LIST
     C           ISLNOR   CABNEISNOS2    NEXTSI
     C                    MOVE USNOR     USINS1
     C           USINS1   CHAINSIPAR1G              64
     C   64               SETON                     42
     C   64               GOTO LIST
     C                    MOVE KAKODR    KAKOK2
     C                    Z-ADD0         TOPISZ  80
     C                    MOVE ISLNOR    ISNOK2
     C** KALAN ISLEMLERININ TOPLAM ISLEM ZAMANLARININ BULUNMASI*****
     C                    SETOF                     41
     C           LAB1     TAG
     C           MCHCOR   COMP MCHCOA                   31
     C   31               DO
     C                    MOVE STANDA    STAZAR
     C                    GOTO LAB1A
     C                    END
     C           KAKO     CHAINKALIT2R              61
     C   61               SETON                     43
     C           LAB1A    TAG
     C           SIPMIK   DIV  STAZAR    PROZAM  30
     C  N41               MOVE PROZAM    ENKIZA  30
     C                    ADD  PROZAM    TOPISZ
     C           USINS2   READESIPAR2G                  66
     C   66               GOTO LAB2
     C                    SETON                     41
     C                    MOVE ISNOS2    ISNOK2
     C                    GOTO LAB1
     C** PRIORITY HESAPLAMA*************************************
     C           LAB2     TAG
     C                    EXSR SUBR1
     C           TERMIN   SUB  TOPISZ    PRIORR
     C                    DIV  TOPISR    PRIORR
     C           PRIORR   COMP ENKIZA               42
```

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ... 7
C   42                  Z-ADDENKIZA    PRIORR
C** CIZELGE  DOSYASINA YAZILMASI********************************
C            LAB3       TAG
C                       WRITECIZELGER
C                       MOVE MCH1      MCHCOR
C*           MCHCOR     SETGTMACHING
C                       GOTO NEXTSI
C** MAKINE DOSYASINDAN SILME*************************************
C            LAB4       TAG
C                       MOVE *LOVAL    PRIORR
C            MCHCOR     SETLLCIZELGER                   70
C   70                  READ CIZELGER                   80
C   80                  SETON                       51
C   80                  GOTO LIST
C  N70                  GOTO TEKRAR
C            LABL8      TAG
C            MACKE      CHAINMACHIN1                61
C   61                  DO
C            MCHCOR     READECIZELGER                   81
C  N81                  GOTO LABL8
C   81                  GOTO TEKRAR
C                       END
C  N61                  DO
C                       MOVE SIMZAM    CONVZA  80
C                       EXSR SUBR2
C                       WRITECIZ1111
C                       DELETMACHIN1
C                       END
C** ISLEMIN BITIS TARIHI HESABI VE GENEL MAKINE DOSYASI UPDATE*
C                       MOVE USNOR     USINS1
C            USINS1     CHAINSIPARIG                72
C   72                  SETON                       52
C   72                  GOTO LIST
C                       MOVE KAKODR    KAKOK2
C                       MOVE ISLNOR    ISNOK2
C            MCHCOR     COMP MCHCOA                     31
C   31                  DO
C                       MOVE STANDA    STAZAR
C                       GOTO LAB4A
C                       END
C            KAKO       CHAINKALIT2R                61
C   61                  SETON                       53
C   61                  GOTO LIST
C            LAB4A      TAG
C            SIPMIK     DIV  STAZAR    PROTIM  80
C*****       MCHCOR     CHAINGENMAKG                61
C                       ADD  SIMZAM    PROTIM
C                       MOVE PROTIM    BOZZAR
C                       UPDATGENMAKG
C                       GOTO YENIBA
C** MAKINELER DOLDU EN YAKIN ZAMANA GIT*************************
C            LAB5       TAG
C                       Z-ADD1         BOZZAR
```

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ...

     C                BOZZAR    SETLLGENMAKK                           68
     C                          READ GENMAKK                           68
     C    68                    SETON                              55
     C    68                    GOTO LIST
     C                BOZZAR    COMP *HIVAL                            19
     C    19                    Z-ADD1         X          10
     C    19                    GOTO LIST
     C                          Z-ADDBOZZAR    SIMZAM
     C                LABL7     TAG
     C                          Z-ADDBOZZAR    BOZZAM  80
     C                          MOVE MCHCOR    MACBOZ 10
     C                          Z-ADD0         BOZZAR
     C                          UPDATGENMAKK
     C                          MOVE *LOVAL    PRIORR
     C                MCHCOR    SETLLCIZELGER                          70
     C   N70                    SETON                              56
     C   N70                    GOTO LIST
     C                LABL9     TAG
     C    70          MCHCOR    READECIZELGER                          80
     C    80                    GOTO LABL6
     C                          MOVE USNOR     USINS2
     C                          MOVE ISLNOR    ISNOS2
     C                PROCS     CHAINSIPAR2G                       67
     C    67                    GOTO LABL9
     C   N67                    DELETSIPAR2G
     C                          MOVE USNOR     USINS2
     C                          MOVE USNOR     USINS1
     C                USINS1    CHAINSIPAR1G                       77
     C   N77                    SUB  1         TOPISR
     C   N77                    UPDATSIPAR1G
     C                          MOVE *LOVAL    ISNOS2
     C                USINS2    SETLLSIPAR2G                           70
     C    70                    GOTO LABL6
     C   N70                    DO
     C                          MOVE USNOR     USINS1
     C                USINS1    CHAINSIPAR1G                       69
     C   N69                    DELETSIPAR1G
     C                          EXSR SUBR1
     C                          MOVE TERMIN    TERMI   80
     C                          MOVE Y7        Y2
     C                          MOVE A7        A2
     C                          MOVE G7        G2
     C                          EXSR SUBR1
     C                SIMZAM    SUB  TERMIN    FLOW
     C                SIMZAM    SUB  TERMI     COMPTI
     C                COMPTI    COMP 0                               24
     C    24                    Z-ADD0         COMPTI
     C                          WRITEISTAT
     C                          END
     C                LABL6     TAG
     C                          MOVE SIMZAM    BOZZAR
     C                BOZZAR    CHAINGENMAKK                       29
     C   N29                    GOTO LABL7
```

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ... 7
     C                      GOTO YENIBA
     C               LIST   TAG
     C               X      COMP 1                            87
     C   N87                EXSR SUBR4
     C                      SETON                       LR
     C                      RETRN
     C****  SUBROUTINE ZAMAN HESABI
     C               SUBR1  BEGSR
     C               BEG11  TAG
     C                      SETOF                       111213
     C                      SETOF                       141516
     C                      SETOF                       1719
     C               Y2     SUB  Y1        YY      40
     C               YY     COMP 0                      111213
     C    13                DO
     C               A2     SUB  A1        AA      40
     C               AA     COMP 0                      141516
     C                      END
     C    11                DO
     C                      SUB  1         YY
     C               YY     MULT 12        YY
     C               12     SUB  A1        AA
     C                      ADD  A2        AA
     C                      ADD  YY        AA
     C                      SETON                       14
     C                      END
     C    12                DO
     C                      ADD  1         YY
     C                      MULT 12        YY
     C               12     SUB  A2        AA
     C                      ADD  A1        AA
     C               YY     SUB  AA        AA
     C                      SETON                       15
     C                      END
     C    16                DO
     C               G2     SUB  G1        GG      40
     C               GG     COMP 0                      171719
     C    17                Z-ADD0         TERMIN  80
     C               GG     MULT 1440      TERMIN
     C                      END
     C    14                DO
     C                      SUB  1         AA
     C               AA     MULT 30        AA
     C               30     SUB  G1        GG
     C                      ADD  G2        GG
     C                      ADD  AA        GG
     C               GG     MULT 1440      TERMIN
     C                      END
     C    15                DO
     C                      ADD  1         AA
     C                      MULT 30        AA
     C               30     SUB  G2        GG
     C                      ADD  G1        GG
```

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ...

C                              SUB  GG        AA
C                AA            MULT 1440      TERMIN
C                              END
C                              ENDSR
C****  SUBROUTINE ZAMAN HESABI II**********.
C                SUBR2         BEGSR
C                CONVZA        DIV  518400    KAL        20
C                              MVR            ART        80
C                Y1            ADD  KAL       Y3         20
C                              MOVE ART       CONVZA
C                CONVZA        DIV  43200     KAL
C                              MVR            ART
C                A1            ADD  KAL       A3         20
C                              MOVE ART       CONVZA
C                CONVZA        DIV  1440      KAL
C                              MVR            ART
C                G1            ADD  KAL       G3
C                              MOVE ART       CONVZA
C                CONVZA        DIV  60        KAL
C                              MVR            ART
C                H1            ADD  KAL       H3
C                M1            ADD  ART       M6G        30
C                M6G           COMP 59                      12
C   12                         DO
C                M6G           SUB  60        M3
C                              ADD  1         H3
C                              END
C  N12                         MOVE M6G       M3
C                H3            COMP 23                      13
C   13                         DO
C                              SUB  24        H3
C                              ADD  1         G3
C                              END
C                G3            COMP 30                      11
C   11                         DO
C                              SUB  30        G3
C                              ADD  1         A3
C                              END
C                A3            COMP 29                      14
C   14                         DO
C                              SUB  12        A3
C                              ADD  1         Y3
C                              END
C                              ENDSR
C*****************SUBROUTINE 3   *************************
C                SUBR3         BEGSR
C                              MOVE *HIVAL    BOZZAR
C                BOZZAR        SETLLGENMAKK                     18
C  N18                         GOTO BASL2
C                BASL1         TAG
C                BOZZAR        READEGENMAKK                     19
C                              MOVE MCHCOR    MCH111 10
C   19                         GOTO BASL2
```

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ... 7

     C                BASL4     TAG
     C                MCHCOR    SETLLMACHING                     20
     C   N20                    GOTO BASL1
     C                BASL3     TAG
     C                MCHCOR    READEMACHING                     11
     C    11                    GOTO BASL1
     C                MCHCOA    COMP *BLANK                      12
     C    12                    GOTO BASL3
     C                MCHCOR    DELETMACHING                 92
     C                          MOVE MCHCOA    MCHCOR
     C                          WRITEMACHING
     C                          MOVE MCH111    MCHCOR
     C                          GOTO BASL4
     C                BASL2     TAG
     C                          ENDSR
     C*******SUBROUTINE 4 ***************************
     C                SUBR4     BEGSR
     C                          MOVE 1         BOZZAR
     C                BOZZAR    SETLLGENMAKK                   17
     C    17                    GOTO SONSB4
     C                TAG1      TAG
     C                          READ GENMAKK                     23
     C    23                    GOTO SONSB4
     C                *HIVAL    COMP BOZZAR                      18
     C    18                    GOTO SONSB4
     C                MCHCOR    SETGTCIZ1111
     C                          READPCIZ1111                     19
     C    19                    GOTO SONSB4
     C                BOZZAR    SUB  ZAMAN     KALZAM  80
     C                          MOVE USNOR     USINS1
     C                USINS1    CHAINSIPARIR                 61
     C                          MOVE KAKODR    KAKOK2
     C                          MOVE ISLNOR    ISNOK2
     C                KAKO      CHAINKALIT2R                 62
     C                STAZAR    MULT KALZAM    SIPMIL  70
     C                SIPMIK    SUB  SIPMIL    SIPMIK
     C                          UPDATCIZ1111
     C                          GOTO TAG1
     C                SONSB4    TAG
     C                          MOVE MACBOZ    MCHCOR
     C                          MOVE BOZZAM    BOZZAR
     C                MCHCOR    SETGTCIZ1111
     C                          READPCIZ1111                     19
     C    19                    GOTO SONSB5
     C                BOZZAR    SUB  ZAMAN     KALZAM  80
     C                          MOVE USNOR     USINS1
     C                USINS1    CHAINSIPARIR                 61
     C                          MOVE KAKODR    KAKOK2
     C                          MOVE ISLNOR    ISNOK2
     C                KAKO      CHAINKALIT2R                 62
     C                STAZAR    MULT KALZAM    SIPMIL  70
     C                SIPMIK    SUB  SIPMIL    SIPMIK
     C                          UPDATCIZ1111
```

```
SEQNBR*... ... 1 ... ... 2 ... ... 3 ... ... 4 ... ... 5 ... ... 6 ... ... 7
37200      C              SONSB5    TAG
37300      C                        ENDSR
                              * * * * * E N D  O F  S O U R C E * * * * *
```

APPENDIX C

COMPUTATIONAL RESULTS

S T A T I S T I C S

GE TARDINESS : 986
GE FLOW TIME : 13309

ENTER..NEXT PAGE
CF2..END-OF-SESSIO

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8324	6884
131.0	5313	3873
165.0	6213	0
200.0	14710	0
201.0	15710	0
202.0	26180	0
203.0	14370	0
204.0	11370	0
205.0	13070	0
206.0	22840	0
207.0	13150	0
210.0	12570	0
211.0	23640	0
212.0	23840	0
300.0	5510	0

Group 1 with S/OPN

STATISTICS

E TARDINESS : 1005 ENTER..NEXT PAGE
E FLOW TIME : 8051 CF2..END-OF-SESSION

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8651	7211
131.0	5313	3873
165.0	6213	0
200.0	7580	0
201.0	4971	0
202.0	9580	0
203.0	2068	0
204.0	9640	0
205.0	6940	0
206.0	11840	0
207.0	1691	0
210.0	21240	0
211.0	27400	0
212.0	2331	0
300.0	6580	0

roup 1 with SPT/T

S T A T I S T I C S

E TARDINESS : 1202

E FLOW TIME : 10590

ENTER..NEXT PAGE
CF2..END-OF-SESSION

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8324	6884
131.0	5372	3932
165.0	6213	0
201.0	11694	0
203.0	10354	0
206.0	19124	0
207.0	10314	0
210.0	13254	0
211.0	19924	0
212.0	20124	0
300.0	6194	0
301.0	3136	6016
302.0	6317	0
303.0	7927	0

roup 2 with S/OPN

S T A T I S T I C S

E TARDINESS : 1221
E FLOW TIME : 7045

ENTER..NEXT PAGE
CF2..END-OF-SESSIOI

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8651	7211
131.0	5313	3873
165.0	6213	0
201.0	4971	0
203.0	2068	0
206.0	7124	0
207.0	1691	0
210.0	16524	0
211.0	22524	0
212.0	2331	0
300.0	6580	0
301.0	3136	6016
302.0	1854	0
303.0	9655	0

roup 2 with SPT/T

STATISTICS

E TARDINESS : 254
E FLOW TIME : 10958

ENTER..NEXT PAGE
CF2..END-OF-SESSION

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	11196	0
131.0	3986	2546
165.0	5925	0
200.0	13786	0
201.0	14786	0
203.0	13446	0
204.0	10446	0
205.0	12146	0
207.0	12226	0
210.0	11646	0

roup 3 with S/OPN.

S T A T I S T I C S

GE TARDINESS : 212
GE FLOW TIME : 5766

ENTER..NEXT PAGE
CF2..END-OF-SESSIO

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	12266	0
131.0	3986	2546
165.0	5925	0
200.0	6656	0
201.0	4120	0
202.0	8656	0
203.0	882	0
204.0	8716	0
205.0	6016	0
206.0	10916	0
207.0	462	0
212.0	1102	0

Group 3 with SPT/T.

S T A T I S T I C S

GE TARDINESS : 1709
GE FLOW TIME : 9108

ENTER..NEXT PAGE
CF2..END-OF-SESSIO

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8873	7433
140.0	3898	0
165.0	6403	0
210.0	13672	0
211.0	19672	0
212.0	19872	0
300.0	6612	0
301.0	3136	6016
302.0	7444	0
303.0	8345	0
304.0	7340	5900
305.0	4040	1160

Group 4 with S/OPN.

S T A T I S T I C S

AGE TARDINESS : 1671
AGE FLOW TIME : 7372

ENTER..NEXT PAGE
CF2..END-OF-SESSI(

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8419	6979
140.0	3444	0
165.0	6425	0
210.0	14072	0
211.0	20072	0
212.0	2579	0
300.0	6328	0
301.0	3136	6016
302.0	2807	0
303.0	9812	0
304.0	7362	5922
305.0	4016	1136

Group 4 with SPT/T.

S T A T I S T I C S

RAGE TARDINESS : 1887
RAGE FLOW TIME : 10354

ENTER..NEXT PAGE
CF2..END-OF-SESSI

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8324	6884
131.0	6772	5332
165.0	6375	0
206.0	19224	0
207.0	10964	0
210.0	13904	0
211.0	20024	0
212.0	20224	0
300.0	7503	0
301.0	3136	6016
302.0	7416	0
303.0	8577	0
304.0	7312	5872
305.0	5206	2326

. Group 5 with S/OPN.

S T A T I S T I C S

RAGE TARDINESS : 1866
RAGE FLOW TIME : 7729

ENTER..NEXT PAGE
CF2..END-OF-SESS

PRODUCTION ORDER-NO	FLOW TIME (MIN)	TARDINESS (MIN)
16.0	8751	7311
131.0	5942	4502
165.0	6425	0
206.0	7224	0
207.0	2170	0
210.0	16624	0
211.0	22624	0
212.0	2931	0
300.0	6680	0
301.0	3136	6016
302.0	2807	0
303.0	10284	0
304.0	7362	5922
305.0	5256	2376

a Group 5 with SPT/T.

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