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Experimental investigation on the Johnson rule for sequencing jobs in a two-bottleneck job shop

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EXPERIMENTAL INVESTIGATION ON THE JOHNSON RULE FOR SEQUENCING JOBS IN A TWO-BOTTLENECK JOB SHOP

A DISSERTATION

SUBMITTED TO THE GRADUATE COLLEGE

in partial fulfillment of the requirements for the

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DOCTOR OF PHILOSOPHY

By

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EXPERIMENTAL INVESTIGATION ON THE JOHNSON RULE

FOR SEQUENCING JOBS IN A

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A DISSERTATION

APPROVED FOR THE SCHOOL OF INDUSTRIAL ENGINEERING

By

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In one of our marginal discussions, a member of my doctoral committee once stated that a dissertation is a joint effort between the candidate and the doctoral committee. At this point I realize that he was absolutely correct.

I am indebted to all five members of my doctoral committee for their contribution to the end result. More specifically, I am indebted to my chairperson Dr. Bobbie Leon Foote for his guidance, patience, input and advice; to Dr. Lawrence Leemis for his contribution and assistance; and to Dr. Al B. Schwarzkopf for his valuable positive criticism, lengthy discussions, helpfulness, and availability when needed. As a teacher, I have also borrowed many of my teaching techniques from these three professors.

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ABSTRACT

EXPERIMENTAL INVESTIGATION ON THE JOHNSON RULE
FOR SEQUENCING JOBS IN A
TWO-BOTTLENECK JOB SHOP

BY: SABA B. BAHOUTH
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This work studies the possibility of using three new sequencing rules in a simple hybrid assembly shop with two bottleneck machines. These three rules, the first of which is a modified version of the two-machine Johnson algorithm, are the JNP, the JHP, and the JFP rules. The first rule does not synchronize parts through the system, the second synchronizes parts halfway through the system, while the third synchronizes parts through the whole system. The three rules are also compared with the Shortest Process Time (SPT) rule.

A simulation model for a nine-machine job shop is developed and used to compare these rules. The total flowtime is the main performance measure used for evaluation. The study is made under a combination of three independent variables: the difference in the average

process time between the two bottleneck machines, the time between job creations, and the difference between the assumed and the actual process time. The effect of the bottleneck machines location is also studied.

The results show that a job shop can be managed by simply managing the bottleneck machines and that the three new rules can be used to manage a job shop with two bottlenecks. The results also show that the location of the bottleneck machines is of importance, and that the level of deviation between the assumed and the actual process time does not have any significant impact on the relative performance of the sequencing rules. The study of the impact of the time between job creations shows that the JNP rule is recommended when dealing with a job shop having two bottleneck machines. The study of the difference in the average process time on the two machines shows that the three rules are very effective for almost all locations of the two bottleneck machines.

EXPERIMENTAL INVESTIGATION ON THE JOHNSON RULE FOR SEQUENCING JOBS IN A TWO-BOTTLENECK JOB SHOP

CHAPTER I

INTRODUCTION

The scheduling problem is an old one. In the last few decades, researchers have shown an increased interest in the scheduling field, as the complexity of manufactured products demanded better and more efficient scheduling techniques.

A scheduling problem can be optimally solved in a very limited number of cases. Most situations are so mathematically complex that even the fastest and the most modern computers would not solve them in a realistic time frame. Branch and bound techniques have been recently used, and have proven to be quite successful in solving the smaller size scheduling problems. With the introduction of several modern and efficient simulation languages, computer simulation became one of the principle means for studying the general scheduling problem.

This research consists of a simulation study of a job shop where two performance measures are evaluated under a combination of different levels of three independent variables. The main objective of this simulation is to study the possibility of using the two-machine Johnson algorithm as a replacement for the more commonly used sequencing rules when managing a job shop with two bottleneck machines. The two performance measures are the total flow time (time elapsed between the start of the first job and the end of the last job) and the average time in the system (average time a job remains in the shop). The three independent variables are the difference in the average expected process time between the two bottleneck machines, the time between job creations, and the difference between the assumed process time and the actual process time. The effect of the bottleneck machines location will also be studied.

As the most popularly used sequencing rule is the Shortest Process Time (SPT) rule, this study concentrates on the difference in performance between the proposed 'modified' Johnson algorithm and the SPT rule.

CHAPTER II

PREVIOUS INVESTIGATIONS

This chapter reviews the literature pertaining to our research. Much has been written on shop scheduling, we therefore limit our review to the literature which relates to our research. However, we found it useful if we start this chapter with a very general overview of the scheduling problem.

This chapter will first overview the scheduling problem, then review the basic scheduling theory, then the shop scheduling studies conducted by means of computer simulation, and will finally look at the gaps in the research conducted to date.

The Structure of the Scheduling Problem

The scheduling problem covers a wide range of applications, environments and criteria. Several attempts have been made to structure the scheduling problem and create a structure representing its different dimensions;

Most of these attempts have resulted in a better understanding of the scheduling environment. In this section, we intend to develop a simple structure for the general scheduling problem for the purpose of defining the limits within which our research is to take place.

A manufacturing process is usually considered either a job shop process or a flow shop process. In a job shop process, the product types tend to be varied and numerous, which means that each set of jobs tend to have its own characteristics and design specifications; this kind of process is associated with a large number of clients, each requiring a different product. In a flow shop process, on the other hand, the product types tend to be very limited, thus imposing very close characteristics and design specifications among products; this kind of process is associated with a limited number of clients, all requiring more or less similar products. While some literature give a looser definition for the above two processes, thus narrowing the gap between the two definitions; others have gone to limiting their definition to the two extremes, thus leaving a wide area of manufacturing processes not covered by either.

Customer's orders and demand are the driving force behind a production process. An open shop environment means that orders are directly generated by several clients, and that material is acquired purposely for each generated order; in such an environment, there is no need to stock inventory. However, in a closed shop environment, the number of clients is limited to a much smaller number, all requiring similar products, and therefore the production facility management can foresee and plan its production horizon; in such an environment, inventory can be stocked in economical quantities in order to serve client's requests in a speedy manner, and therefore in a more timely way. In an open shop environment, production sequencing and scheduling are of main concern, and in-production batching is necessary to meet due dates requirements by reducing the number of machine setups, and therefore reducing the total setup time. In a closed shop environment, inventory replenishment batching (lot sizing) plays a major role along with sequencing, with the main purpose being minimizing cost at an acceptable level of customer service.

The job shop tends to be associated with open shop, meaning that order placing is open to any potential client, while flow shop process tends to be associated with closed shop, meaning that order placing is open to a limited number of clients. This association, while practical for some applications, could lead to confusion in others.

A distinction between two categories of production problems should be made: the production scheduling problem and the production and inventory management problem. The production scheduling problem is a resources oriented problem, where efficient scheduling is necessary to make the best use out of machine/operator availability; material and inventory conditions and costs need to be satisfied without the need to be optimized. The production and inventory management problem is more of a material and inventory problem, where materials and inventory management, along with minimizing cost, are of major concern; resources constraints need to be satisfied without the need to be optimized.

Different production designs are evaluated under two criteria: the first is cost and the second is schedule performance measures. If cost is the measure scale, the major cost factors like fixed costs, material costs, labour costs, inventory costs, order costs, setup costs, service-level costs, expediting costs, and delivery costs should be considered. When performance measures are used as a measure scale, several measures can be applied. Mellor (1966) lists 27 different scheduling objectives based on performance measures. French (1982) lists the most commonly used performance measures. These are either based on processing time or due dates or inventory and machine utilization.

Performance measures based on processing time include:

- Maximum flow time: Fmax
- Mean flow time: $\bar{F}$
- Maximum completion time: Cmax
- Mean completion time: $\bar{C}$

Performance measures based on due dates include:

- Maximum lateness: Lmax
- Mean lateness: $\bar{L}$
- Maximum Tardiness: Tmax
- Mean tardiness: $\bar{T}$
- Number of Tardy jobs: NT

Performance measures based on inventory and machine utilization include:

- Mean number of jobs waiting machines: $\bar{N}w$
- Mean number of unfinished jobs: $\bar{N}u$
- Mean number of completed jobs: $\bar{N}c$
- Mean number of jobs being processed: $\bar{N}p$
- Mean number of machine idle times: $\bar{I}$

- Maximum machine idle time: Imax

Production scheduling problems have commonly been analyzed using performance measures, while production and inventory management problems have been commonly analyzed using the total cost function scale.

The environment under which production takes place plays a crucial role in productivity analysis. A distinction should be made between the internal environment and the external environment. The internal environment can be defined as either deterministic or probabilistic. In a deterministic internal environment, variables like the processing time of a certain job on a certain machine, or the setup time of a certain machine, or the machine maintenance schedule, etc. are fixed and known. In a probabilistic internal environment, these same variables are random variables with either a specified or non-specified probability distribution. The external environment can be defined as either static or dynamic. In a static external environment, orders generated by the different customers are well defined, accurately specified, and are not subject to change with respect to quantity, quality, and time requirements. In a dynamic external environment, changes in customers orders are expected and their dynamics should be considered while analyzing scheduling alternatives.

Process complexity relates to the number of operations associated with each job. Graves (1981) breaks down process complexity into four levels:

1. One-stage, one-processor (facility)

2. One-stage, Parallel-processors (facilities)

3. Multistage, flow shop

4. Multistage, job shop.

The one-stage, one-processor (known as the one machine problem) represents the simplest form of the scheduling problem. In this situation, all jobs require one operation on one machine; The processing time of each job is different. This same situation applies in some more complex facilities where a bottleneck machine exists. In the one-stage, parallel-processor facility, each of the jobs requires one operation which can be performed on any of the available machines; such a situation is commonly found in the service industry. In the multistage, flow shop facility, each job needs to be processed on several machines, however the required sequence of these operations is the same for all involved jobs. It is also implied that similar operations are performed on the same machine. Finally, the multistage, job shop facility is the most general and most complex of these classes: in this situation, each job is processed on more than one machine, but there are no restrictions on the required operations sequence in any of the jobs other than the technological sequence. This last class can cover a wide variety of complex scheduling problems, however it is almost always impossible to optimize.

Spinner (1968) sees the scheduling theory as three related areas within the field of operations research. The first being sequencing, the second queueing, and the third scheduling. Sequencing involves specifying fixed routing which the jobs should follow in order to reach an efficient solution to the specified problem. A sequencing solution assigns jobs to the earliest available machine (provided it is an appropriate machine) without considering the time element. Queueing involves studying and arranging jobs waiting in front of the different machines. This job arranging becomes more important as the resources become scarce, and jobs start competing for the different limited resources. Scheduling involves assigning a starting time and a processing time for each job and each machine on which a job needs to be operated upon. The complete set of times and machines for a particular job define the schedule for that job. The complete set of jobs, times, and machines define the schedule for a project.

In a flow shop, the main concern is usually the sequence of the jobs, and therefore the sequencing theory takes the prominent position in the problem solution; once an appropriate sequence, which takes into consideration the technological constraints, is established, that sequence is no longer subject to change. When resources become quite critical, causing line formation in front of the machines, then a flow shop problem should be analyzed with an eye on queueing theory. Under these conditions, the technological sequence of the jobs remains fixed, and the main concern shifts to ordering the queues in a way to satisfy the technological sequence and optimize the objective function. In a job shop, the technological sequence of the jobs and the schedule of the machines, are more flexible, and the problem generalizes to trying to optimize the objective function taking advantage of the non-rigidity in the sequence of operations and the queues ordering. Under these conditions, batching becomes very helpful.

The Basic Scheduling Problem.

The scheduling literature is full of different approaches for solving a wide range of scheduling problems. The following highlights the major basic contributions which are necessary for developing the more appropriate techniques which will capture more realistic situations. This basic review will cover the one-stage-one-processor problem; the flow shop problem, and finally the job shop problem.

The One-Stage, One-Processor Problem.

The one-stage, one-processor problem, the simplest type of the sequencing problems, was addressed and solved under different performance measures almost forty years ago. Jackson (1955) minimized the maximum tardiness with the Earliest-Due-Date (EDD) schedule, Moore (1968) minimized the number of late jobs with a slightly more complex algorithm, and Smith (1956) minimized the mean flow time with the Shortest-Process-Time (SPT) schedule. As for the problem of minimizing weighted tardiness, which was proven to be an NP-complete, Lawler (1964), Emmons (1969), and later Schrage and Baker (1978), among others have addressed it. The most efficient results have been those of Schrage and Baker who formulated the problem as a dynamic program and made use of the dominance properties introduced by Emmons to solve the problem quite efficiently.

In the closed-shop environment, Elmaghraby (1978) reviewed the literature for the economic lot scheduling problem, and also improved on the most efficient approaches. For the joint replenishment problem, where economies of scale play an important role, Silver (1976) has provided one of the simplest and most efficient solutions which is based on establishing a good replenishment base period. Wagner and Whitin (1958) studied the time-varying-demand, capacitated, lot-sizing problem. Silver and Dixon (1978) proposed a heuristic for the single facility constrained lot-sizing problem which, they report, ends with an optimal solution in 83% of the cases, and gets very close to an optimum solution otherwise. Dixon and Silver (1980) also proposed an efficient heuristic for the capacitated multi-item problem, which is an extension of the Silver-Meal (1973) heuristic for the uncapacitated lot-sizing problem.

The Flow Shop Problem.

The flow shop problem aroused the interest of several researchers mainly because it is the simplest of the multi-stage scheduling problems. Researchers even limited their studies, in most instances, to a permutation schedule, which dictates that the sequence of jobs on each processor is the same. It is to be noted that the importance of the permutation schedules is derived from the fact that they are optimal for the two-processor problem, and for the three-processor problem with maximum flow time performance measure. Even with such simplicity and limitation, the flow shop problem remains (with very few exceptions) a very large problem to optimize.

Among the earliest and best known of the non-permutation flow-shop scheduling results is an algorithm due to Johnson (1956) for solving the two-processor maximum flow time problem. Starting with the job which has the shortest processing time on any of the two processors, his algorithm simply sequences the jobs with the shortest processing time on the first processor first, and the jobs with the shortest processing time on the second processor last. The above Johnson algorithm can be extended, under very special conditions, to the case of three processors: If the maximum processing time on the second processor is not greater than the minimum time on either the first or the third processor, then an optimum sequence can be found by using the Johnson algorithm after adding the second processor time to each of the first and the third processor time and treating the three-processor problem as a two-processor problem. Johnson was also credited for another algorithm for optimizing the two-processor maximum flow time problem in a job shop environment; we will be looking at that algorithm in the section which deals with the job shop problem.

With the exception of the above cases, the general flow shop problem was proven to be NP-complete. Several combinatorial optimization procedures were used in trying to solve the maximum flow time general flow shop problem; the most successful have been the branch and bound procedures which also use the elimination procedure to eliminate dominated sequences. Baker (1975) and Lageweg, Lenstra and Kan (1978) have studied and evaluated the different bounding and elimination strategies proposed by the different researchers. Lageweg et al. reported that a bound based on the Johnson's algorithm, combined with the elimination procedure of Szwarc (1971) gives the best overall performance for a wide range of problems.

Several heuristics for solving the flow shop problem have also been tested; most of them tried to minimize the maximum flow time. Salimian (1988) solved a general 3-machine problem using a heuristic which is so far the best compared to other heuristics applied to the 3-machine problem. The heuristic proposed by Palmer (1965) calculates and assigns a slope index to each of the jobs based on their processing time on each processor, then uses the Johnson's two-processor algorithm to sequence the different jobs. The heuristic proposed by Campbell, Dudek and Smith (1970) devises m-1 schedules, solves each one using the Johnson's two- processor algorithm, and then selects the best schedule among these m-1. Dannenbring's heuristic (1977) also uses the Johnson's algorithm to solve a modified, sloped-indexed problem, then tries to improve on the solution by switching adjacent tasks in the sequence. The heuristic proposed by Nawaz, Enscore and Ham (1983) gives priority to the jobs with the highest work content: starting with the two jobs with the highest work content, the two permutation schedules are evaluated and the best is selected. The job which has the highest work content among the unscheduled jobs is then inserted in all possible slots of the already established schedule, and the best among the newly formed schedules is selected. The procedure continues until all jobs are scheduled.

Simulation approaches exist but are not covered here as we focus only on structure based approaches in this section.

The Job Shop Problem.

The job shop scheduling problem is the most general and complex of all the scheduling problems. In a job shop environment, each job could require processing on any set of processor in any order.

Most of the research in the area of job shop scheduling reports results based on one measure, like the mean, standard deviation, maximum value, and percentage of some measurable criteria like the flowtime, completion time, lateness, tardiness, etc. A good performance based on one measure almost never guarantees a good performance in other measures. In fact, when dealing with a single machine setup, Blackstone, Phillips, and Hogg (1982) report that the shortest processing time rule (SPT) minimizes mean flowtime and mean lateness but results in a high variance in both flowtime and lateness; also, earliest due date rule (EDD) minimizes maximum tardiness and lateness variance, but does not perform well on flowtime. The analysis becomes much more complex when working with a multi-machine setups.

Of unique interest is the Johnson algorithm for the special case of two processors in a job shop environment. The algorithm minimizes the maximum flow time when jobs are processed on a maximum of two processors. Johnson's job shop algorithm separates all jobs according to the following classification:

- A: jobs which need to be processed on machine m1 only.
- B: jobs which need to be processed on machine m2 only.
- C: jobs which need to be processed on machine

m1 first and m2 second.

- D: jobs which need to be processed on machine m2 first and m1 second.

- Put jobs type A in any sequence resulting in a sequence SA.

- Put jobs type B in any sequence resulting in a sequence SB.

- Sequence jobs type C according to the Johnson's flow shop algorithm for two machines resulting in a sequence SC.

- Sequence jobs type D according to the Johnson's flow shop algorithm for two machines (keeping in mind that the second machine needs to process first) resulting in a sequence SD.

- The optimal sequence is [SC,SA,SD] on machine m1 and [SD,SB,SC] on machine m2.

Management is usually interested in satisfying more than one performance measure. This interest was the motivation behind researchers looking into combining scheduling rules and also considering the multicriteria scheduling problem.

Panwalker and Iskander (1977) listed and described twenty one rules that combine simple priority rules, twenty two priority indexed rules, and twelve heuristic rules involving trade-off. While the idea sounds very promising, actual implementation did not result in any major breakthrough.

Those who researched the multicriteria problem limited their scope to the static, one machine setup. Among them Lin (1983) who used dynamic programming to minimize mean flowtime and mean tardiness, Emmons (1975) who looked at the mean flowtime and the number of tardy jobs, and Sen and Gupta (1983), Van Wassenhove and Gelders (1980),and Heck and Roberts (1972), all of whom worked on minimizing flowtime and maximum tardiness. Nelson, Sarin and Daniels (1986) developed an efficient set of schedules while considering three performance measures: mean flowtime, maximum tardiness, and number of tardy jobs.

With very few exceptions, researchers have limited their work to minimizing the maximum flow time when they tried to optimize the job shop problem under one performance measure. All these optimization approaches have used the branch and bound procedures "where the various procedures differ primarily with respect to the branching rules, the bounding mechanism, and the generation of the upper bounds. Despite the preponderance of effort on this problem, the largest problems reported solved have less than 10 tasks scheduled on less than 10 processors" (Graves in 1981).

Heuristic approaches to the job shop problem have been limited and not very encouraging. The two commonly used approaches have been the constructive approach and the random sampling approach. The constructive approach tries to schedule all tasks as early as possible, and the random sampling approach samples feasible schedules and selects the best among them.

The probabilistic and dynamic job shop problem has also been addressed by several researchers. All their efforts have concentrated on simulation studies for a certain setup or a certain product structure in which the effect of different sequencing rules on performance measures have been evaluated. Simulation has always been considered the most flexible and most appropriate approach to complex scheduling problems modeling actual real life job shop situations.

Research related to the scheduling problem in the first thirty years has been mainly within the confined area of static, deterministic, one or two machine setup. The past decade or so has not seen much progress in this same area due to the fact that most approaches and alternatives in this confined area have been exhausted. At the same time, as manufacturing is becoming more complex, the demand for efficient scheduling techniques under complex environment is increasing. The tools available to us, as a result of forty years of research, do not appear to fit the requirements of the job shop scheduling problem. Schedulers seem to be unaware, in some instances, and ignoring, in many other instances, the result of the research pertaining to their area of application. At the same time, schedulers seem to enjoy much more flexibility than usually modeled by researchers. McKay, Safayeni, and Buzacott (1988) have surveyed over two hundred job shop schedulers and concluded the following:

- Schedulers are usually trying to sequence the work to meet stated and unstated conflicting goals using "soft information that is possibly incomplete, ambiguous, biased, outdated, and erroneous."

- The shop is seldom stable for more than half an hour. The effect of the change normally lasts longer than the batch processing time.

- Schedulers are not strictly confined within the physical and logical constraints imposed by the nature of the job and the facility: They can alter the short-term and the long-term processing logic and facility.

- Schedulers use their intuition, when appropriate, to fill the "blanks" about what is happening and what will happen on the floor.

- Many operational, physical, process planning, work force, and administrative constraints can affect the scheduling of different parts at different times.

- Many schedulers have been using simple sequencing logic (shortest processing time, first come-first served, earliest due date, highest priority, keeping bottleneck machines loaded) without knowing the results of the research in this area. Schedulers use these rules for very short time horizons.

Researchers, generally speaking, try to model actual real life applications. Researchers efforts have been facing impossible hurdles when modeling multistage job shop environments: the theory is simply not developed enough (and will not be in the near future) to model such complex situations. The most recently rewarding results have been in the areas of efficient algorithms development and also in the area of effective heuristic approaches. While research needs to be continued in these two areas, present and future research should concentrate more on bridging the gap between the available research results and the actual complex real life applications. Presently, such applications are being modeled using computer simulation.

Shop Scheduling Studies by Simulation

The widespread availability of powerful computers, and the high level of sophistication of modern simulation languages, promise major advancement in understanding and modeling job shops. This section reviews the relevant shop scheduling studies which were conducted by means of computer simulation.

In a job shop environment, the priority dispatching rule is basically a conflict resolution rule in the sense that a decision is made on what job should be loaded next as soon as the machine is free. The possible improvement in shop efficiency due to a "look ahead" schedule (where jobs are purposely delayed) is not considered. Jobs are loaded on the available machine from the corresponding queue according to the value - maximum or minimum - of a certain attribute attached to each job in the queue.

Several researchers have compared the validity and efficiency of these rules in an attempt to find if there is any significant difference among them. Others have also studied the common impact of these dispatching rules when combined with different due date assignment rules.

A comprehensive review of the research on job shop priority dispatching rules was made by Blackstone, Phillips, and Hogg (1982), Conway, Maxwell, and Miller (1967), Elmaghraby (1968), More and Wilson (1967), Panwalker and Iskander (1977), and Sawaqed (1987). Blackstone, Phillips, and Hogg (1982) summarize the research on dispatching rules in a simple job shop setup saying that the shortest processing time (SPT) rule is the best rule when the shop does not set the due dates or sets very tight due dates or sets very loose due dates during highly congested periods.

In some of the well known studies, Ashour and Vaswani (1972) reported that the SPT rule was better than other rules when the performance measure was job lateness or shop flow time; Weeks (1979) and also Baker and Dzielinski (1960) reported similar results. Elvers (1973) studied ten priority dispatching rules in relation with five due date rules, all based on total work content (TWK). Elvers concluded that the SPT rule's performance is best as long as the due dates were assigned based on six times total processing time or less. He also noted that due date based rules produced more late jobs than the SPT rule. Eilon and Chowdhury (1976) reported that the percentage of late jobs under the SPT rule was lower than under the "First arrived at shop served first" rule (FAS).

Eilon and Hodgson (1967) observed that the job waiting time increased with the shop load, and that the SPT dispatching rule was the best for minimizing job waiting time. Nelson (1967) reported that the flow time variance is lower with the FIFO rule and higher with the SPT rule. However, he also reported that the SPT rule was better than the FIFO rule for reducing the mean flow time.

Conway, Johnson, and Maxwell (1960) simulated a non-assembly job shop in their study of the effect of thirteen different dispatching rules on the following four performance measures:

1. The distribution of times to complete a job.
2. The distribution of lateness of jobs.
3. The amount of work-in-process inventory.
4. The utilization of shop facilities.

Conway, Johnson, and Maxwell (1960) concluded the following: Priority rules differ very greatly with respect to the variance of the distribution of job lateness. At one extreme are the variance-minimizing lateness rules that favor the jobs with the greatest current lateness. At the other extreme are the rules that select jobs according to some characteristic that does not depend upon when this job arrived or when it is supposed to be completed. Rules of the latter type can have a variance 100 times as great as rules of the former type. Simple priority rules can do an effective job of reducing a weighted average completion time, as compared to the selection of jobs at random. A rule that simply segregated jobs into two classes, giving preference to members of one class, also proved to be effective. Determination of the point of division between the classes is important, but in the neighborhood of the optimum performance, the performance measure is not highly sensitive to the value used.

Conway (1965) also simulated a non-assembly job shop with the desire to complete the processing of individual jobs before the assigned due date. His investigation considered both the various methods that might be used to assign due dates and the various priority dispatching rules that might be used to enforce the assigned due dates. While he recognized the importance and impact on the performance measures of having the due dates assigned internally (i.e. by the shop), his conclusions mainly addressed the case where due dates are exogenous and arbitrary, without regard to the processing characteristics of the job itself, the other jobs in the shop, or the priority rule to be used. Conway concludes that none of the standard and obvious priority rules is particularly powerful under these conditions, even when the due dates were, on the average, attainable. Overall, Conway stated, one would probably have to conclude that the shortest processing time (SPT) priority rule exhibited the best performance of all the rules tested; the SPT rule was much less sensitive to the method of setting due dates and the degree of congestion in the shop. Conway also stated that the slack/operation rule is the best of the simple due date type of priority rules and that further development should be based on this rule, in particular, methods of introducing some "shortest processing time influence" into the rule would seem to be useful.

Elvers and Taube (1983) also simulated a non-assembly job shop. They were mainly concerned with two aspects of the job shop behavior:

1. The relevance of stochastic versus deterministic assumptions in job shop dispatching rules research over the same level of shop utilization.

2. The relative ranking of various priority dispatching rules (they used five rules) in a job shop environment over various levels of shop utilization.

The performance measure used by Elvers and Taube was the percentage of jobs completed on time. Their research was partly a continuation of a previous research conducted by Conway and Maxwell (1962), in which they concluded that the advantages of the shortest processing time rule over the random rule were not lessened by the introduction of uncertain processing time estimates.

Elvers and Taube's experiments were run under both the deterministic and the stochastic assumptions. For simulation runs under the deterministic assumption, the actual processing time was set equal to a predetermined processing time which was unique for each job. For simulation runs under the stochastic assumption, a randomly generated multiplier was used in converting from the predetermined (assumed) processing time to the actual processing time. The multiplier was generated from a triangular distribution with a mean of 1.0 and a range from 0.675 to 1.602. Job allowance time was calculated as a multiple of seven times the total of the predetermined processing time for the job.

Five different priority dispatching rules were used in Elver's and Taubes study:

1. Shortest predetermined processing time (SPT), which they called MINIM.

2. Earliest due date (EDD), which they called DUEDA.

3. Minimum current job slack (SLACK).

4. Minimum current job slack per remaining

processing time (JSPRP).

5. First in shop, first out (FIFO).

The above study resulted in the following recommendations:

1. Stochastic assumptions do not provide substantially stronger results in most situations. However, for utilization levels between 91.6 and 94.3%, the study showed that stochastic assumptions are more statistically significant (smaller p-values) concerning the best versus the second best dispatching rule than are those of deterministic assumptions.

2. The SPT rule outperforms other rules in the heavily loaded shop, which confirms several previous studies done on dispatching rules performance.

3. When shop utilization is below 91.6%, SPT is dominated by other dispatching rules. Based on the study figures, one could recommend changing the dispatching rule based on the utilization level: when utilization is low, use the SLACK rule. When utilization is in the range 87.6 to 91.6%, use the JSPRP rule. Above 91.6% utilization, use the SPT rule. If ease of application is important, use EDD rule for any utilization below 91.6%.

Baker (1984) noticed that, when the mean tardiness is the evaluation criterion, there appears to be conflicting results in the existing literature. He conducts simulation studies, trying to relate mean tardiness with the due-date tightness. His study concluded the following:

1. The SPT rule exhibits a very flat mean tardiness curve (versus due-date tightness), which gives rise to performance crossovers with nearly all other rules tested.

2. Slack-based rules offer no great advantage over simpler allowance-based rules.

3. Due-date assignment should reflect work content.

Barrett and Barman (1986) simulated a simple flow shop with two work centers, each having two identical machines. They studied the shop under a combination of five different dispatching rules, three different shop load levels, and two different levels of processing time variation.

The expected processing time of each job on each machine was drawn from an exponential distribution. The two levels of processing time variation were controlled using the following formula:

Actual Processing Time = Expected Processing Time + N

where N is a value drawn from a normal distribution with a mean of zero and a standard deviation of 0.3 and 0.6, thus creating two levels of variation in processing time.

The three levels of the shop load were controlled by changing the mean arrival rate of the jobs. The three shop load levels were 91% (considered high), 86% (considered medium), and 81% (considered low).

The five different dispatching rules used were:

- FIQ First arrived at queue served first.
- FAS First arrived at shop served first.
- EDT Earliest due date served first.
- SPT Shortest processing time served first.
- LPT Longest processing time served first.

The due dates were established based on the total work content using the following formula:

Due Date = Arrival time + 4 x Expected Processing Time.

Barrett and Barman used all possible combinations of the above conditions to study the effect on the following performance measures:

1. Number of completed jobs.
2. Percentage of tardy jobs.
3. Mean flow time.
4. Flow time standard deviation.

5. Mean lateness.

6. Lateness standard deviation.

7. Mean tardiness.

8. Mean waiting time.

After noting that the flow time mean, the lateness mean and the waiting time mean are three identical performance measures, the authors analyze their results as follows:

1. With regard to number of completed jobs, it was found that the level of the shop load has a significant effect. However, the level of variation in the processing time did not have a significant effect on the number of completed jobs regardless of the level of the shop load. The combination of dispatching rules on the two different work centers made a very slight influence on the number of completed jobs.

2. The LPT rule exhibited the worst results under almost all performance measures. Even when used in conjunction with any other rule at either work center, the LPT rule tends to deteriorate these performance measures. For the reasons just mentioned, the LPT rule should be avoided in a flow shop environment.

3. The SPT rule on both work centers resulted in the lowest flow time mean (which also results in the

lowest lateness mean and lowest waiting time mean), and the lowest percentage of tardy jobs. Excluding the LPT rule, the FAS rule on both work centers resulted in the highest flow time mean and highest percentage of tardy jobs.

4. The SPT rule on both work centers resulted in a high variance in flow time. The FAS rule on both work centers resulted in the minimum variance in flow time. The EDT rule on both work centers resulted in the minimum variance in lateness.

5. Any rule, when combined with another rule, retained its ability to improve or deteriorate any given performance measure. However, the first work center appears to be more crucial than the second one in this respect.

6. A significant improvement in mean tardiness can be achieved by combining the SPT and the EDT rules (SPT x EDT). Regardless of the shop load level and the processing time variation, SPT x EDT minimized the mean tardiness of late jobs.

7. The SPT x EDT combination consistently performed better than the EDT x EDT with respect to flow time mean, lateness mean, and percentage of tardy jobs.

8. Based on the average of the six combinations

for three shop load levels and two processing time variation levels, Barrett and Barman generally recommend the following:

- Use SPT x SPT when trying to minimize the percentage of tardy jobs, the flow time mean, the lateness mean, and the waiting time mean.

- Use SPT x EDT when trying to minimize the tardiness mean.

- Use EDT x EDT when trying to minimize the flow time standard deviation and the lateness standard deviation.

Although simulating a very simple flow shop with two work centers, Barrett and Barman's study can be considered as a stepping stone for any research involving the study of a shop with two bottleneck machines. However, it is important to note that the study conducted by Barrett and Barman did not include statistical analysis other than descriptive statistics.

Huang (1984) conducted a comparative study of priority dispatching rules in a hybrid assembly/job shop manufacturing both single components and multiple components products. Huang simulated a nine machine shop producing three different products (one assembly and two non-assemblies). Jobs were scheduled to arrive at the shop according to a Poisson distribution; the job's processing times at each machine center was generated randomly from an exponential distribution; job's due dates were determined as a constant multiple of the total estimated processing time along the longest path.

Among the twelve priority rules tested by Huang, the SPT (Shortest processing time) rule and the ASMF-SPT (Assembly jobs first with SPT as a tie breaker) rule performed very well with respect to measures like lateness, flow time, tardiness, staging time, and percentage of tardy jobs. The SPT rule was very effective in meeting the due dates and in reducing in-process inventory; the ASMF-SPT rule was competitive with the first one in these same performance measures, and also surpassed the SPT rule with respect to staging time. To combine the strength of these two rules, Huang simulated his shop using a MIXED rule: The MIXED rule applied the ASMF-SPT rule to all machine centers processing a component for an assembly job, and the SPT rule for all other machines. The MIXED rule improved the staging time statistics over the SPT rule and yielded better results with regards to lateness, flow time, and percentage of tardy jobs versus the ASMF-SPT rule, meaning that the MIXED rule did not improve on the better performer among the two simple rules. However, the MIXED rule achieved the minimum variation in flow time distribution when there were a higher percentage of assembly jobs.

By simulating a dual resource constrained system, Elvers and Treleven (1985) studied the relative performance of five priority dispatching rules as the routing pattern changed from being a full job shop, to two thirds job shop and one third flow shop, and finally one third job shop and two thirds flow shop. They also examined the effect of the routing pattern on each rule individual performance.

Elvers and Treleven concluded that, although the magnitude of the differences in performance of the dispatching rules changes with the change in the routing pattern, their rankings do not. The rankings indicated that the earliest due date (EDD) rule and the least slack per remaining number of operations (SPRO) rule performed best with regards to lateness variance; the SPT rule performed best with regards to percentage of tardy jobs, mean lateness, and mean time in queue. Elvers and Treleven analysis also indicated that the more flow shop routings there are, the more effective the priority dispatching rule becomes, resulting in productivity improvement. They recommend to attempt to convert as much as possible from job shop to flow shop.

In a work paper by Gunal, Smith, and Moras

(1988), the question of the interaction between a dispatching rule's performance and the job's operations sequence and processing time is addressed. The authors concluded that there exists an interaction between the operation time of a job on the busiest machine and dispatching rules. They also observed that the position of the operation on the busiest machine in the operation sequence of a job has some important effects on the performance of the different dispatching rules.

Sawaqed (1987) recently conducted one of the most extensive studies on simulating hybrid job shops. One of the several conclusions reached by Sawaqed was that the location of job shop bottleneck machines on job routings does not impact the relative performance of the best sequencing rules (such as the shortest processing time rule, the earliest processing time rule, and the assembly first rule), while bottleneck machine location has impact on the relative performance of other inferior rules. Sawaqed also concludes that "the most crucial element in managing a job shop is the management of its bottleneck machines. A good or a poor management of a job shop is reflected by a good or a poor management of its bottleneck machines. More than 96% of the potential improvement in job shop performance may be achieved by effectively managing its bottleneck machines... This may lead one to conjecture that a job shop can be represented by a subset of its machines which represents its bottleneck machines... Previous research in the context of dual constrained job shops has shown that the longest queue labour assignment rule is the best labour assignment rule. This is supportive of the result obtained (in Sawaqed's research) since a bottleneck machine most probably has the longest queue".

The same year Sawaqed's research was published, Fry, Philipoom, Leong and Smith (1987) published the results of their study on bottleneck machine position in a multi-stage job shop. Fry et al.'s job shop consisted of ten machines with two hypothetical multi-stage bill of material (BOM), each of the BOM having equal chance of being chosen. Three due date oriented dispatching rules were used to assign job priority; these rules were:

- Early Due Date (EDD).

- Branch Critical Ratio (BCR), [which is equal to (job due date - current time)/remaining processing time in branch].

- Branch Slack per Number of Remaining Operations (BS/NOP).

The jobs due date was assigned based on the total work on the critical path (TWKCP) according to the following formula:

$$\text{Due Date} = r + k(\text{TWKCP})$$

where r is the arrival date and k is an allowance factor. Two allowance factors were used in their research (3 and 5). Fry et al. considered the case of one bottleneck machine in their shop and changed its location in the multi-stage BOM to study the effect of the bottleneck location on different performance measures. They studied five different locations in the two BOM, which they called HIGATE, LOGATE, INTER, HITERM, and LOTERM. The HIGATE referred to a gateway operation located near the top of the BOM, the LOGATE referred to gateway operation located at the bottom of the BOM, the INTER referred to an intermediate operation, the HITERM referred to a terminating operation located high in the BOM, and the LOTERM referred to a terminating operation located low in the BOM. Figure 1 shows one of the two BOMs together with some of these locations identified.

Fry and his colleagues varied the location of the bottleneck machine and the operation this bottleneck machine performed throughout the two BOM to study the effect of the location on job shop performance. They found that the best combination for a bottleneck machine for most performance measures is at a gateway operation located at the lowest level of the BOM. They also found

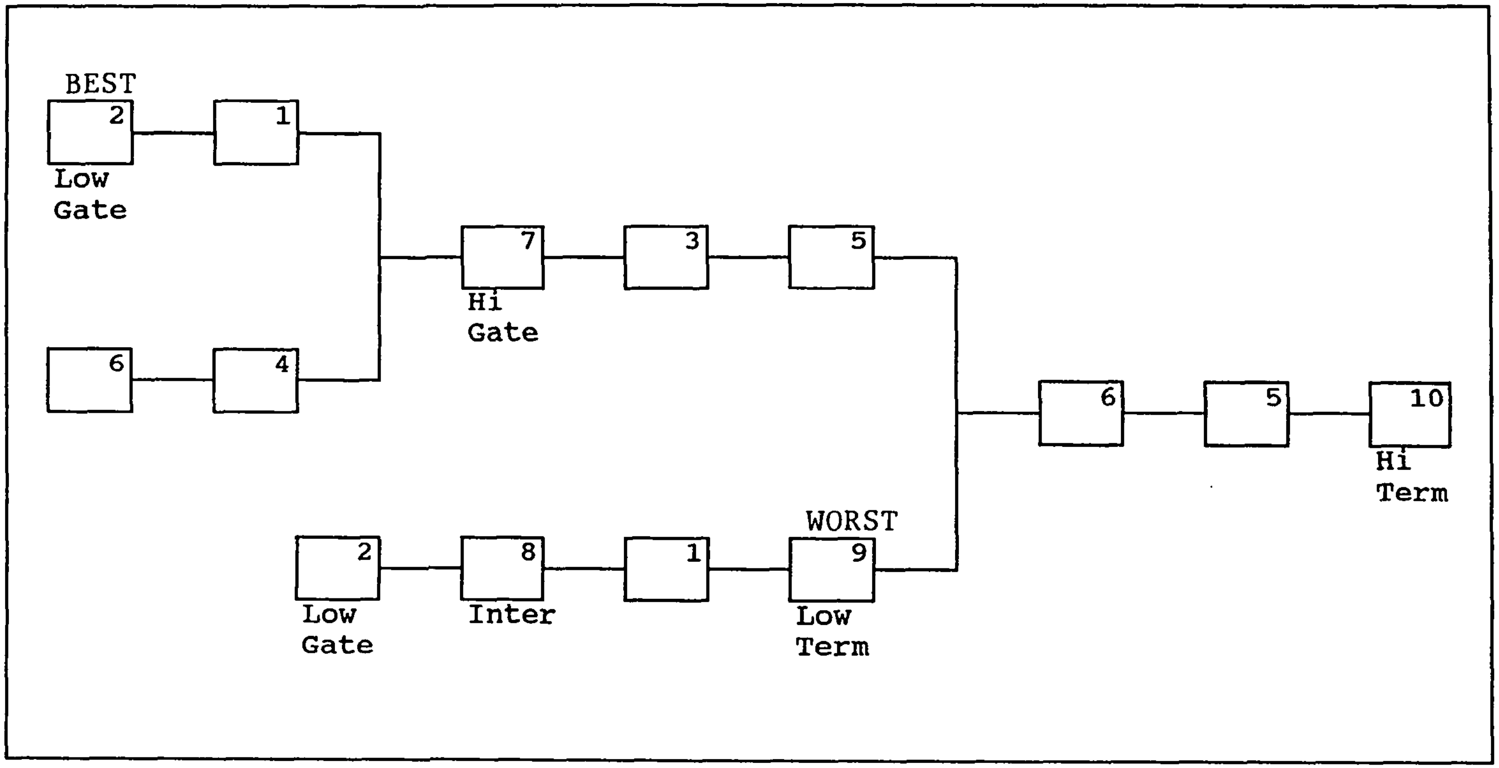


Figure 1. Bottleneck machine location identification for the Fry, Philipoom, Leong, and Smith study.

that the worst combination was a terminating combination located low in the BOM (refer to figure 1 for these two locations). They conclude that whenever a bottleneck machine is located at a low terminating location, it would be beneficial to open this bottleneck; however, if a bottleneck is located at a low gateway location, then shop performance may worsen if the bottleneck capacity is increased.

In 1988, Fry, Philipoom, and Markland (1988) published the results of another study which concentrated on a multistage assembly job shop with one bottleneck machine causing unbalance. They studied eight performance measures under twelve different priority dispatching rules. The two major objectives of that study were first to find if the different sequencing rules do not perform equally in a multistage job shop where capacities are not balanced, and second to determine whether sequencing rule performance will be the same for jobs which are routed through the bottleneck machine when compared to jobs which are not routed through the bottleneck machine. In their paper, Fry, Philipoom,and Markland confirmed that the operation performed by the bottleneck was distributed throughout the bills of material (BOM) to reduce any effect the location in the product structure of the bottleneck machine might have on the performance of the various dispatching rules; thus eliminating the important effect of the location of the bottleneck. As expected, no rule was found to be superior in all cases for all measures. Since all their jobs were assembly jobs, the Earliest Due Date rule had an slight edge, in general, over the other rules. However, while they stated that one of the rules under consideration is the SPT rule, they failed to report results under this rule.

The important results of this Fry, Philipoom, and Markland study is that no rule is superior in all cases for all measures, that different sequencing rules perform differently, that the performance of sequencing rules is not consistent for jobs which use the bottleneck machine and jobs which do not, and that the degree of capacity imbalance does not affect the ranking of the various sequencing rules. They also propose future research in the are of location of the bottleneck machine and how to schedule this bottleneck machine.

The results of the above studies lead to further investigation in the area of bottleneck machine management. More specifically, one wonders if it is possible to reduce the problem of job shop management to managing the bottleneck machines only. Is it possible to represent a job shop by its bottleneck machines only? If so, under what machine utilization levels? What is the effect of inaccurately estimating the process time on the bottleneck machines? Our research concentrates on the study of a two-bottleneck-machine job shop.

Gaps in the Research

We notice, from the above literature review, that the scheduling problem is still far from being well confined and well understood. The numerous factors involved in the scheduling problem makes it so easy to locate gaps in this research area. For this reason, we will list only the points which are of interest to us and which will be a factor in our research.

1. The three Johnson algorithms reviewed in the above literature review are optimal for certain performance measures under certain conditions. Researchers have not tried to expand on Johnson's algorithms trying to compare it with other sequencing rules. Will one of the Johnson's algorithms dominate some of the popular and commonly used priority dispatching rules, like the Shortest Processing Time?

2. Researchers have recognized the importance of managing the bottleneck machine, but very few of them addressed the importance of the location of the bottleneck. Does the location of the bottleneck in the

product structure significantly affect performance?

3. A lot of research was conducted in the area of one bottleneck machine setup but none in the area of two bottleneck machines setup. Can a two bottleneck machine setup be managed in a way similar to the one bottleneck machine setup? Can we make use of the Johnson's two-machine algorithms to manage a two bottleneck machines setup? Does the relative location of the two bottleneck machines impact the shop performance? What is the impact on performance when one of the two bottlenecks load is slightly increased or decreased?

4. Researchers have always studied and analyzed their simulation models while under steady state conditions. Job shops always experience times of slow demand as well as high demand. These times of slow demand cause a regenerating condition which can be modeled under transient conditions. Such conditions could favour Johnson's rules as these rules apply to a predefined number of existing jobs. How much of an impact will the time between jobs creation have on the relative performance of the different priority dispatching rules?

5. The actual processing time on each machine is always different from the assumed processing time. The difference between the assumed time and the actual time could vary depending on different factors, like machine

performance or human performance. Will a change in this difference have an effect on the way a shop should be managed?

The above points highlight some of the gaps in the area of shop scheduling research. We will explore some combinations of these gaps in our proposed research.

CHAPTER III

PILOT STUDY AND RESULTS

This chapter discusses the pilot study which was conducted before experimenting with the final model. It first highlights the main factors which were considered in this pilot study, describes the pilot study, and presents a summary report on the results which will have an impact on our decision concerning the final research model which will be presented in chapter 4.

The Basics of the Pilot Study

We have previously mentioned, in the research gaps section, that researchers have left numerous gaps in the scheduling field for others to explore. We have also listed some ideas which will form the basis of our research. We now intend to combine these ideas to form the boundaries around the pilot model we intend to study before we decide on the details of the research model

This pilot research will concentrate on comparing the results of using the Two-Machine Johnson

(TMJ) rule versus the most popular and most commonly used rule, the Shortest Process Time (SPT). The main idea is to explore the possibility of managing a production facility with two bottleneck machines by managing only the bottleneck machines, or by simply applying the Johnson rule.

In this pilot study, the impact of the following three factors will be assessed:

1. The level of the time span between the creation of consequent jobs (TBCREA).

2. The average level of deviation between the assumed processing time and the actual processing time (PCDEV).

3. The difference in average processing time between the first and the second bottleneck machines (DFAVPT). This will also help in identifying, in some particular cases, the preferred location of the bottleneck machine.

The following two performance measures will be analyzed:

1. The Total Flowtime (TFLOW). In this research, the Total Flowtime is defined as the elapsed time between the start of the first job and the finish of the last job.

2. The Average Time in System (AVTIS). In this research, the Average Time in System is defined as the average elapsed time between the start of a job and the finish of that same job.

The Pilot Study

A pilot study was conducted to get a preliminary understanding of the impact of the different factors involved in this research. This section will first describe the pilot model, and then gives a summary of the analysis and recommendations concerning the final model.

The Pilot Model

The pilot model consists of a shop with nine machines labeled M1-M9. Three different types of jobs (J1,J2,J3) are processed in this shop, all of which are series (non-assembly) jobs and all having the same probability of being created. The first job consists of three operations, the second of six, and the third of nine. The technological sequence of the process is as shown in figure 2.

The bottleneck machines are machines M1 and M2. In order to include the importance of the relative position of the bottleneck machines in our pilot study, we

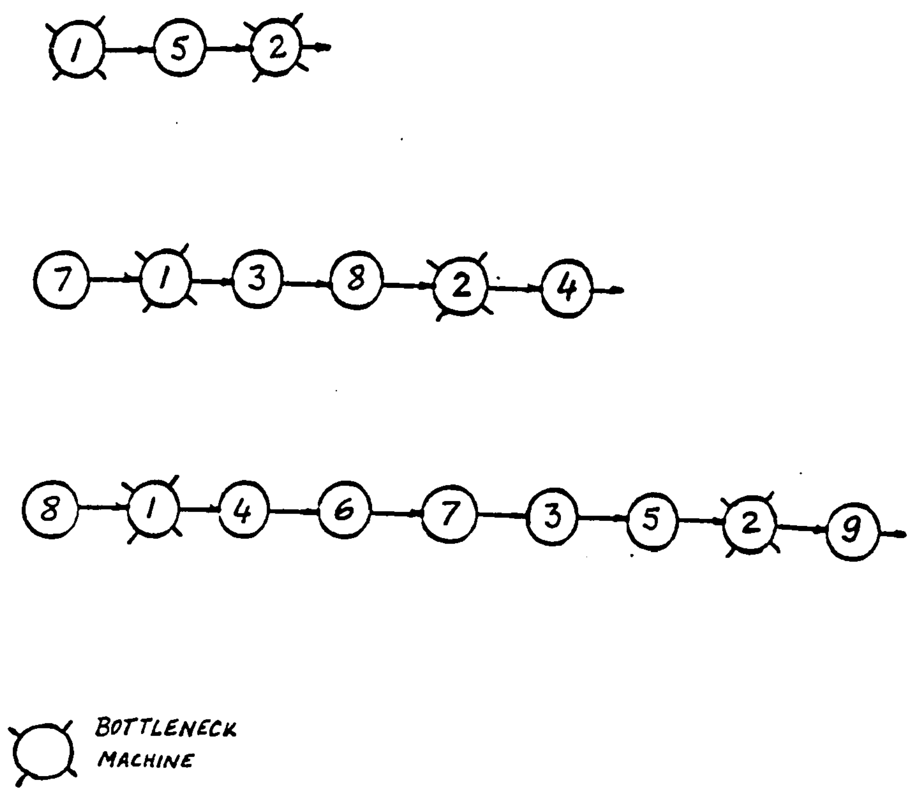


Figure 2. Task technological sequence for the pilot model

positioned machine M1 near the first task, and machine M2 near the last task on each job. This will enable us to analyze later the importance of the relative position of the bottleneck machines, as well as which of the two positions is more critical from a bottleneck point of view, by assessing the impact of the factor DFAVPT (difference in average process time) on shop performance. This implies that we have a situation similar to the flow shop on the two bottleneck machines, while in general the shop is a job shop.

Each simulation run consisted of one hundred jobs. The assumed processing time for non-bottleneck machines was randomly generated from a uniform distribution with a minimum of 2 and a maximum of 8 (The research model has different parameters). The assumed processing time for the bottleneck machines was also randomly generated from a uniform distribution, however the parameter of this distribution changed to create the different levels for the variable DFAVPT. These parameters and levels are summarized below:

	M1		M2		
LEVEL	MIN	MAX	MIN	MAX	DFAVPT
1	6.0	12.0	8.0	14.0	-2
2	6.5	12.5	7.5	13.5	-1
3	7.0	13.0	7.0	13.0	0
4	7.5	13.5	6.5	12.5	1
5	8.0	14.0	6.0	12.0	2

The TBCREA factor was considered under four different levels: 0, 4, 8, and 12 (The research model has a different number of levels). As our purpose is to study the effect of the three factors previously mentioned, it was decided to generate the time between job creation deterministically, thus eliminating any unnecessary contribution to variance due to a probabilistic time between job creation.

The variable factor PCDEV is a measure of the difference between the assumed process time (PTT) and the actual process time (PTA). When jobs are sequenced based on their process time, the assumed process time (in our case generated from a uniform distribution) is used. The actual process time on the machine is always different from the assumed one and we intend to experiment with the levels of this difference to find if this difference factor has an impact on the shop performance measures. The actual processing time is generated from a triangular distribution with a mode equal to the assumed process time, and two end points at a distance equal to a multiplying factor F times the actual processing time. Thus if the actual processing time is equal to 10 and the factor F is equal to 0.25, then the actual process time will be a random variable drawn from a triangular distribution which has a mode of 10, a minimum of 7.5 and a maximum of 12.5. Four different levels for the factor PCDEV (i.e. F) were used for the pilot model under study, these levels are: 0.25, 0.50, 0.75, 1.00 (The research model has a different number of levels).

The probability distribution of the actual process time is therefore a stochastic distribution where the parameters are a random variables.

The above three factors (DFAVPT, TBCREA, and PCDEV) resulted in eighty different treatments.

Each job was first created then sequenced independently in two different ways: the first way according to TMJ rule on the first bottleneck machine and first-in-queue-first on the other machines, and the second way according to the SPT rule on all machines. The fact that parts are processed on non-bottleneck machines between the two bottleneck machines seriously upsets the TMJ original sequence (in the research model simulations, the jobs will be resequenced according to the TMJ rule on all machines). We made sure that the same job parameters were used in the two sequencing methods (i.e. we cloned each job), thus eliminating any within treatment variances due to random error other than in the three factors under study.

To eliminate any between treatment variances, the assumed process time of all the jobs on all machines was stored in an array and repeatedly used for all eighty treatments. Ten simulation runs were conducted. The assumed process time array was initialized with new values at each run.

The simulation was run using Slamsystem. Figure 3 shows the Slamsystem simulation network for the pilot model in a graphical form, highlighting the major segments.

The standard Slamsystem output report was not used. Instead, FORTRAN user inserts were used to generate the required data in a form that is readily available to be transferred and analyzed by the SAS statistical package on a VAX computer. Some of the SAS output was also generated as a data file that was transferred back to the micro-computer and run under Microsoft Excel for better presentation and analysis.

The data that was collected from the simulation consisted of the following:

1. Treatment number (TRTM)
2. Run number (RUN)
3. Rule, Johnson [JF2] or SPT [SS2] (RULE)
4. Average process time on M1 (AVPT1)

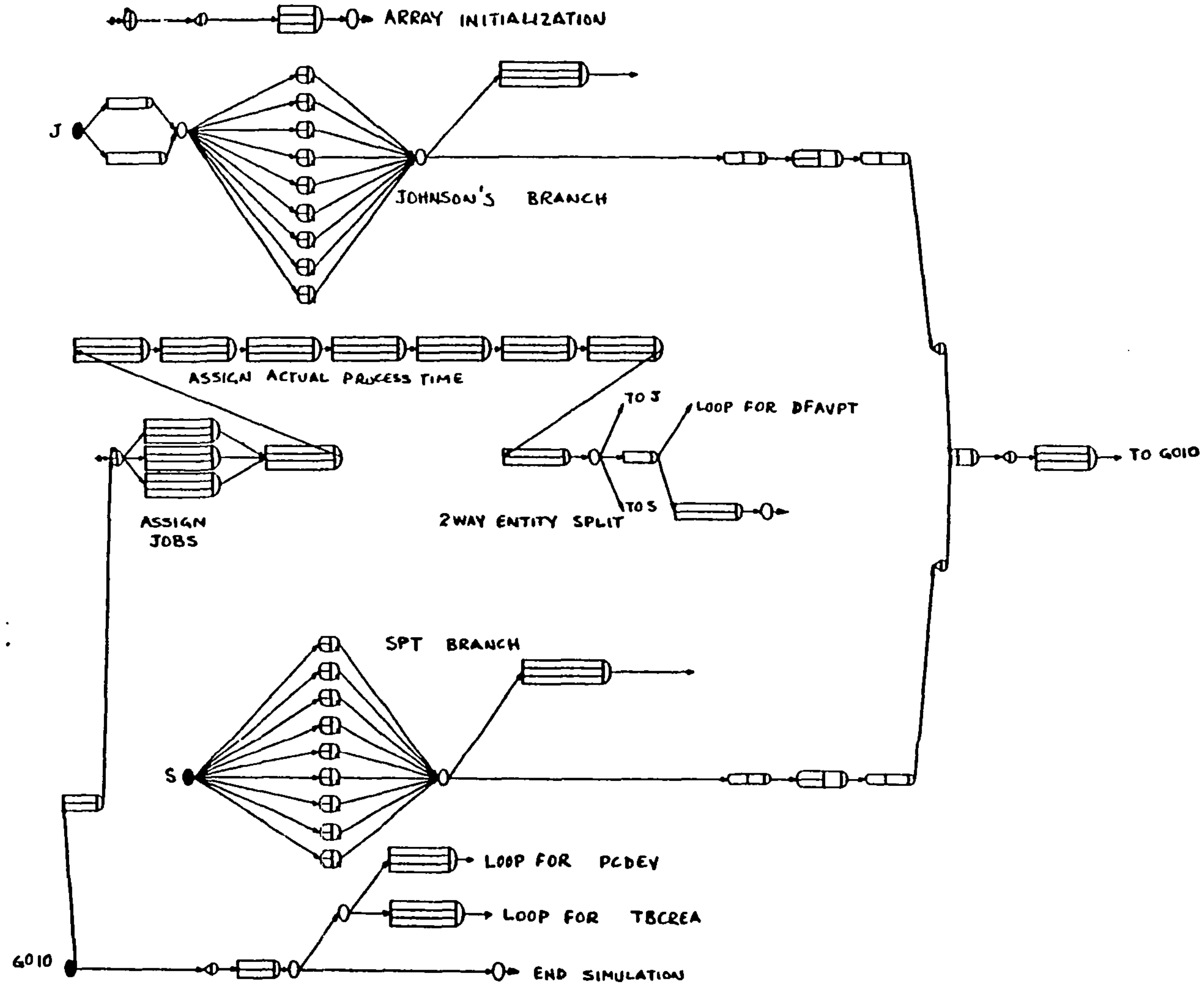


Figure 3. Simulation network for the pilot model

5. Average process time on M2 (AVPT2)

6. Average time in system (AVTIS)

7. Maximum time in system (MXTIS)

8. Total flow (TFLOW)

9. Standard deviation of time in system (SDTIS)

10. Difference in average process time (DFAVPT)

11. Time between creation (TBCREA)

12. The multiplying variation factor F (PCDEV)

13. Utilization of the nine machines (UT1 - UT9)

The data file consisted of 1600 entries, each entry included the 21 variables listed above.

The Pilot Study Analysis and Results.

In this and the following section, we will report on the results of the statistical analysis which was conducted on the pilot model. Several statistical tests were run and graphical plots were studied before coming to the conclusions listed below. As these results pertain to the pilot model only, we will present the results without going through the details of the statistical analysis. A complete statistical analysis will be presented when studying the final research model.

As the intention in this pilot study is to compare two methods of jobs sequencing, our statistical tests will be conducted on the paired data generated by the two sequencing rules. Therefore two new dependent variables are created, which are equal to the difference between the already existing dependent variables (performance measures):

1. The difference in total flow time:

TFLOWDIF = TFLOW(SPT) - TFLOW(TMJ)

2. The difference in average time in system:

AVTISDIF = AVTIS(SPT) - AVTIS(TMJ)

A three factor analysis of variance (ANOVA) procedure was run on each of these two dependent variables. For both variables, results consistently indicated that the different levels of the two factors DFAVPT and TBCREA had a significant impact on the two performance measures at the 95 percent significance level, while the levels of the factor PCDEV did not show statistically significant differences between the two sequencing rules. The ANOVA procedure also showed significant interaction between the two variables DFAVPT and TBCREA and no other interactions.

The data analysis also indicated that the difference between the two performance measures becomes insignificant as the value of the independent variable TBCREA increases to 8 and 12.

The Pilot Study Results Summary

From the above results, we can conclude the following:

The PCDEV factor, which is a measure of the difference between the assumed and the actual process time, does not have any significant impact on the two performance measures (TFLOW and AVTIS) when considered under the four levels stated above. The two other factors (DFAVPT and TBCREA) do have a significant impact on these same two performance measures. The impact of the factor TBCREA decreases as its value increases. These results will be taken into consideration when finalizing the research model.

It is to be noted that the Johnson rule was seriously handicapped by not resequencing the jobs on the second bottleneck machine, and by the large number of machines inserted between the two bottleneck machines. Both of these factors will be eliminated in the final research model.

CHAPTER IV

EXPERIMENTAL RESEARCH MODEL AND EXTENSION

This chapter describes and justifies the research model and, its extension, and the main statistical test which will be used later. In this chapter, we reiterate some of what we described in the previous chapter 3. This obvious repetition is intentional as some readers might not be interested in going through the pilot model, and instead cover only the research model.

Research Model Description

This section describes the experimental research model. Some of the conclusions previously highlighted as results of the pilot research are used to decide on the research model, its boundaries, and its limitations. A necessary extension to the original. model, and another optional extension are discussed, implemented, and later analyzed.

The experimental research simulation model needs to be built in a way providing enough flexibility to test different alternative sequencing rules, and at the same time robust enough to efficiently cover all combinations of all possible factors under study in a reasonable span of simulation time. As computer simulation runs could take a long time to initialize and then to complete, we have decided to incorporate, in our simulation model, some looping to cover all possible levels and combinations of three of the five factors we wanted to study. The combinations of the two other factors were dealt with as separate simulation runs for each combination. All these combinations are explained later.

Two performance measures are used as decision criteria for studying four different sequencing rules under different conditions. These two criteria are:

1. The Total Flowtime (TFLOW). In this research, the Total Flowtime is defined as the elapsed time between the start of the first job and the finish of the last job.

2. The Average Time in System (AVTIS). In this research, the Average Time in System is defined as the average elapsed time between the start of a job and the finish of that same job.

Table 1 summarizes the performance measures, the factors under consideration, and the total number of simulations.

The total flow time is of major importance in a job shop environment as it represents the total time needed by the shop to finish a certain set of jobs. Machine utilization is also directly related to the total flow time. The average time in the system is a commonly used performance measure for evaluating the general performance of a sequencing rule. This research will consider the first measure (TFLOW) a primary performance measure, and considers the second (AVTIS) a secondary performance measure.

Most simulation studies are conducted under steady-state conditions after a long warm-up period. This research is conducted without any warm-up as we believe it will better represent a job shop which receives an order for several jobs, and the aim of the shop manager is to finish and deliver such an order in the shortest period of time. In such an environment, jobs are available for processing at a particular point in time, with an estimated process time for each operation: the job of the shop planner is to sequence these jobs in order to minimize the time between the start and the finish of this particular order. This approach is also applicable to the

A. PERFORMANCE MEASURES: TFLOW and AVTIS

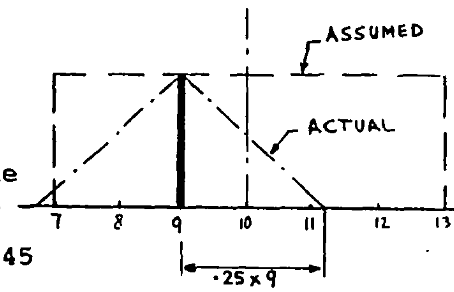
Primary performance measure: Total Flow Time: **TFLOW**
Defined as the time between the start of the first job and the end of the last job.

Secondary performance measure: Average Time In System: **AVTIS**
Defined as the average time a job remains in the system (or shop).

B. FACTORS CONSIDERED

1. Time Between Job Creations: **TBCREA**
Deals with the time between job arrivals to the shop. A value of zero means that all jobs are available at the starting time.
Two levels: 0 and 4

2. Percent Deviation: **PCDEV**
Deals with the degree of deviation between the assumed process time and the actual process time on each machine.
Three levels: .05, .25, .45



3. Difference in Average Process Time: **DFAVPT**
Deals with the relative load (criticality) of each of the two bottleneck machines. A positive value means that the first bottleneck is more critical than the second, and vice versa.
Five levels: -2, -1, 0, 1, 2

C. OTHER FACTORS

1. Bottleneck machines location: 6 locations

2. Sequencing rule: 4 rules

D. SIMULATION COMBINATIONS

RUNS: each treatment was simulated 20 times :	20 runs
TREATMENTS: 2 TBCREA x 3 PCDEV x 5 DFAVPT :	30 treatments
RULES :	4 rules
BOTTLENECK MACHINES LOCATIONS :	6 locations
TOTAL NUMBER OF SIMULATIONS (RECORDS):	**14,400 simulations**

Table 1. Summary of the performance measures, the factors under consideration, and the total number of simulations

case where the job shop passes through a period of slow demand, thus creating a regenerative condition.

We will be studying the effectiveness of the Two-Machine Johnson rule when applied to simple assembly jobs in a job shop environment with two bottleneck machines. The main idea is to explore the possibility of managing a production facility with two bottleneck machines by managing only the bottleneck machines or by simply applying the Johnson rule.

The research model consists of a shop with nine machines labeled M1-M9. Three different types of jobs (J1, J2, J3) are processed in this shop, all of which are simple assemblies and all having the same probability of being created. The first job consists of eight operations, the second of six, and the third also of six. The product tree of these jobs and the technological sequence of the operations is as shown in figure 4. We will label the bottleneck machines M1 and M2.

We had originally intended to position these two bottleneck machines in two stationary positions on the product tree, and study their effect on the performance measures. However, in order to include the importance of the relative position of the bottleneck machines in our research, we have to study all possible combinations of bottleneck machine positions. This enables us to analyze

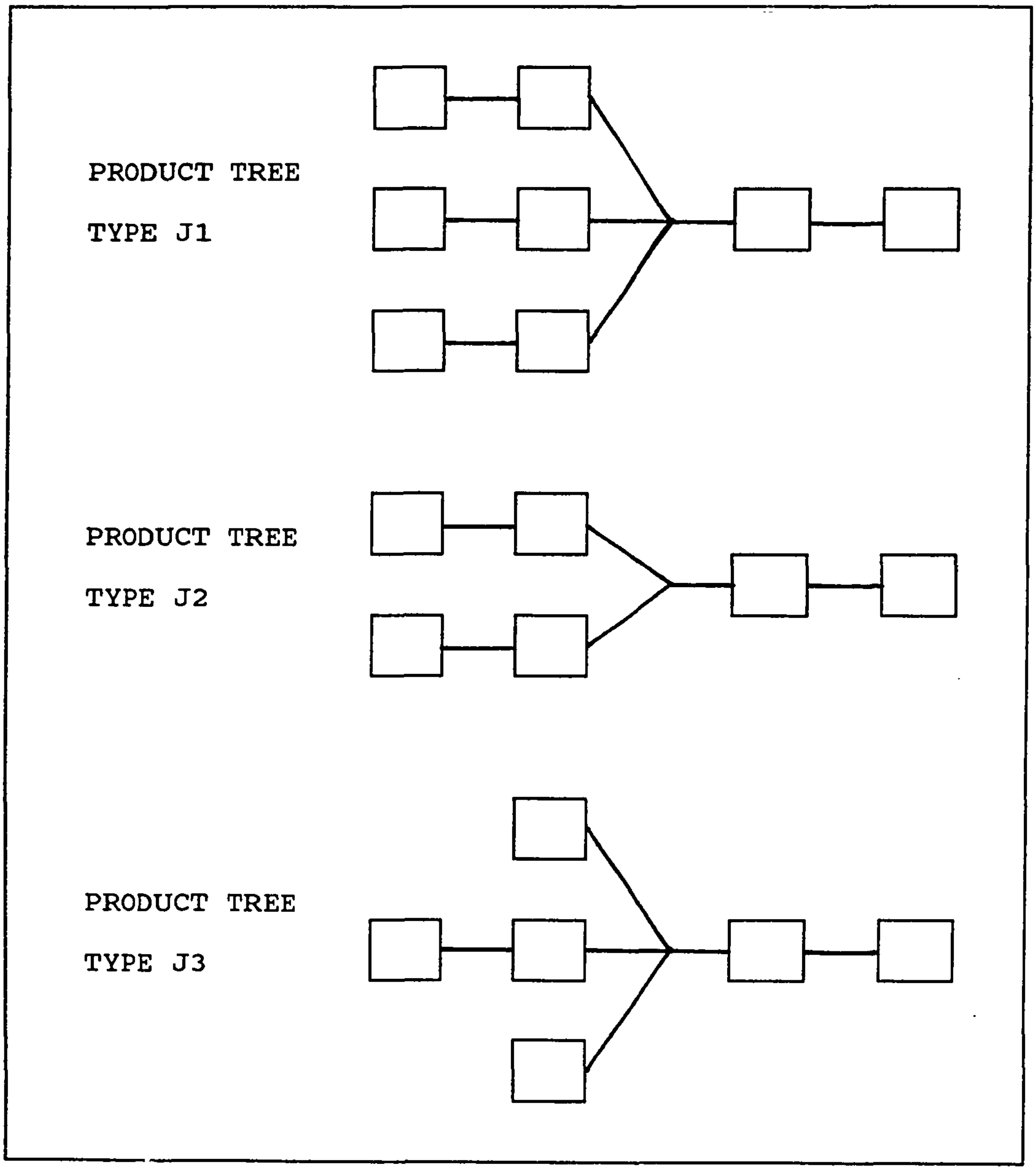


Figure 4. Product tree of the three jobs of the experimental model

later the importance of the relative position of the bottleneck machines, as well as which of the two positions is more critical from a bottleneck point of view, by assessing the impact of the variable DFAVPT (difference in average process time) on shop performance. As each part of each job goes through four operations, we will study six different bottleneck locations covering all possible combinations (4.C.2). These six levels of bottleneck machines location make the "necessary extension" we previously referred to. The location of the bottleneck machines in each of these six situations is shown in figure 5.

Other than the above factor, we also include the three factors which were considered in the pilot study. these three factors are:

1. The level of the time span between the creation of consequent jobs (TBCREA).

2. The average level of deviation between the assumed processing time and the actual processing time (PCDEV).

3. The difference in average processing time between the first and the second bottleneck machines (DFAVPT). This will also help in identifying, in some particular cases, the preferred location of the bottleneck

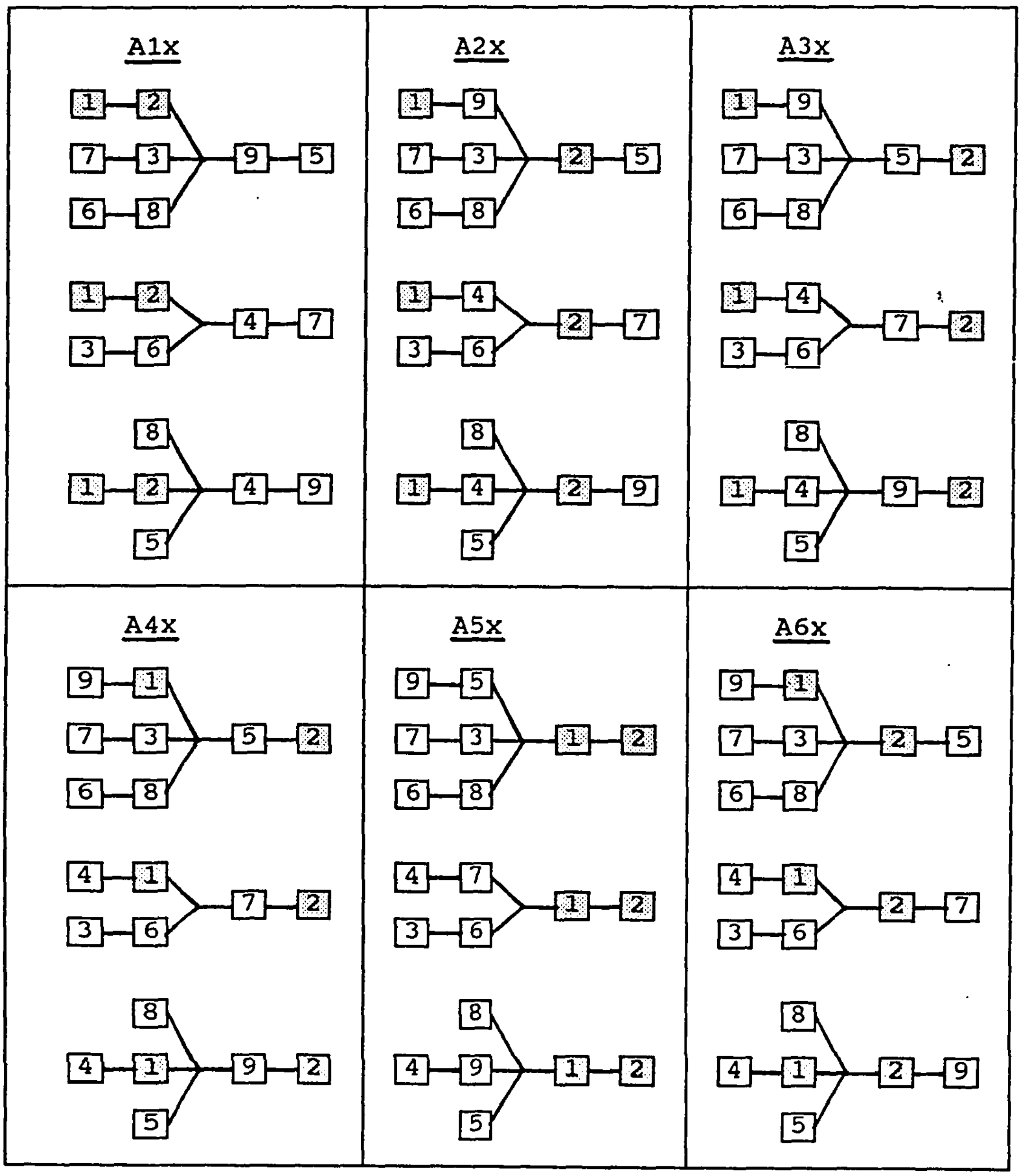


Figure 5. Location of the two bottleneck machines in the six combinations

machine in a setup with one bottleneck machine.

Based on the results of the pilot study, the level values of the above factors are modified as follows:

1. The TBCREA factor is considered under two levels: 0 and 4. The other two levels of 8 and 12, which were considered in the pilot study, are dropped because the pilot study showed no significant results at these higher levels.

2. The PCDEV factor is considered under three levels: 0.05, 0.25, and 0.45. The variable factor PCDEV is a measure of the difference between the assumed process time (PTT) and the actual process time (PTA). When jobs are sequenced based on their process time, the assumed process time (in our case generated from a uniform distribution) is used. The actual process time on the machine is always different from the assumed one and we intend to experiment with the levels of this difference to find if this difference factor has an impact on the shop performance measures. The actual processing time is generated from a triangular distribution with a mode equal to the assumed process time, and two end points at a distance equal to a multiplying factor F times the actual processing time (The probability distribution of the actual process time is therefore a stochastic distribution where the parameters are a random variables). The above

stated levels were reduced from the higher levels (0.25, 0.50, 0.75, and 1.00) of the pilot study because that study showed no significant results at these higher levels. This lack of significance could have been caused by high variances caused by the high PCDEV values used in the pilot study; reduced level values of PCDEV could give more significant results.

3. The DFAVPT factor is considered under the same levels as the pilot study. The assumed processing time for the bottleneck machines is randomly generated from a uniform distribution, however the parameters of this distribution change to create the different levels for the variable DFAVPT. These parameters and levels are summarized below:

	M1		M2		
LEVEL	MIN	MAX	MIN	MAX	DFAVPT
1	6.0	12.0	8.0	14.0	-2
2	6.5	12.5	7.5	13.5	-1
3	7.0	13.0	7.0	13.0	0
4	7.5	13.5	6.5	12.5	1
5	8.0	14.0	6.0	12.0	2

The assumed process time for the non-bottleneck machines is generated from a uniform distribution with a minimum of 7 and a maximum of 13. The average processing time for the non-bottleneck machines is therefore the same as the bottleneck machines, but the bottleneck machines M1 and M2 are used for more operations than the other machines. In fact, two uses of each of the non-bottleneck machines correspond to three uses of each of the bottleneck machines. This is apparent from figure 5 where we can see that in each case machines 1 and 2 are used three times, while machines 3 to 9 are used twice. The average load time on machines 3 to 9 is therefore equal to 2/3 of the average load on machines 1 and 2.

The original intention was to experiment with two rules, the Two-machine Johnson rule (please refer to chapter two for the details of this rule) and the Shortest Process Time rule. For the purpose of our research, the Two-machine Johnson rule means that parts will have to be resequenced, in front of each machine, according to the Johnson rule, every time a new part enters the queue; the Shortest Process Time rule means that parts will have to be resequenced, in front of each machine, according to the Shortest Process Time rule, every time a new part enters the queue.

While the above mentioned two rules formed our basic research experiment, we intended to extend our research later to two additional rules which are variations on the Two-machine Johnson rule. These two additional rules add the impact of parts synchronization to our model. However, we realize that it would be more appropriate not to separate the basic model analysis from the model extension, and therefore analyze the impact of all four rules at the same time.

The four rules are shown in table 2 and are defined as follows:

1. JNP (Johnson No Priority) rule, which is the same as the Two-machine Johnson rule we have been referring to.

2. JHP (Johnson Half Priority) rule, which still applies the JNP rule on all machines, but gives first priority to parts on which an operation has been performed. This priority will apply only on parts before the assembly stage. Ties in priority levels are broken by the JNP rule.

3. JFP (Johnson Full Priority) rule, which still applies the JNP rule on all machines, but gives first priority to parts on which operations have been performed. This priority will apply on all parts before and after the assembly stage. The more operations are performed on a certain part, the higher is the priority of that part. Ties in priority levels are broken by the JNP rule.

4. SPT (Shortest Process Time) rule, which gives priority to parts having a shorter expected process

THE FOUR SEQUENCING RULES

JNP (Johnson No Priority) rule

The Two-machine Johnson rule sequence (on the two bottlenecks) applied on all machines. Each time a part enters a queue, that queue is resequenced according to the two-machine Johnson rule as applied on the two bottleneck machines.

JHP (Johnson Half Priority) rule

Applies the JNP rule on all machines, but gives first priority to parts on which an operation has been performed. This priority will apply only on parts before the assembly stage. Ties in priority levels are broken by the JNP rule.

JFP (Johnson Full Priority) rule

Applies the JNP rule on all machines, but gives first priority to parts on which operations have been performed. This priority will apply on parts before and after the assembly stage. The more operations are performed on a certain part, the higher is the priority of that part. Ties in priority levels are broken by the JNP rule.

SPT (Shortest Process Time) rule

Gives priority to parts having a shorter expected process time.

Table 2. Description of the four sequencing rules

time.

The first and the fourth rules constitute the basic research, while the second and the third rules constitute the extension which we previously referred to as "optional extension" to the basic research.

Contrary to the pilot simulation runs where each job was run under the two sequencing rules at the same time (by cloning each part), in the research simulation we ran each rule separately. As we have six different bottleneck machine locations (code A1x - A6x) and 4 different rules, we had to run 24 different simulations, and each of the 24 simulations was run 20 times (replications) for each combination of TBCREA (2 levels), PCDEV (3 levels), and DFAVPT (5 levels). These last three factors resulted in thirty different treatments. Each output data file consisted of 600 records, for a total dataset consisting of 14,400 records (24 x 600). Table 3 shows the 24 different output data files, generated by the different simulation runs, for possible future reference:

M1-M2 Location:	A1x	A2x	A3x	A4x	A5x	A6x
Rule:						
JNP (x1)	A11	A21	A31	A41	A51	A61
JHP (x2)	A12	A22	A32	A42	A52	A62
JFP (x3)	A13	A23	A33	A43	A53	A63
SPT (x4)	A14	A24	A34	A44	A54	A64

Table 3. Reference tabulation for the 24 data files.

To eliminate between-treatment variances, both assumed and actual process times of all jobs on all machines were stored in an array and repeatedly used for all thirty treatments. This approach guaranteed that the same stream of process time values was used in all treatments. The assumed and actual process time array was initialized with new values in each of the twenty runs. Such a design was necessary for the paired-data statistical tests which were conducted later. A representation of the Slam II array is shown in figure 6.

The simulation was run using Slamsystem under the Microsoft Windows environment on an AT class micro-computer using an Intel 80286 microprocessor and an Intel 80287 math co-processor. The computer was also equipped with 4 megabytes of extended memory. Each of the twenty four simulations took around six hours to complete. Figure 7 shows the Slamsystem simulation network for the research model in a graphical form, highlighting the major segments of the model. The upper segment of the network was used for the Johnson rule and the two extensions, while the lower segment was used for the Shortest Process Time rule. The detailed simulation network is attached to the back cover of this document.

The standard Slamsystem output report was not used. Instead, FORTRAN user inserts were used to generate

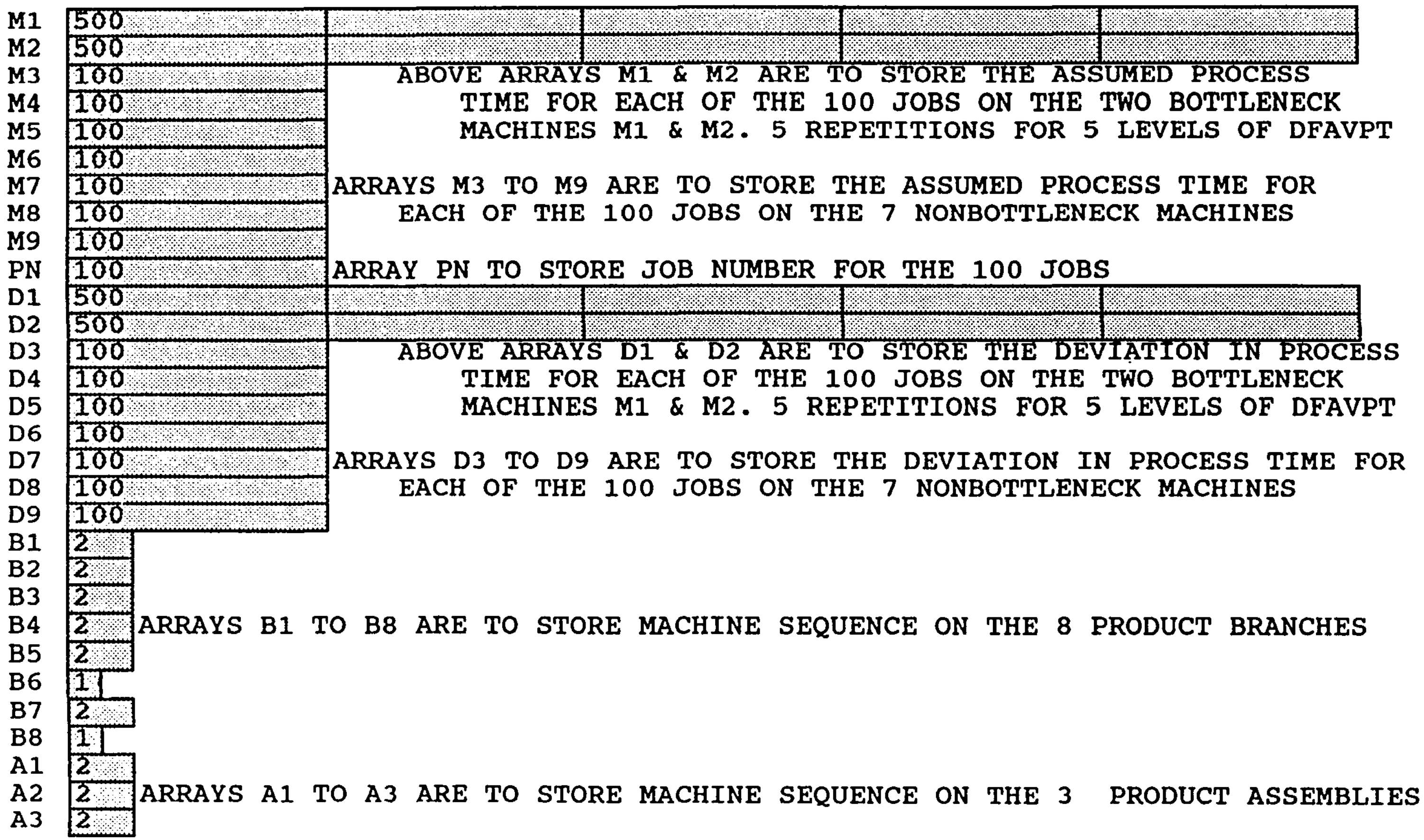


Figure 6. Representation of the Slamsystem storage array

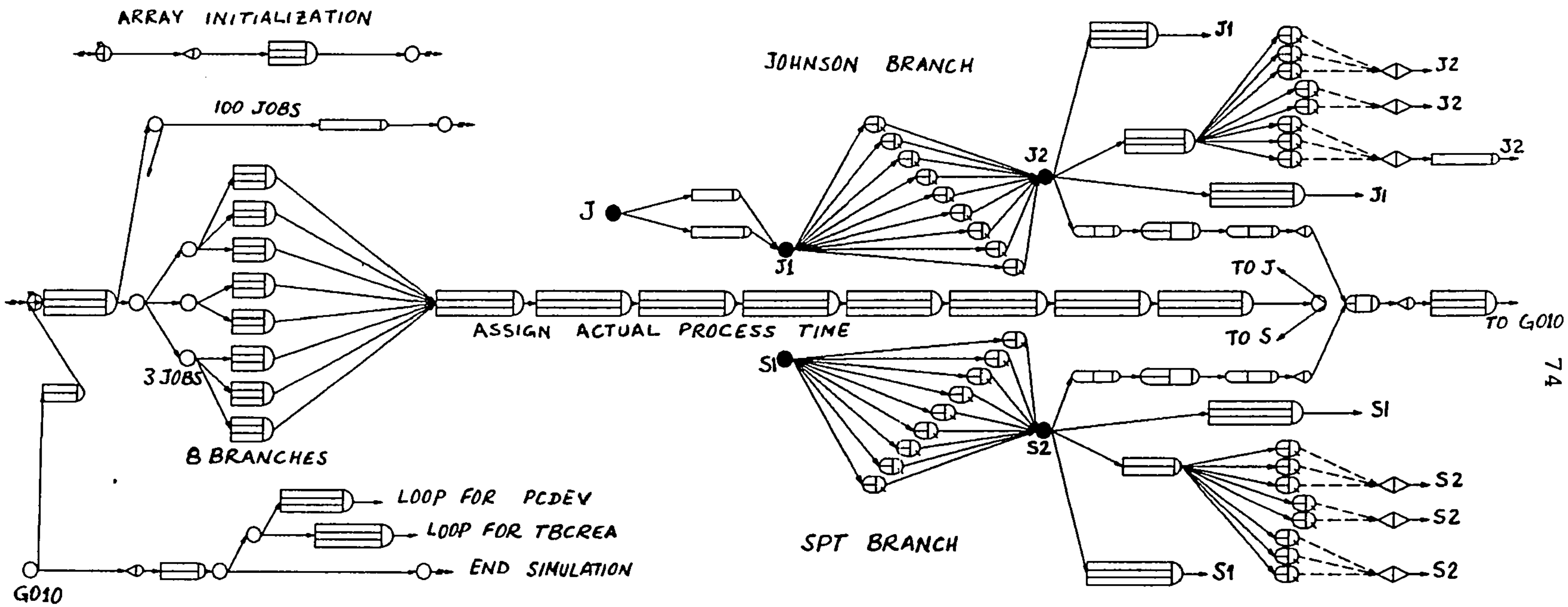


Figure 7. Simulation network of the research model

the required data in a form that is readily available to be transferred and analyzed by the SAS statistical package on a VAX computer. The Slamsystem Control, Network Statements, and FORTRAN Events files are enclosed in the appendixes 1, 2 and 3 respectively.

The data that was collected from the simulation consisted of the following:

1. Treatment number (TRTM)
2. Run number (RUN)
3. Rule, Johnson [JF2] or SPT [SS2] (RULE)
4. Average process time on M1 (AVPT1)
5. Average process time on M2 (AVPT2)
6. Average time in system (AVTIS)
7. Maximum time in system (MXTIS)
8. Total flow (TFLOW)
9. Standard deviation of time in system (SDTIS)
10. Difference in average process time (DFAVPT)
11. Time between creation (TBCREA)
12. The multiplying variation factor F (PCDEV)
13. The simulation model [11 - 64] (MODEL)
14. Utilization of the nine machines (UT1 - UT9)

A sample of a data file (for model 31) is included in appendix 4. Machine utilization tables are included in appendixes 5 and 6.

Analysis Methodology.

This section describes the statistical testing methodology and the statistical tests which were performed on the data generated by the different simulation runs.

Later in this study we will show that no significant interaction exists between the factor PCDEV and the different sequencing rules. For this reason, we will conduct our study using only one level of the factor PCDEV, mainly 0.25. The purpose of this study can therefore be summarized as detecting any statistically significant differences in the two performance measures TFLOW and AVTIS due to the application of the different sequencing rules and the different bottleneck machines locations, under the different levels of the two factors TBCREA, and DFAVPT.

Skewness and kurtosis were calculated for all the data of interest. The kurtosis values indicated that the data was not close to a normal distribution. These results indicated to us that it would be more appropriate to use nonparametric statistics for our statistical tests of significance. The multi-comparison Friedman test (1937, 1940) was initially tried, but preliminary results indicated that this test was not powerful enough to result in significant differences. We therefore decided to use pairwise comparison.

As our intention is to compare two methods of sequencing, our statistical tests can be conducted on paired data generated by two different sequencing rules. Therefore, for each paired set of dependent variables we wanted to compare, we needed to create a new variable made out of the difference of the two original variables. For example, when the two rule JNP and SPT are compared on the basis of the total flowtime (TFLOW) and the average time in the system (AVTIS), the analysis should be conducted on the two new variables TF(JNP.SPT) and AV(JNP.SPT), where:

$$TF(JNP.SPT) = TFLOW(JNP) - TFLOW(SPT)$$

$$AV(JNP.SPT) = AVTIS(JNP) - AVTIS(SPT).$$

As we wanted to perform paired tests on four different rules, we found it more appropriate to select one of the four rules as our basis, and test the other rules with respect to this basis, instead of dealing with all different combinations. Since we are mainly concerned with the two-machine Johnson rule, we found it most appropriate to compare the performance of the different rules with the performance of the JNP rule.

For each of the six different bottleneck machines locations, six variables were created. These variables are:

TF(JNP.SPT) = TFLOW(JNP) - TFLOW(SPT)

TF(JNP.JHP) = TFLOW(JNP) - TFLOW(JHP)

TF(JNP.JFP) = TFLOW(JNP) - TFLOW(JFP)

AV(JNP.SPT) = AVTIS(JNP) - AVTIS(SPT)

AV(JNP.JHP) = AVTIS(JNP) - AVTIS(JHP)

AV(JNP.JFP) = AVTIS(JNP) - AVTIS(JFP).

The same approach was used to decide on the testing methodology for any statistically significant difference in the two performance measures TFLOW and AVTIS due to the bottleneck machines locations, under the different levels of the two factors TBCREA and DFAVPT.

As we wanted to perform paired tests for six different bottleneck machines locations, we found it more appropriate to select one of the six locations as our basis, and test the other locations with respect to this basis, instead of dealing with all different combinations. Since the location coded 6x (bottleneck machines on second and third stages) seemed to be the preferred location whenever the JNP rule was not dominated, we found it most appropriate to compare this bottleneck machines location with all other five bottleneck machines locations.

The analysis was conducted on the case when the JNP rule is used. The PCDEV factor was also held constant at 0.25 for the above stated reason.

Ten new variables were created. These variables are:

TF61.11 = TFLOW(61) - TFLOW(11)

TF61.21 = TFLOW(61) - TFLOW(21)

TF61.31 = TFLOW(61) - TFLOW(31)

TF61.41 = TFLOW(61) - TFLOW(41)

TF61.51 = TFLOW(61) - TFLOW(51)

AV61.11 = AVTIS(61) - AVTIS(11)

AV61.21 = AVTIS(61) - AVTIS(21)

AV61.31 = AVTIS(61) - AVTIS(31)

AV61.41 = AVTIS(61) - AVTIS(41)

AV61.51 = AVTIS(61) - AVTIS(51)

Table 4 lists all 16 paired dependent variables.

Skewness and kurtosis were calculated for the above sixteen datasets for each combination of TBCREA/DFAVPT at a value of PCDEV equal to 0.25. The skewness and kurtosis values indicated that the data was

PAIRED VARIABLES

To study the effect of rules

TF(JNP.SPT) = TFLOW(JNP) - TFLOW(SPT)
TF(JNP.JHP) = TFLOW(JNP) - TFLOW(JHP)
TF(JNP.JFP) = TFLOW(JNP) - TFLOW(JFP)

AV(JNP.SPT) = AVTIS(JNP) - AVTIS(SPT)
AV(JNP.JHP) = AVTIS(JNP) - AVTIS(JHP)
AV(JNP.JFP) = AVTIS(JNP) - AVTIS(JFP)

To study the effect of the bottleneck machines location

TF61.11 = TFLOW(61) - TFLOW(11)
TF61.21 = TFLOW(61) - TFLOW(21)
TF61.31 = TFLOW(61) - TFLOW(31)
TF61.41 = TFLOW(61) - TFLOW(41)
TF61.51 = TFLOW(61) - TFLOW(51)

AV61.11 = AVTIS(61) - AVTIS(11)
AV61.21 = AVTIS(61) - AVTIS(21)
AV61.31 = AVTIS(61) - AVTIS(31)
AV61.41 = AVTIS(61) - AVTIS(41)
AV61.51 = AVTIS(61) - AVTIS(51)

Table 4. Listing of the sixteen paired dependent variables

in general not close to a normal distribution. The twenty values of a sample paired variable (TF41-44), together with the corresponding histogram, are shown in table 5. These results indicated to us that it would be appropriate to use nonparametric statistics for our statistical tests of significance. The Wilcoxon (1945) matched-pairs signed-ranks test will be used for that purpose.

Interpretation of the Wilcoxon Test Results

The Wilcoxon matched-pairs signed ranks test is a nonparametric test for location for two related samples. The test works under the following five assumptions:

1. The data consists of n values which are the calculated differences between the values of two paired sets of data.

2. The differences represent observations on a continuous random variable.

3. The distribution of the population of differences is symmetric.

4. The differences are independent.

5. The differences are measured on at least an interval scale.

The null and the alternative hypotheses must

TOTAL FLOW TIME (TFLOW)
MODEL 4x
DIFFERENCE BETWEEN JNP (41) AND SPT (44)
At TBCREA = 4, DFAVPT = 0, and PCDEV = .25

RUN	TF41-44
1	-120.5
2	-29.77
3	-6.76
4	-8.49
5	-50.32
6	-10.86
7	-4.58
8	-8.71
9	-10.45
10	-33.18
11	-37.18
12	23.44
13	-3.63
14	-20.14
15	-16.53
16	-39.57
17	-4.58
18	-9.71
19	-37.65
20	-13.88
MEAN	-22.152
MEDIAN	-12.37
Sk.	-2.145
Kr.	7.118

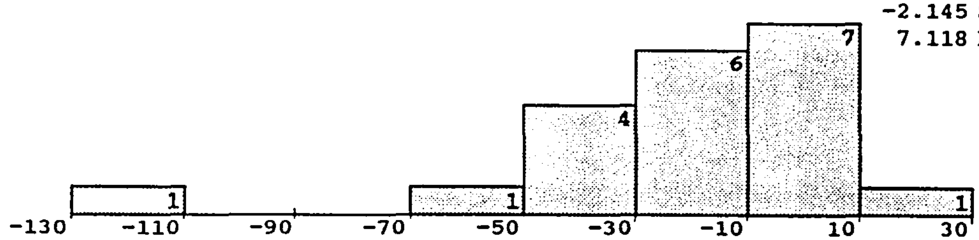


Table 5. Listing of the 20 values of the paired variable TF41-44 with histogram

first be defined. The hypotheses for the one-sided Wilcoxon test are (Daniel - 1978):

> Ho: The median of the population of differences is greater than or equal to zero.
>
> Ha: The median of the population of differences is less than zero.

A relatively large p-value leads us to fail to reject the null hypothesis, meaning there is not enough statistical evidence to prove that the median of the population of differences is different from zero, therefore there is not enough evidence to say that the median of the first population is smaller than the median of the second population. In such a situation, the population of differences is assumed to be symmetric, and we can deduce the same conclusion for the mean of the two populations as we did for the median of the two populations.

A relatively small p-value leads us to reject the null hypothesis and accept the alternative hypothesis, meaning there is enough statistical evidence to prove that the median of the population of differences is different from zero, therefore there is enough evidence to say that the median of the first population is smaller than the median of the second population. In such a situation, the population of differences is not symmetric. With a non-symmetric population of differences, conclusions regarding the median of the two populations generally apply to the mean of the two populations, but with a lower confidence level.

In this second case, the median of the first population being smaller than the median of the second population indicates that for the twenty simulation runs, the bulk of the performance measure data pertaining to the first set of data is smaller than the bulk of the performance measure data pertaining to the second set of data. Some extreme case values will have more effect on the mean than on the median, thus resulting in no statistically significant difference in the means. However, the majority of the first set of data is significantly smaller than the majority of the second set of data. The representation below clarifies the situation referred to above.

```
     x x x x x                                   x dataset 1
     x                                   x x x x x dataset 2
----------------------------------------------------------------
          ^       ^                    ^     ^
      median    mean                 mean   median
       of 1     of 1                 of 1    of 2
```

CHAPTER V

ANALYSIS OF RESULTS

In this chapter we report, study, and analyze our results. We also explain and justify these results.

We first explain our approach to the analysis of these results and then present a descriptive summary. We later study the impact of the deviation between the assumed process time and the actual process time (PCDEV). We then study the impact of the time between job creations (TBCREA). We also study the impact of the difference in average process time (DFAVPT). Because the results of the above studies show that the Johnson-no-priority (JNP) rule is recommended when the primary performance measure is the total flowtime, we therefore study the impact of the six locations of the bottleneck machines when the JNP rule is used.

General Approach to the Analysis of Results

In our model we have incorporated five different factors to study their effect on the primary performance measure TFLOW, and the secondary performance measure AVTIS. It is not advisable to study the impact of all these factors at once as it would be impossible to relate the results to practical situations, and therefore difficult to understand and use. We have therefore decided to study each factor at a time. At each step of our study, we will make use of the analysis and conclusions derived in previous steps. The detailed pilot study which was previously conducted helped to a great extend in identifying which of the factors we have to address first.

The first results we present will be a tabulated summary of averages and graphical representations of these averages. The tabulation indicates the possibility of absence of impact caused by the different levels of the factor PCDEV.

A study of the impact of the PCDEV factor is then conducted, and statistical tests of interaction confirm that, for the levels under consideration, this factor does not have any impact on the relative performance of the different sequencing rules. These results allow us to eliminate the PCDEV factor from further consideration and conduct our study at a fixed level of PCDEV, mainly 0.25.

An analysis of the results of the impact of the factor TBCREA is then conducted on the results of the Wilcoxon matched-pairs signed-ranks tests. This analysis shows that, with one exception, the Johnson based sequencing rules are recommended for both levels of TBCREA when the primary performance measure is TFLOW.

An analysis of the results of the impact of the factor DFAVPT is also conducted on the results of the Wilcoxon matched-pairs signed-ranks tests. This analysis shows that, with one exception, the Johnson based sequencing rule are recommended for all levels of DFAVPT when the primary performance measure is TFLOW.

The above results lead us to extend our analysis to study the impact of the six different locations of the two bottleneck machines. However, since the JNP rule proved to be a powerful rule in comparison with the other rules under consideration, the impact of the different bottleneck machines locations was assessed under the JNP rule only.

The impact of the other two modified Johnson rules, the Johnson-half-priority (JHP) and the Johnson-full-priority (JFP) rules, previously referred to as synchronization, is included in all the analysis referred to above.

Descriptive Results

This section presents, in tabulation and graphical forms, the summary results for the two performance measures TFLOW and AVTIS. It is to be noted that any analysis conducted in this section is a descriptive analysis on the mean of the performance measures. Statistical tests are conducted, and their results analyzed, in later sections.

Tables 6 and 7 tabulate the average value of TFLOW and AVTIS for the twenty simulation runs under all different combination levels of the five factors TBCREA, PCDEV, DFAVPT, bottleneck machines location, and sequencing rule. The four main horizontal sections of the tables correspond to the four sequencing rules in the following order: JNP, JHP, JFP, and SPT. The six main vertical sections represent the location of the bottleneck machine as follows:

1. Bottleneck machines on stages 1 and 2
2. Bottleneck machines on stages 1 and 3

TFLOW — MEAN — PCDEV

TBCREA	DFAVPT	MODEL=11			MODEL=21			MODEL=31			MODEL=41			MODEL=51			MODEL=61		
		0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45
0	-2	1126.4	1125.8	1125.3	1133.9	1133.0	1133.4	1140.4	1139.0	1139.3	1149.6	1149.3	1150.4	1135.6	1135.4	1136.4	1133.7	1133.5	1133.6
	-1	1080.1	1079.8	1079.6	1086.2	1085.6	1085.7	1091.9	1090.7	1091.4	1101.1	1100.3	1102.8	1086.3	1086.3	1087.6	1085.7	1085.2	1086.1
	0	1043.4	1044.2	1046.2	1045.7	1047.2	1049.3	1047.1	1047.6	1050.5	1051.8	1054.2	1055.8	1052.5	1054.7	1058.5	1041.8	1042.8	1046.6
	1	1075.9	1077.6	1079.8	1078.2	1079.5	1081.7	1077.0	1078.9	1081.8	1072.6	1074.3	1076.3	1093.8	1095.9	1099.7	1072.5	1073.9	1075.8
	2	1124.7	1126.6	1128.8	1125.7	1127.2	1129.4	1125.4	1127.4	1130.1	1121.9	1123.6	1125.6	1140.8	1143.6	1146.7	1121.9	1123.4	1125.2
4	-2	1126.8	1126.7	1126.6	1131.5	1130.9	1130.3	1137.8	1136.8	1137.9	1141.2	1140.0	1141.4	1134.3	1132.4	1132.7	1133.1	1131.9	1130.9
	-1	1081.0	1080.4	1081.3	1084.1	1082.7	1082.8	1090.5	1088.7	1088.9	1092.5	1093.9	1093.3	1084.9	1083.5	1084.2	1085.3	1084.2	1083.7
	0	1044.3	1045.7	1048.2	1046.6	1047.0	1048.8	1046.5	1046.8	1048.0	1050.0	1052.9	1050.7	1049.5	1050.3	1054.1	1042.9	1043.2	1044.9
	1	1076.1	1078.0	1079.8	1078.3	1079.8	1081.6	1077.0	1079.1	1081.5	1074.1	1075.8	1078.0	1087.5	1090.9	1092.9	1074.0	1075.5	1077.5
	2	1124.7	1126.6	1128.7	1125.7	1127.2	1129.3	1125.4	1127.4	1129.7	1123.3	1125.1	1127.2	1138.0	1139.2	1140.5	1123.3	1124.9	1126.8

TBCREA	DFAVPT	MODEL=12			MODEL=22			MODEL=32			MODEL=42			MODEL=52			MODEL=62		
0	-2	1126.4	1125.8	1125.3	1169.8	1170.6	1168.9	1166.7	1172.5	1171.7	1166.3	1170.3	1169.6	1130.4	1129.5	1127.9	1160.4	1160.1	1158.0
	-1	1080.1	1079.8	1079.2	1134.2	1134.0	1129.0	1127.8	1132.3	1131.3	1126.3	1129.0	1130.3	1081.8	1081.1	1081.5	1126.1	1125.4	1123.4
	0	1043.4	1044.2	1046.7	1089.4	1092.1	1092.7	1082.9	1088.4	1089.6	1082.1	1086.1	1087.3	1052.2	1053.9	1058.4	1087.5	1084.4	1084.3
	1	1075.9	1077.6	1079.8	1091.7	1093.8	1095.3	1088.3	1093.5	1094.9	1088.9	1089.6	1090.2	1092.1	1095.5	1099.9	1090.0	1091.7	1091.3
	2	1124.7	1126.6	1128.8	1125.2	1126.5	1128.6	1124.9	1126.9	1129.5	1121.9	1123.8	1125.6	1135.7	1138.5	1142.3	1121.9	1123.6	1125.2
4	-2	1126.8	1126.4	1126.1	1146.1	1144.3	1145.1	1152.2	1151.0	1153.4	1155.4	1154.8	1156.6	1131.4	1131.1	1130.6	1144.6	1144.7	1144.7
	-1	1081.0	1080.5	1081.5	1103.0	1101.8	1101.3	1109.0	1109.1	1109.8	1109.6	1107.2	1111.0	1083.6	1083.5	1084.1	1099.8	1101.0	1105.1
	0	1044.4	1045.7	1048.4	1057.5	1056.1	1059.1	1060.3	1060.2	1062.9	1062.3	1063.4	1063.1	1047.1	1046.9	1051.4	1053.2	1054.0	1060.4
	1	1075.9	1077.6	1079.8	1079.6	1081.5	1082.2	1080.6	1082.2	1083.8	1077.5	1078.7	1080.6	1084.9	1086.2	1089.0	1077.1	1078.9	1080.4
	2	1124.7	1126.6	1128.8	1125.6	1126.5	1128.6	1125.4	1127.1	1129.5	1123.9	1125.1	1127.2	1133.8	1134.7	1137.8	1123.8	1124.9	1126.8

TBCREA	DFAVPT	MODEL=13			MODEL=23			MODEL=33			MODEL=43			MODEL=53			MODEL=63		
0	-2	1126.9	1126.3	1125.8	1161.3	1162.0	1163.0	1151.4	1158.5	1159.2	1148.8	1153.1	1154.8	1130.4	1129.5	1127.9	1155.8	1156.3	1157.0
	-1	1080.7	1080.4	1079.2	1123.6	1124.6	1122.4	1114.8	1118.3	1117.6	1111.5	1115.4	1114.3	1081.8	1081.1	1081.5	1119.9	1121.8	1121.6
	0	1044.5	1045.7	1046.5	1080.0	1084.9	1084.7	1069.3	1075.7	1076.3	1065.0	1070.7	1071.2	1052.2	1053.9	1058.4	1077.5	1078.7	1077.9
	1	1075.9	1077.6	1079.8	1086.5	1090.3	1092.5	1082.1	1089.0	1090.3	1078.4	1084.3	1085.8	1092.1	1095.5	1099.9	1081.5	1087.3	1088.0
	2	1124.7	1126.6	1128.8	1125.8	1127.2	1129.4	1125.4	1127.4	1130.1	1121.9	1123.6	1125.6	1135.7	1138.5	1142.3	1121.9	1123.4	1125.2
4	-2	1127.2	1126.8	1126.6	1144.4	1143.8	1144.6	1145.8	1142.9	1146.0	1146.7	1146.7	1147.3	1131.4	1131.1	1130.6	1146.1	1144.0	1144.7
	-1	1081.6	1081.0	1081.5	1101.8	1101.4	1100.7	1101.8	1100.0	1100.1	1101.9	1100.1	1100.4	1083.6	1083.5	1084.1	1098.2	1100.2	1102.9
	0	1045.5	1047.3	1048.8	1059.6	1059.6	1058.6	1055.7	1053.9	1057.0	1054.7	1052.4	1054.8	1047.1	1046.9	1051.4	1054.1	1052.3	1058.9
	1	1075.9	1077.5	1080.0	1081.7	1083.2	1084.6	1080.6	1082.6	1084.4	1077.2	1078.7	1080.4	1084.9	1086.2	1089.0	1077.1	1078.9	1080.3
	2	1124.7	1126.6	1128.7	1126.1	1127.7	1129.3	1125.9	1127.8	1130.1	1123.9	1125.1	1127.2	1133.8	1134.7	1137.8	1123.8	1124.9	1126.8

TBCREA	DFAVPT	MODEL=14			MODEL=24			MODEL=34			MODEL=44			MODEL=54			MODEL=64		
0	-2	1123.7	1122.9	1122.6	1142.8	1141.8	1142.3	1176.2	1177.5	1179.2	1221.9	1220.9	1220.8	1169.9	1170.6	1172.3	1147.3	1147.8	1148.1
	-1	1074.5	1073.8	1073.6	1096.4	1096.2	1096.6	1131.8	1133.8	1135.4	1175.8	1174.5	1174.5	1124.8	1126.6	1128.7	1101.2	1102.8	1103.8
	0	1037.0	1037.6	1040.6	1054.5	1055.6	1058.6	1089.9	1089.9	1092.2	1131.2	1131.1	1131.0	1090.3	1092.7	1097.5	1059.8	1060.8	1063.9
	1	1076.2	1078.3	1080.8	1076.8	1078.7	1082.1	1079.1	1081.8	1085.3	1092.5	1094.2	1097.8	1125.9	1128.0	1130.2	1074.1	1075.6	1077.7
	2	1125.4	1127.5	1129.9	1125.5	1127.6	1130.2	1126.1	1128.0	1130.1	1123.7	1125.4	1127.4	1173.0	1175.2	1177.2	1123.6	1125.0	1126.8
4	-2	1124.0	1123.3	1123.5	1131.7	1132.5	1132.7	1146.4	1146.6	1145.3	1156.1	1156.8	1154.6	1137.2	1135.1	1134.7	1133.8	1133.1	1131.3
	-1	1075.3	1074.6	1074.8	1083.7	1084.3	1085.4	1100.8	1100.0	1099.8	1112.2	1114.0	1112.0	1089.8	1088.0	1088.7	1085.6	1085.5	1085.1
	0	1037.5	1038.0	1041.5	1044.4	1045.6	1048.9	1058.0	1059.1	1064.2	1076.7	1075.1	1075.6	1053.1	1053.3	1057.9	1047.2	1046.4	1046.9
	1	1076.0	1078.3	1081.0	1076.9	1078.5	1081.3	1077.3	1079.7	1082.6	1076.7	1079.8	1082.5	1090.2	1092.4	1095.6	1075.5	1077.1	1079.1
	2	1125.4	1127.5	1130.1	1125.5	1127.6	1130.8	1126.1	1128.0	1130.5	1125.1	1126.9	1129.1	1138.7	1141.0	1143.4	1125.0	1126.5	1128.3

Table 6. Average of the 20 values of TFLOW for each treatment

		MODEL=11			MODEL=21			MODEL=31			MODEL=41			MODEL=51			MODEL=61		
		AVTIS			AVTIS			AVTIS			AVTIS			AVTIS			AVTIS		
		MEAN			MEAN			MEAN			MEAN			MEAN			MEAN		
		PCDEV			PCDEV			PCDEV			FCDEV			PCDEV			PCDEV		
TBCREA	DFAVPT	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45
0	-2	597.9	597.2	596.9	605.9	605.1	606.5	610.6	609.7	610.4	619.7	619.9	621.3	605.9	606.1	607.6	607.6	607.7	608.3
	-1	581.2	580.8	580.5	589.8	589.2	590.1	594.2	593.5	594.6	603.4	603.1	605.9	588.7	589.2	591.0	591.3	591.0	592.2
	0	569.4	569.1	569.2	577.4	577.3	578.2	581.7	581.5	583.1	589.8	591.7	592.5	576.8	577.2	579.7	578.6	579.0	580.2
	1	569.1	569.4	570.8	575.6	576.7	578.4	577.8	579.0	581.0	584.0	586.2	588.2	578.4	580.1	583.4	575.5	576.3	578.3
	2	584.1	585.0	586.6	588.7	590.0	591.3	590.2	591.1	592.7	592.4	594.6	596.7	595.3	597.5	599.8	588.6	589.7	590.7
4	-2	400.6	400.0	400.0	406.7	406.3	406.2	410.4	409.8	411.6	413.7	413.1	415.1	407.0	405.7	406.5	408.8	407.8	407.8
	-1	384.7	384.3	384.3	391.4	390.7	390.5	395.6	394.6	395.4	397.3	399.1	399.1	389.9	389.0	390.5	392.5	392.0	392.5
	0	374.0	373.8	375.9	380.8	380.7	381.1	383.9	383.5	384.7	389.0	392.2	389.2	379.8	379.4	381.0	381.8	382.1	382.7
	1	373.8	374.3	376.5	377.5	377.8	379.3	381.2	380.5	382.6	386.0	384.3	384.9	380.0	381.8	382.6	378.0	378.1	379.3
	2	388.6	389.5	392.4	391.4	391.6	394.0	393.0	393.5	395.9	394.4	395.9	397.9	397.2	397.3	398.6	391.5	391.4	393.4

		MODEL=12			MODEL=22			MODEL=32			MODEL=42			MODEL=52			MODEL=62		
0	-2	621.5	621.8	620.7	636.5	638.0	637.1	632.1	637.3	637.3	633.1	636.8	636.6	600.1	599.4	598.3	628.2	629.1	627.6
	-1	606.6	606.6	605.9	629.5	630.2	627.6	623.7	627.7	628.0	623.4	626.2	628.3	583.3	582.8	581.9	622.9	623.0	622.5
	0	592.8	593.7	594.4	616.8	620.1	621.0	612.5	617.5	619.7	613.7	618.5	620.2	571.7	572.5	573.2	615.8	614.4	614.5
	1	593.5	595.0	595.9	622.1	620.4	620.5	613.3	616.4	619.1	619.2	617.6	620.9	576.1	578.1	580.4	620.6	618.3	616.2
	2	611.6	612.0	610.6	630.6	628.9	626.5	625.5	625.8	624.5	628.7	627.8	626.9	589.3	591.2	593.8	630.6	627.4	624.8
4	-2	411.6	410.5	411.2	420.1	419.0	419.7	422.4	422.0	424.9	425.1	425.1	427.8	403.2	403.1	402.9	419.1	418.6	419.7
	-1	395.2	395.0	397.0	407.7	407.2	407.3	411.0	411.6	412.7	411.1	410.7	414.1	387.6	387.8	388.9	404.8	406.0	409.5
	0	382.8	383.5	384.8	393.0	394.2	397.5	396.2	397.6	400.2	399.2	401.5	402.1	376.5	376.5	379.7	390.7	394.1	398.5
	1	384.0	384.6	388.8	395.7	396.9	397.4	396.0	397.6	401.1	397.8	399.9	401.3	377.9	378.1	380.5	394.4	394.1	396.7
	2	398.4	400.1	402.4	407.1	407.9	409.7	406.7	409.5	412.7	407.2	409.6	413.6	393.9	393.7	396.7	405.3	406.8	410.2

		MODEL=13			MODEL=23			MODEL=33			MODEL=43			MODEL=53			MODEL=63		
0	-2	616.4	616.9	616.7	626.1	627.9	629.2	618.0	623.9	625.4	615.0	618.3	620.3	600.1	599.4	598.3	620.5	621.4	622.5
	-1	600.9	601.5	601.4	617.5	619.5	618.9	610.5	614.2	614.7	606.9	610.7	610.8	583.3	582.8	581.9	613.5	615.5	616.9
	0	587.5	588.8	588.7	603.8	608.6	609.0	597.2	603.2	603.9	594.1	599.9	599.8	571.7	572.5	573.2	602.8	604.8	604.3
	1	587.6	589.3	591.0	610.1	609.4	611.2	598.9	605.8	607.8	596.5	602.5	603.3	576.1	578.1	580.4	606.4	609.4	607.5
	2	605.4	606.8	606.8	620.4	620.1	619.5	613.9	616.1	616.6	611.1	612.7	614.1	589.3	591.2	593.8	617.7	616.9	616.4
4	-2	409.5	408.5	409.7	415.2	415.6	416.6	415.9	414.5	417.6	416.5	416.7	417.9	403.2	403.1	402.9	416.2	415.2	416.1
	-1	394.2	394.1	395.2	404.2	404.5	404.2	404.7	403.6	403.9	403.8	402.9	403.5	387.6	387.8	388.9	400.3	402.5	404.6
	0	381.2	382.1	382.9	391.3	392.3	393.6	390.2	389.4	392.2	389.9	389.2	390.8	376.5	376.5	379.7	389.1	389.0	394.7
	1	382.5	382.9	386.4	392.3	394.0	394.8	389.7	391.2	394.4	388.6	390.4	392.0	377.9	378.1	380.5	389.4	390.7	392.8
	2	396.7	397.6	400.7	405.0	405.2	408.1	403.1	405.1	407.3	402.3	402.3	406.0	393.9	393.7	396.7	403.1	402.2	407.0

		MODEL=14			MODEL=24			MODEL=34			MODEL=44			MODEL=54			MODEL=64		
0	-2	577.6	577.8	578.1	590.2	589.1	589.4	609.7	610.3	611.5	650.9	649.9	649.7	608.8	609.1	610.2	603.0	603.2	603.1
	-1	561.9	561.9	562.7	574.9	575.2	574.9	594.6	595.6	596.9	633.8	632.6	633.0	594.1	595.6	597.3	587.9	589.1	589.5
	0	548.3	548.3	549.3	562.4	561.7	562.6	582.8	582.6	583.1	619.2	619.1	619.6	583.3	584.8	587.2	576.6	576.5	578.0
	1	547.0	547.2	548.7	557.5	557.9	559.4	573.8	574.0	575.1	607.3	606.6	606.9	584.3	585.8	588.1	570.8	571.4	571.1
	2	561.0	561.7	563.4	566.3	567.1	568.2	577.1	577.1	578.5	601.4	601.5	602.5	600.3	601.7	604.4	579.2	579.2	580.7
4	-2	376.0	376.2	377.2	382.9	384.3	384.5	386.8	387.8	387.3	395.6	396.8	396.5	379.4	379.3	379.2	388.6	388.1	388.0
	-1	360.2	359.9	361.3	366.5	367.5	368.6	370.9	371.6	371.4	381.2	383.7	382.8	363.5	363.3	364.7	372.1	372.8	372.7
	0	346.0	346.5	348.0	353.8	353.9	355.8	359.0	359.7	362.1	373.4	373.2	373.1	351.3	350.6	353.0	360.1	359.7	360.7
	1	345.0	346.2	348.2	349.4	351.3	353.7	354.7	357.5	358.6	373.0	374.0	372.7	353.8	354.3	357.4	358.1	356.8	358.9
	2	360.0	360.7	362.7	362.6	363.7	365.7	365.2	367.5	369.3	380.2	379.7	381.8	371.6	372.5	374.8	370.7	370.1	371.7

Table 7. Average of the 20 values of AVTIS for each treatment

3. Bottleneck machines on stages 1 and 4

4. Bottleneck machines on stages 2 and 4

5. Bottleneck machines on stages 3 and 4

6. Bottleneck machines on stages 2 and 3

Each combination of sequencing rule and bottleneck machines location is assigned a model number. These combinations and model numbers are shown in figure 8 for ease of reference.

The same above mentioned tables are shown again as tables 8 and 9, with some marking on them. This marking shows the minimum performance measure value for each bottleneck machines location for the combination of the three factors TBCREA, PCDEV, and DFAVPT. The thick marking shows the absolute minimum values under the five levels of the factor DFAVPT for each bottleneck machines location, while the thin marking shows the minimum values at the other levels of the factor DFAVPT. It is to be noted that some ties exist among the three variations of the Johnson rule.

For each of the six bottleneck machines locations, four charts are drawn: one for each of the two performance measures TFLOW and AVTIS, at each of the two levels of the factor TBCREA. The factor PCDEV was considered at the single level of 0.25 because, as we will

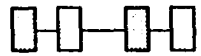
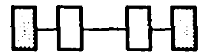
	Bottleneck machines at locations 1 and 2	Bottleneck machines at locations 1 and 3	Bottleneck machines at locations 1 and 4	Bottleneck machines at locations 2 and 4	Bottleneck machines at locations 3 and 4	Bottleneck machines at locations 2 and 3
RULE	 1x	 2x	 3x	 4x	 5x	 6x
JNP x1 Johnson no Priority	Model 11	Model 21	Model 31	Model 41	Model 51	Model 61
JHP x2 Johnson Half Priority	Model 12	Model 22	model 32	Model 42	Model 52	Model 62
JFP x3 Johnson Full Priority	Model 13	Model 23	Model 33	Model 43	Model 53	Model 63
SPT x4 Shortest process Time	Model 14	Model 24	Model 34	Model 44	Model 54	Model 64

Figure 8. Identification of the 24 research models

		MODEL=11			MODEL=21			MODEL=31			MODEL=41			MODEL=51			MODEL=61		
		TFLOW MEAN PCDEV			TFLOW MEAN PCDEV			TFLOW MEAN PCDEV			TFLOW MEAN PCDEV			TFLOW MEAN PCDEV			TFLOW MEAN PCDEV		
TBCREA	DFAVPT	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45	0.05	0.25	0.45
0	-2	1126.4	1125.8	1125.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1135.6	1135.4	1136.4	[illegible]	[illegible]	[illegible]
	-1	1080.1	1079.8	1079.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1086.3	1086.3	1087.6	[illegible]	[illegible]	[illegible]
	0	1043.4	1044.2	1046.2	[redacted]									1052.5	1054.7	1058.5	[redacted]		
	1	[illegible]	[illegible]	[illegible]	1078.2	1079.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1093.8	1095.9	1099.7	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	1125.7	1127.2	1129.4	1125.4	1127.6	1130.1	[illegible]	[illegible]	[illegible]	1140.8	1143.6	1146.7	[illegible]	[illegible]	[illegible]
4	-2	1126.8	1126.7	1126.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1134.3	1132.4	1132.7	[illegible]	[illegible]	[illegible]
	-1	1081.0	1080.4	1081.3	1084.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1084.9	1083.5	1084.2	[illegible]	[illegible]	[illegible]
	0	1044.3	1045.7	1048.2	1046.6	1047.0	[redacted]							1049.5	1050.3	1054.1	[redacted]		
	1	1076.1	1078.0	1079.8	1078.3	1079.8	1081.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1087.5	1090.9	1092.9	[illegible]	[illegible]	[illegible]
	2	1124.7	1126.6	1128.7	1125.7	1127.2	1129.3	1125.4	1127.4	1129.7	[illegible]	[illegible]	[illegible]	1138.0	1139.2	1140.5	[illegible]	[illegible]	[illegible]

		MODEL=12			MODEL=22			MODEL=32			MODEL=42			MODEL=52			MODEL=62		
0	-2	1126.4	1125.8	1125.3	1169.8	1170.6	1168.9	1166.7	1172.5	1171.7	1166.3	1170.3	1169.6	[illegible]	[illegible]	[illegible]	1160.4	1160.1	1158.0
	-1	1080.1	1079.8	1079.2	1134.2	1134.0	1129.0	1127.8	1132.3	1131.3	1126.3	1129.0	1130.3	[illegible]	[illegible]	[illegible]	1126.1	1125.4	1123.4
	0	1043.4	1044.2	1046.7	1089.4	1092.1	1092.7	1082.9	1088.4	1089.6	1082.1	1086.1	1087.3	[redacted]			1087.5	1084.4	1084.3
	1	[illegible]	[illegible]	[illegible]	1091.7	1093.8	1095.3	1088.3	1093.5	1094.9	1088.9	1089.6	1090.2	[illegible]	[illegible]	[illegible]	1090.0	1091.7	1091.3
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1121.9	1123.8	1125.6	[illegible]	[illegible]	[illegible]	1121.9	1123.6	1125.2
4	-2	1126.8	1126.4	1126.1	1146.1	1144.3	1145.1	1152.2	1151.0	1153.4	1155.4	1154.8	1156.6	[illegible]	[illegible]	[illegible]	1144.6	1144.7	1144.7
	-1	1081.0	1080.5	1081.5	1103.0	1101.8	1101.3	1109.0	1109.1	1109.8	1109.6	1107.2	1111.0	[illegible]	[illegible]	[illegible]	1099.8	1101.0	1105.1
	0	1044.4	1045.7	1048.4	1057.5	1056.1	1059.1	1060.3	1060.2	1062.9	1062.3	1063.4	1063.1	[redacted]			1053.2	1054.0	1060.4
	1	1075.9	1077.6	1079.8	1079.6	1081.5	1082.2	1080.6	1082.2	1083.8	1077.5	1078.7	1080.6	[illegible]	[illegible]	[illegible]	1077.1	1078.9	1080.4
	2	1124.7	1126.6	1128.8	1125.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1123.9	1125.1	1127.2	[illegible]	[illegible]	[illegible]	1123.8	1124.9	1126.8

		MODEL=13			MODEL=23			MODEL=33			MODEL=43			MODEL=53			MODEL=63		
0	-2	1126.9	1126.3	1125.8	1161.3	1162.0	1163.0	1151.4	1158.5	1159.2	1148.8	1153.1	1154.8	[illegible]	[illegible]	[illegible]	1155.8	1156.3	1157.0
	-1	1080.7	1080.4	1079.2	1123.6	1124.6	1122.4	1114.8	1118.3	1117.6	1111.5	1115.4	1116.3	[illegible]	[illegible]	[illegible]	1119.9	1121.8	1121.6
	0	1044.5	1045.7	1046.5	1080.0	1084.9	1084.7	1069.3	1075.7	1076.3	1065.0	1070.7	1071.2	[redacted]			1077.5	1078.7	1077.9
	1	[illegible]	[illegible]	[illegible]	1086.5	1090.3	1092.5	1082.1	1089.0	1090.3	1078.4	1084.3	1085.8	[illegible]	[illegible]	[illegible]	1081.5	1087.3	1088.0
	2	[illegible]	[illegible]	[illegible]	1125.8	1127.2	1129.4	1125.4	1127.4	1130.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	-2	1127.2	1126.8	1126.6	1144.4	1143.8	1144.6	1145.8	1142.9	1146.0	1146.7	1146.7	1147.3	[illegible]	[illegible]	[illegible]	1146.1	1144.0	1144.7
	-1	1081.6	1081.0	1081.5	1101.8	1101.4	1100.7	1101.8	1100.0	1100.1	1101.9	1100.1	1100.4	[illegible]	[illegible]	[illegible]	1098.2	1100.2	1102.9
	0	1045.5	1047.3	1048.8	1059.6	1059.6	1058.6	1055.7	1053.9	1057.0	1054.7	1052.4	1054.8	[redacted]			1054.1	1052.3	1058.9
	1	[illegible]	[illegible]	[illegible]	1081.7	1083.2	1084.6	1080.6	1082.6	1084.4	1077.2	1078.7	1080.4	[illegible]	[illegible]	[illegible]	1077.1	1078.9	1080.3
	2	[illegible]	[illegible]	[illegible]	1126.1	1127.7	1129.3	1125.9	1127.8	1130.1	1123.9	1125.1	1127.2	[illegible]	[illegible]	[illegible]	1123.8	1124.9	1126.8

		MODEL=14			MODEL=24			MODEL=34			MODEL=44			MODEL=54			MODEL=64		
0	-2	[illegible]	[illegible]	[illegible]	1142.8	1141.8	1142.3	1176.2	1177.5	1179.2	1221.9	1220.9	1220.8	1169.9	1170.6	1172.3	1147.3	1147.8	1148.1
	-1	[illegible]	[illegible]	[illegible]	1096.4	1096.2	1096.6	1131.8	1133.8	1135.4	1175.8	1174.5	1174.5	1124.8	1126.6	1128.7	1101.2	1102.8	1103.8
	0	[redacted]			1054.5	1055.6	1058.6	1089.9	1089.9	1092.2	1131.2	1131.1	1131.0	1090.3	1092.7	1097.5	1059.8	1060.8	1063.9
	1	1076.2	1078.3	1080.8	[illegible]	[illegible]	1082.1	1079.1	1081.8	1085.3	1092.5	1094.2	1097.8	1125.9	1128.0	1130.2	1074.1	1075.6	1077.7
	2	1125.4	1127.5	1129.9	1125.5	1127.6	1130.2	1126.1	1128.0	1130.1	1123.7	1125.4	1127.4	1173.0	1175.2	1177.2	1123.6	1125.0	1126.8
4	-2	[illegible]	[illegible]	[illegible]	1131.7	1132.5	1132.7	1146.4	1146.6	1145.3	1156.1	1156.8	1154.6	1137.2	1135.1	1134.7	1133.8	1133.1	1131.3
	-1	[illegible]	[illegible]	[illegible]	[illegible]	1084.3	1085.4	1100.8	1100.0	1099.8	1112.2	1114.0	1112.0	1089.8	1088.0	1088.7	1085.6	1085.5	1085.1
	0	[redacted]					1048.9	1058.0	1059.1	1064.2	1076.7	1075.1	1075.6	1053.1	1053.3	1057.9	1047.2	1046.4	1046.9
	1	1076.0	1078.3	1081.0	[illegible]	[illegible]	[illegible]	1077.3	1079.7	1082.6	1076.7	1079.8	1082.5	1090.2	1092.4	1095.6	1075.5	1077.1	1079.1
	2	1125.4	1127.5	1130.1	[illegible]	1127.6	1130.8	1126.1	1128.0	1130.5	1125.1	1126.9	1129.1	1138.7	1141.0	1143.4	1125.0	1126.5	1128.3

Table 8. Minimum average values of TFLOW for each bottleneck machines location and TBCREA

TBCREA	DFAVPT	MODEL=11 AVTIS MEAN PCDEV 0.05	0.25	0.45	MODEL=21 0.05	0.25	0.45	MODEL=31 0.05	0.25	0.45	MODEL=41 0.05	0.25	0.45	MODEL=51 0.05	0.25	0.45	MODEL=61 0.05	0.25	0.45
0	-2	597.9	597.2	596.9	605.9	605.1	606.5	[illegible]	[illegible]	[illegible]	619.7	619.9	621.3	605.9	606.1	607.6	607.6	607.7	608.3
	-1	581.2	580.8	580.5	589.8	589.2	590.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	588.7	589.2	591.0	591.3	591.0	592.2
	0	569.4	569.1	569.2	577.4	577.3	578.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	576.8	577.2	579.7	578.6	579.0	580.2
	1	569.1	569.4	570.8	575.6	576.7	578.4	577.8	579.0	581.0	[redacted]			578.4	580.1	583.4	575.5	576.3	578.3
	2	584.1	585.0	586.6	588.7	590.0	591.3	590.2	591.1	592.7	[illegible]	[illegible]	[illegible]	595.3	597.5	599.8	588.6	589.7	590.7
4	-2	400.6	400.0	400.0	406.7	406.3	406.2	410.4	409.8	411.6	413.7	413.1	415.1	407.0	405.7	406.5	408.8	407.8	407.8
	-1	384.7	384.3	384.3	391.4	390.7	390.5	395.6	394.6	395.4	397.3	399.1	399.1	389.9	389.0	390.5	392.5	392.0	392.5
	0	374.0	373.8	375.9	380.8	380.7	381.1	383.9	383.5	384.7	389.0	392.2	389.2	379.8	379.4	381.0	381.8	382.1	382.7
	1	373.8	374.3	376.5	377.5	377.8	379.3	381.2	380.5	382.6	386.0	384.3	384.9	380.0	381.8	382.6	378.0	378.1	379.3
	2	388.6	389.5	392.4	391.4	391.6	394.0	393.0	393.5	395.9	394.4	395.9	397.9	397.2	397.3	398.6	391.5	391.4	393.4
		MODEL=12			MODEL=22			MODEL=32			MODEL=42			MODEL=52			MODEL=62		
0	-2	621.5	621.8	620.7	636.5	638.0	637.1	632.1	637.3	637.3	633.1	636.8	636.6	[illegible]	[illegible]	[illegible]	628.2	629.1	627.6
	-1	606.6	606.6	605.9	629.5	630.2	627.6	623.7	627.7	628.0	623.4	626.2	628.3	[illegible]	[illegible]	[illegible]	622.9	623.0	622.5
	0	592.8	593.7	594.4	616.8	620.1	621.0	612.5	617.5	619.7	613.7	618.5	620.2	[redacted]			615.8	614.4	614.5
	1	593.5	595.0	595.9	622.1	620.4	620.5	613.3	616.4	619.1	619.2	617.6	620.9	[illegible]	[illegible]	[illegible]	620.6	618.3	616.2
	2	611.6	612.0	610.6	630.6	628.9	626.5	625.5	625.8	624.5	628.7	627.8	626.9	[illegible]	[illegible]	[illegible]	630.6	627.4	624.8
4	-2	411.6	410.5	411.2	420.1	419.0	419.7	422.4	422.0	424.9	425.1	425.1	427.8	403.2	403.1	402.9	419.1	418.6	419.7
	-1	395.2	395.0	397.0	407.7	407.2	407.3	411.0	411.6	412.7	411.1	410.7	414.1	387.6	387.8	388.9	404.8	406.0	409.5
	0	382.8	383.5	384.8	393.0	394.2	397.5	396.2	397.6	400.2	399.2	401.5	402.1	376.5	376.5	379.7	390.7	394.1	398.5
	1	384.0	384.6	388.8	395.7	396.9	397.4	396.0	397.6	401.1	397.8	399.9	401.3	377.9	378.1	380.5	394.4	394.1	396.7
	2	398.4	400.1	402.4	407.1	407.9	409.7	406.7	409.5	412.7	407.2	409.6	413.6	393.9	393.7	396.7	405.3	406.8	410.2
		MODEL=13			MODEL=23			MODEL=33			MODEL=43			MODEL=53			MODEL=63		
0	-2	616.4	616.9	616.7	626.1	627.9	629.2	618.0	623.9	625.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	620.5	621.4	622.5
	-1	600.9	601.5	601.4	617.5	619.5	618.9	610.5	614.2	614.7	606.9	610.7	610.8	[illegible]	[illegible]	[illegible]	613.5	615.5	616.9
	0	587.5	588.8	588.7	603.8	608.6	609.0	597.2	603.2	603.9	594.1	599.9	599.8	[redacted]			602.8	604.8	604.3
	1	587.6	589.3	591.0	610.1	609.4	611.2	598.9	605.8	607.8	596.5	602.5	603.3	[illegible]	[illegible]	[illegible]	606.4	609.4	607.5
	2	605.4	606.8	606.8	620.4	620.1	619.5	613.9	616.1	616.6	611.1	612.7	614.1	[illegible]	[illegible]	[illegible]	617.7	616.9	616.4
4	-2	409.5	408.5	409.7	415.2	415.6	416.6	415.9	414.5	417.6	416.5	416.7	417.9	403.2	403.1	402.9	416.2	415.2	416.1
	-1	394.2	394.1	395.2	404.2	404.5	404.2	404.7	403.6	403.9	403.8	402.9	403.5	387.6	387.8	388.9	400.3	402.5	404.6
	0	381.2	382.1	382.9	391.3	392.3	393.6	390.2	389.4	392.2	389.9	389.2	390.8	376.5	376.5	379.7	389.1	389.0	394.7
	1	382.5	382.9	386.4	392.3	394.0	394.8	389.7	391.2	394.4	388.6	390.4	392.0	377.9	378.1	380.5	389.4	390.7	392.8
	2	396.7	397.6	400.7	405.0	405.2	408.1	403.1	405.1	407.3	402.3	402.3	406.0	393.9	393.7	396.7	403.1	402.2	407.0
		MODEL=14			MODEL=24			MODEL=34			MODEL=44			MODEL=54			MODEL=64		
0	-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	609.7	610.3	611.5	650.9	649.9	649.7	608.8	609.1	610.2	[illegible]	[illegible]	[illegible]
	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	594.6	595.6	596.9	633.8	632.6	633.0	594.1	595.6	597.3	[illegible]	[illegible]	[illegible]
	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	582.8	582.6	583.1	619.2	619.1	619.6	583.3	584.8	587.2	[illegible]	[illegible]	[illegible]
	1	[redacted]									607.3	606.6	606.9	584.3	585.8	588.1	[redacted]		
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	601.4	601.5	602.5	600.3	601.7	604.4	[illegible]	[illegible]	[illegible]
4	-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[redacted]	[illegible]	[redacted]			[illegible]	[illegible]	[illegible]
	1	[redacted]										[illegible]	[redacted]	[illegible]	[illegible]	[illegible]	[redacted]		
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 9. Minimum average values of AVTIS for each bottleneck machines location and TBCREA

later show, the different levels of this factor do not impact the relative performance of the four sequencing rules. These six sets, of four charts each, are shown in figures 9a to 9f.

Results of the Performance Measure TFLOW

The tabulation of the primary performance measure TFLOW (table 8), at the zero level of TBCREA, shows that the JNP rule could be dominant in four of the six different bottleneck machines locations, mainly in models 2x, 3x, 4x and 6x. This possible dominance is applicable to at least four of the five levels of DFAVPT in three of the four models mentioned above. As for the remaining two models, this tabulation shows that the two rules JHP and JFP compete for dominance over the other two rules for model 5x, and share possible dominance with the JNP and SPT rules for model 1x. It is interesting to notice that only one model (model 2x) exhibits a reaction, in rule preference, to the different levels of the factor PCDEV. Such reaction will be further explored later to determine any statistically significant interaction.

It is important to highlight the fact that the study of the performance measure TFLOW, at the zero level

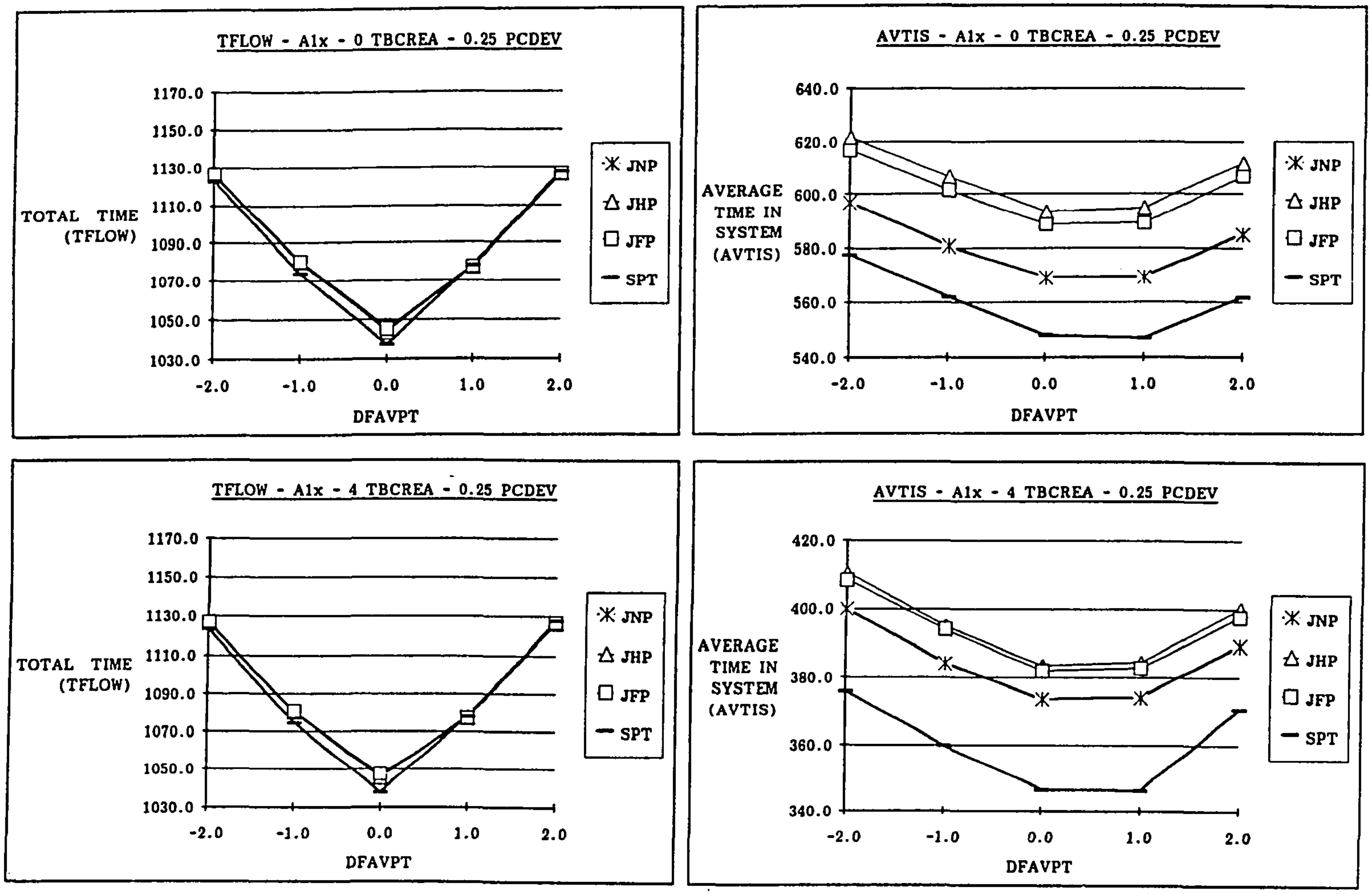


Figure 9a. Graphical representation of the two performance measures TFLOW and AVTIS (model 1x).

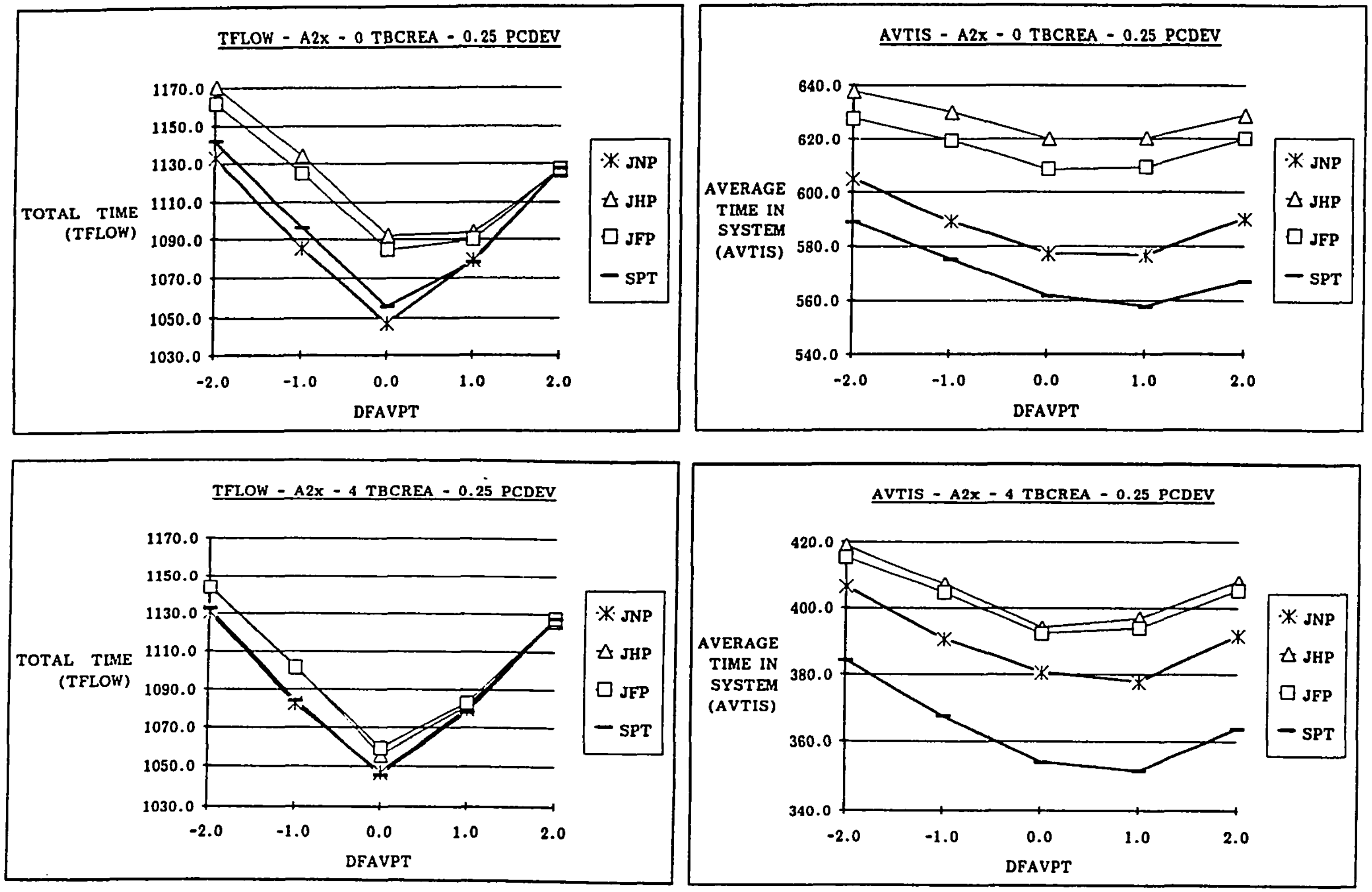


Figure 9b. Graphical representation of the two performance measures TFLOW and AVTIS (model 2x).

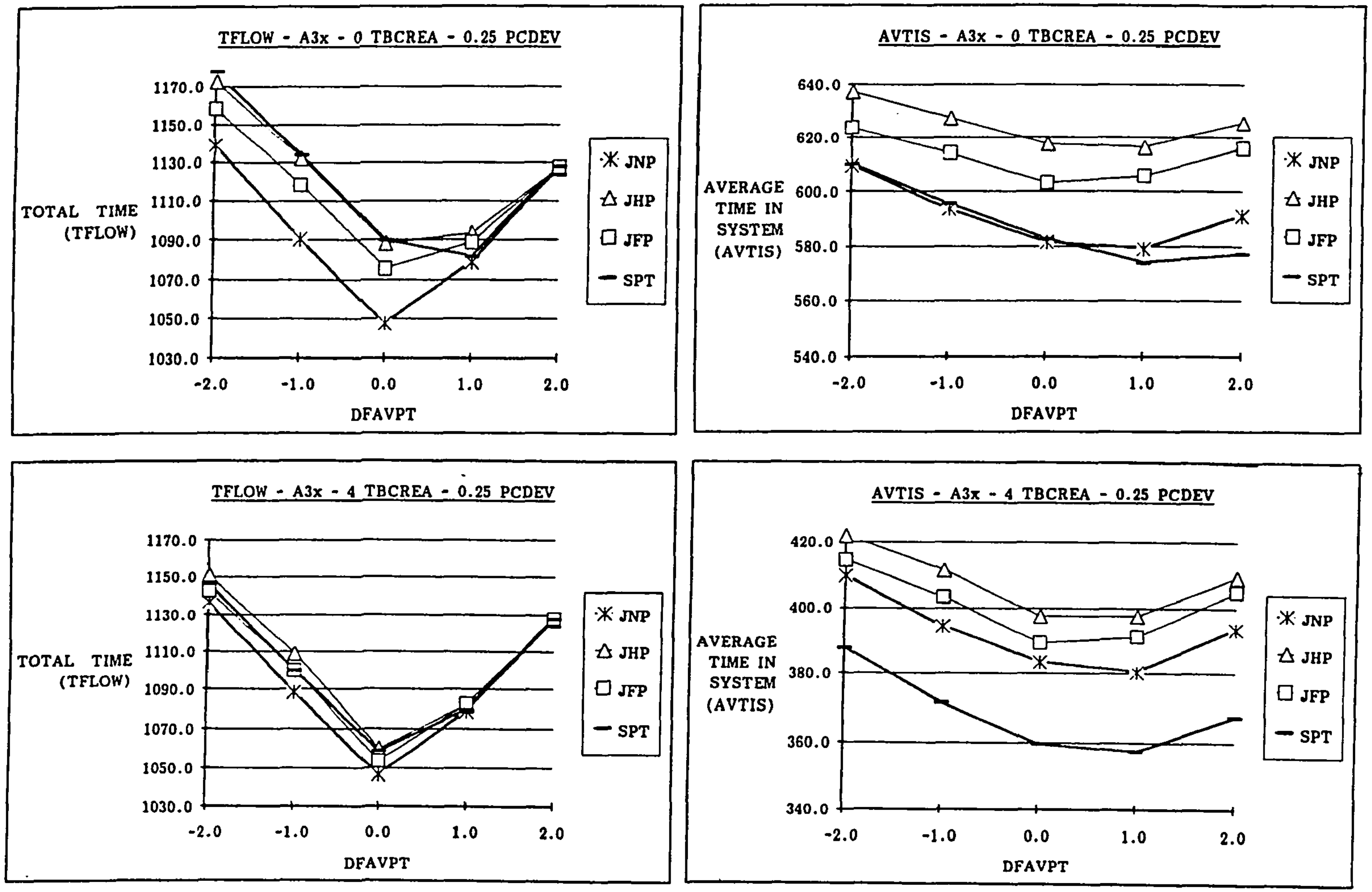


Figure 9c. Graphical representation of the two performance measures TFLOW and AVTIS (model 3x).

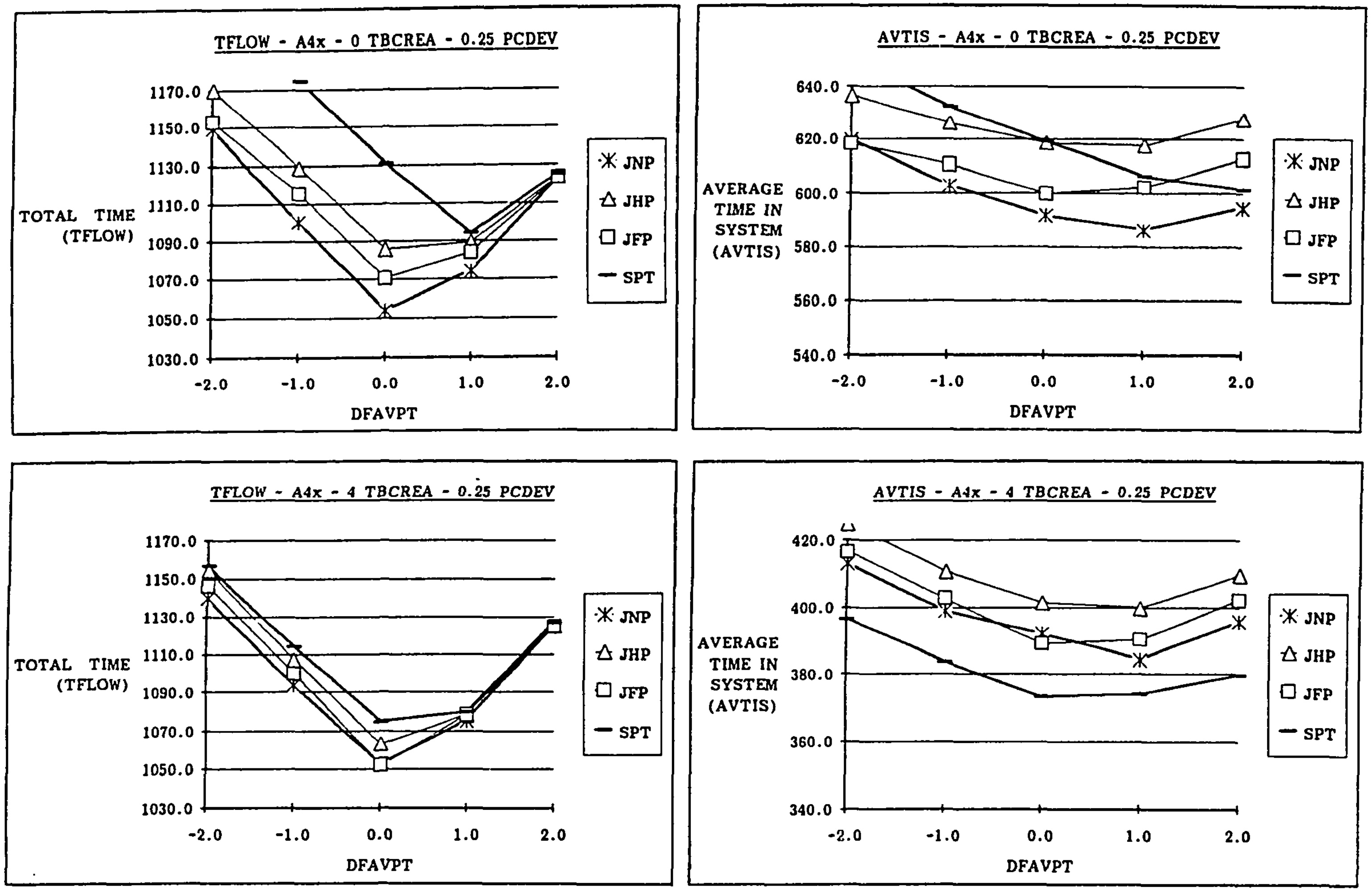


Figure 9d. Graphical representation of the two performance measures TFLOW and AVTIS (model 4x).

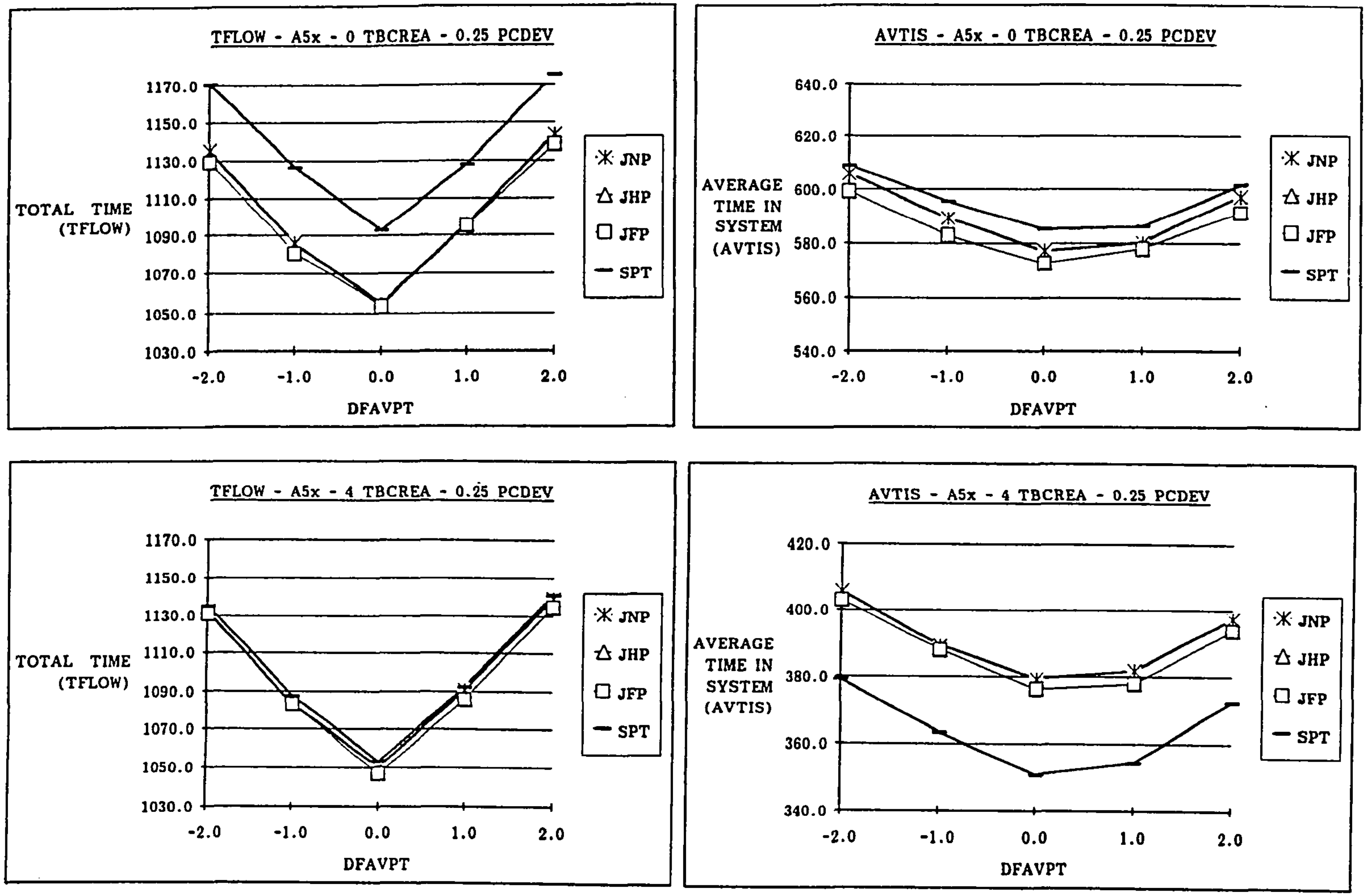


Figure 9e. Graphical representation of the two performance measures TFLOW and AVTIS (model 5x).

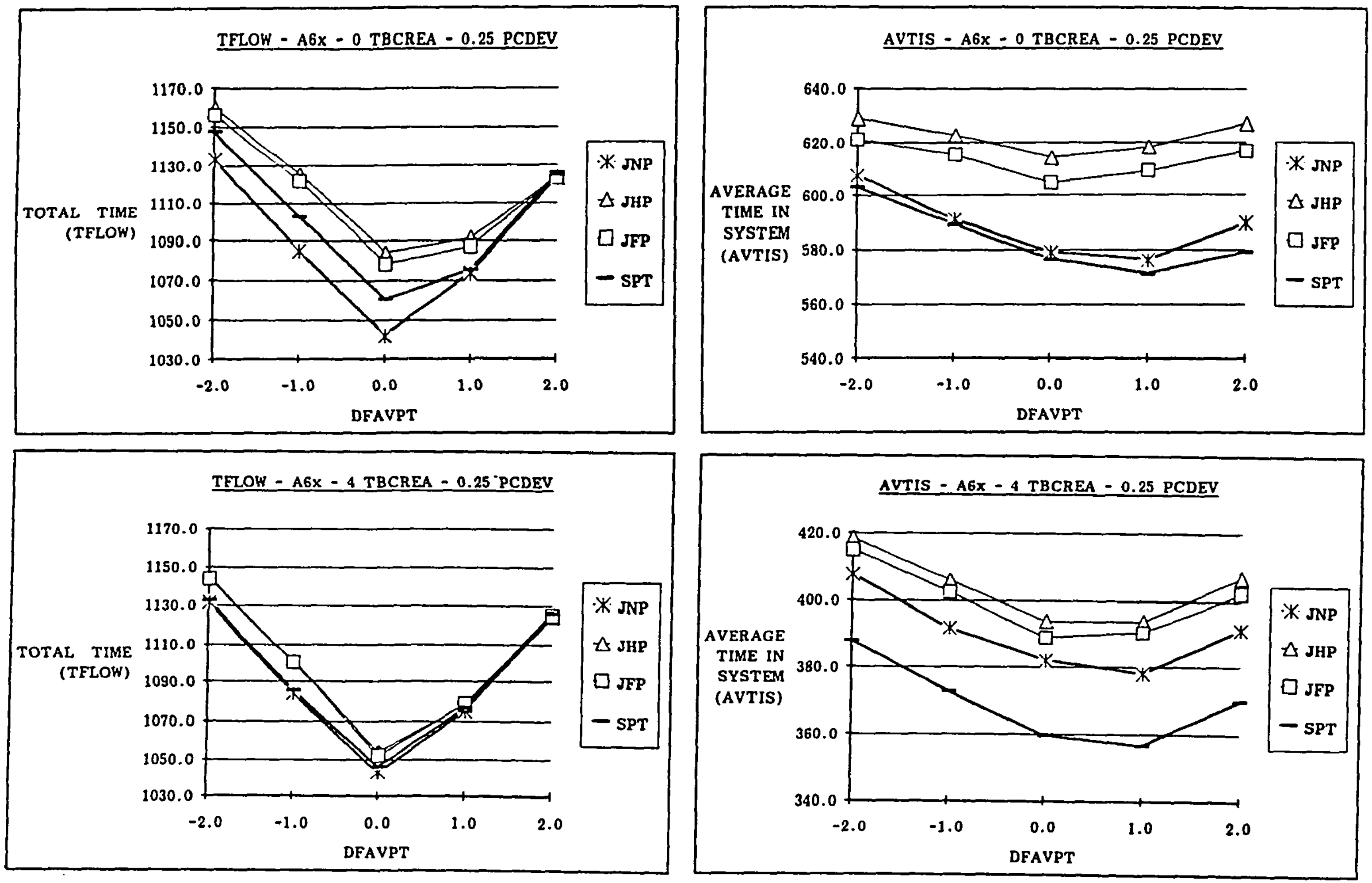


Figure 9f. Graphical representation of the two performance measures TFLOW and AVTIS (model 6x).

of TBCREA, represents the most important and most critical part of our research because our study concentrates on a job shop environment. A project in a job shop environment consists of few jobs, having similar types of product trees, and all available for processing at a certain point in time. The main objective of the shop manager is to complete all these jobs in the shortest possible span of time. Such a situation satisfies the conditions of our model when the time between job creations is zero and the decision criteria is the total flow time.

The tabulation of the primary performance measure TFLOW, at the second level of TBCREA, 4, shows almost the same results as when the factor TBCREA is zero, with one exception, model 2x. For the case of model 2x, the tabulation again shows a reaction to the different levels of the factor PCDEV, and also shows an appreciable shift in preference from the JNP rule to the SPT rule.

The charts in figures 9a to 9f give a better idea about the magnitude of the differences due to the four sequencing rules. Figure 9a shows that for model 1x, the difference between the most efficient rule, SPT, and the three Johnson based rules, is quite small. It also shows that the difference is reversed when the first bottleneck machine's load becomes higher than that of the second bottleneck machine, making the JNP rule more efficient (the reason for that change in rule preference is given later). It is also clear that the increase in the value of TBCREA does not have a noticeable impact on the relative performance of the four sequencing rules.

Figure 9b shows that for model 2x, the three sequencing rules JNP, JHP, and SPT share the title for the most efficient rule. The above is applicable to both levels of TBCREA, although the SPT rule gains an edge over the JNP rule when the value of TBCREA is increased to four. It is noticeable that the increase in the value of TBCREA makes the less competitive rules more competitive than when the value of TBCREA is held at zero: this is due to the fact that the JNP rule is optimal on two machines, for a given set of available jobs. The reaction to the different levels of the factor PCDEV is not shown in this figure, however we will study this reaction and it's significance later.

Figures 9c, 9d, and 9f, for models 3x, 4x, and 6x exhibit very common features. They show that the JNP rule is the most efficient rule at both levels of TBCREA. They also show that the increase in the value of TBCREA makes the less competitive rules more competitive than when the value of TBCREA is held at zero (due to the above mentioned reason).

Figure 9e for model 5x highlights the power of the three Johnson based sequencing rules. The difference in performance between the Johnson based rules and the SPT rule is greatly diminished when the TBCREA factor is increased from zero to four.

From the above six figures, it can be clearly seen that, with the exception of model 5x, the increase in the value of DFAVPT to levels above zero decreases the magnitude of the effect of the different sequencing rules on the performance measure TFLOW. The biggest gainer is the SPT rule. This is easily explained by the fact that an increase in the load on the first bottleneck machine tends to make the shop behave more like a one bottleneck machine shop on the first machine. The process time on the first bottleneck machine becomes, in general, higher than the process time on the second bottleneck machine. In such a situation the Johnson rule, which sequences parts having lower process time on the first machine first, will behave almost like the SPT rule. This causes the JNP rule to lose its efficiency in comparison with the SPT rule: the SPT and the JNP rules converge. We do not have similar results when the value of DFAVPT is decreased to values below zero. In that case, the JNP rule retains its power because the SPT rule is not converting to the JNP rule; the SPT sequences will be different. The two cases shown in figure 10 will clarify the above:

Case 1: DFAVPT > 0

Job	Process time M1	Process time M2
1	15	5
2	13	7
3	17	3
4	14	6
5	16	4

Rule	Sequence
JNP	2,4,1,5,3
SPT(on M1)	2,4,1,5,3
SPT(on M2)	2,4,1,5,3

Case 2: DFAVPT < 0

Job	Process time M1	Process time M2
1	5	15
2	7	13
3	3	17
4	6	14
5	4	16

Rule	Sequence
JNP	3,5,1,4,2
SPT(on M1)	3,5,1,4,2
SPT(on M2)	3,4,2,1,5

Figure 10. Effect of the value of DFAVPT on the SPT and JNP rules.

Model 5x did not exhibit the same kind of behavior because the two bottleneck machines are located after the parts assembly. In such a case, no delays take place before the assembly, and the whole system acts like a two machine flow shop. In a two machine shop, the Johnson rule is optimum with respect to the total flow time, and therefore it will perform optimally when compared with the SPT rule at all levels of the factor DFAVPT.

The above results are very important as they highlight the power of the Johnson sequencing rule when used to minimize the total flow time.

Results of the Performance Measure AVTIS

For this study, AVTIS is considered a secondary performance measure. We will therefore only highlight the summary results at this stage without going through the details.

The tabulation of the secondary performance measure AVTIS (table 9), at the zero level of TBCREA, shows that the SPT rule could be dominant in four of the six different bottleneck machines locations, mainly in models 1x, 2x, 3x, and 6x. This possible dominance is applicable to all five levels of DFAVPT in three of the four models mentioned above. As for the remaining two models, 4x and 5x, this tabulation shows that the two rules JHP and JFP compete for dominance over the other two rules for model 5x, and the JNP rule is efficient for model 4x. None of the models exhibits a reaction, in rule preference, to the different levels of the factor PCDEV.

The tabulation of the performance measure AVTIS at the second level of TBCREA, 4, shows that the SPT rule could be the dominating rule for all six models.

This exhibited power of the SPT is expected when the performance measure is AVTIS because the SPT rule tends to shorten, to the maximum possible, the time of each job in the system. The SPT rule exhibits even more power when the factor TBCREA is increased.

The charts in figures 9a to 9f show preference for the SPT rule for all six models at both levels of TBCREA except for the two models 4x and 5x when the TBCREA is equal to zero. We can also notice that, with the exception of models 4x and 5x, the value of AVTIS reaches its minimum when the value of DFAVPT is equal to 1, meaning that it is preferable, as far as AVTIS is concerned, to have a one bottleneck machine shop at the beginning of the product tree. This confirms the results of the research conducted by Fry, Philipoom, Leong, and Smith (1987), concluding that the best location of a bottleneck machine on a multi-stage product tree is at the lowest level of the tree, that is at the beginning stage. At the same time, our results contradict Sawaqed's (1987) who reports that the location of the bottleneck machine does not have an impact on the relative performance of powerful sequencing rules. However, it should be noted that Sawaqed's study was restricted to a job shop with one bottleneck machine.

Impact of the Levels of Deviation Between the Assumed and the Actual Process Time

In this section, we assess the impact of the factor PCDEV on the relative performance of the four sequencing rules.

Our approach is to first detect any model which exhibits a reaction in rule preference to the different levels of the factor PCDEV. At present we are only interested in a shift in the preferred rule within the limits of our factors levels. If a reaction is detected (meaning a shift in the preferred rule), then a statistical test of interaction will be conducted. If the statistical test confirms the presence of interaction, then we will have to consider this interaction in our study. On the other hand, if the statistical test fails to confirm the presence of interaction, then we can assume that the model does not exhibit any reaction to the different levels of the factor PCDEV, and therefore we can complete our study while considering only one of the three levels of PCDEV.

Let us first consider the secondary performance measure AVTIS. The tabulation of the means of AVTIS shows that none of the models exhibits a reaction, in rule preference, due to changes in the levels of the factor PCDEV. The shift in the preferred DFAVPT value in model 4x (at TBCREA equal to four) does not reflect a change in the preferred sequencing rule, and therefore is not subject to our consideration.

If we now consider the primary performance measure TFLOW, we notice that only model 2x reacts, in terms of rule preference, to the different levels of PCDEV. This reaction takes place at the +1 level of DFAVPT when TBCREA is zero, and at the -1, 0, and +2 levels of DFAVPT when TBCREA is four.

Charts corresponding to model 2x for each of the three levels of PCDEV for both levels of TBCREA are shown in figures 11 and 12. These charts are drawn to study the magnitude of the reaction. As these charts do not show an appreciable reaction, individual charts for the four obvious situations mentioned above are drawn. These four charts are shown in figure 13. In all four charts, we see changes in the preferred rule due to changes in the value of PCDEV; these changes mainly affect the two rules JNP and SPT. It is also noticed that the magnitude of the shift in the preferred rule is quite marginal.

A statistical test of significance for interaction (slope difference) is run on the worst two

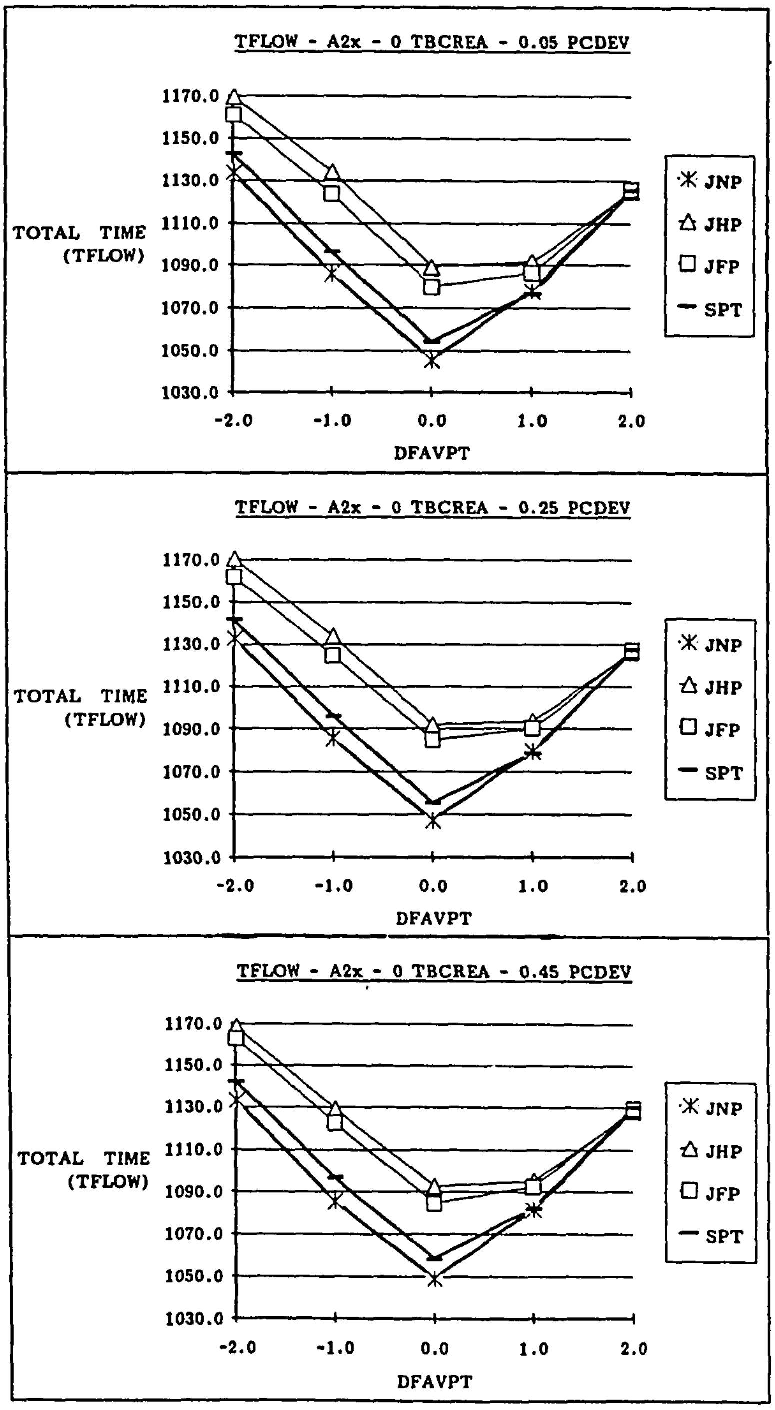


Figure 11. Plots of the total flowtime for each priority rule for each level of deviation versus the difference in the average process time (TBCREA = 0)

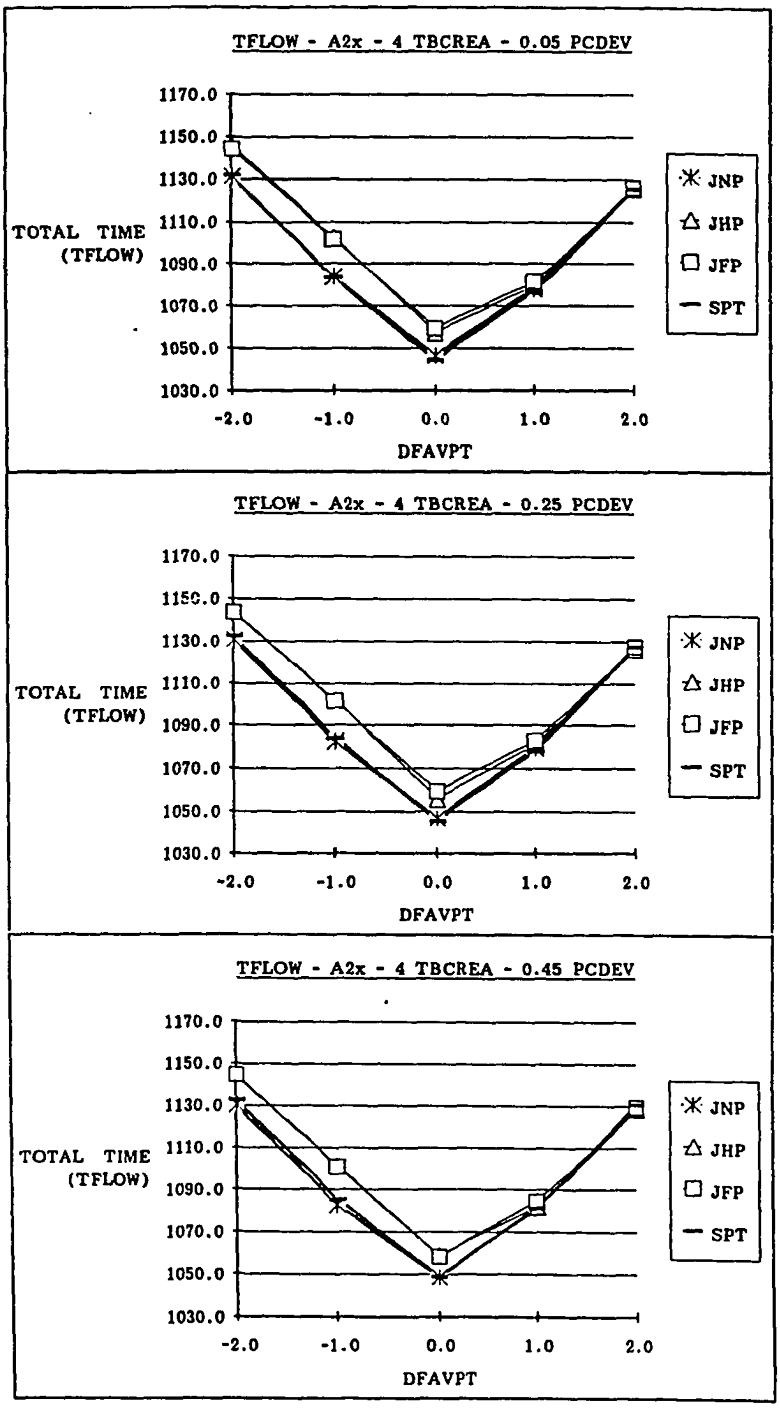


Figure 12. Plots of the average time in system for each priority rule for each level of deviation versus the difference in the average process time (TBCREA = 4)

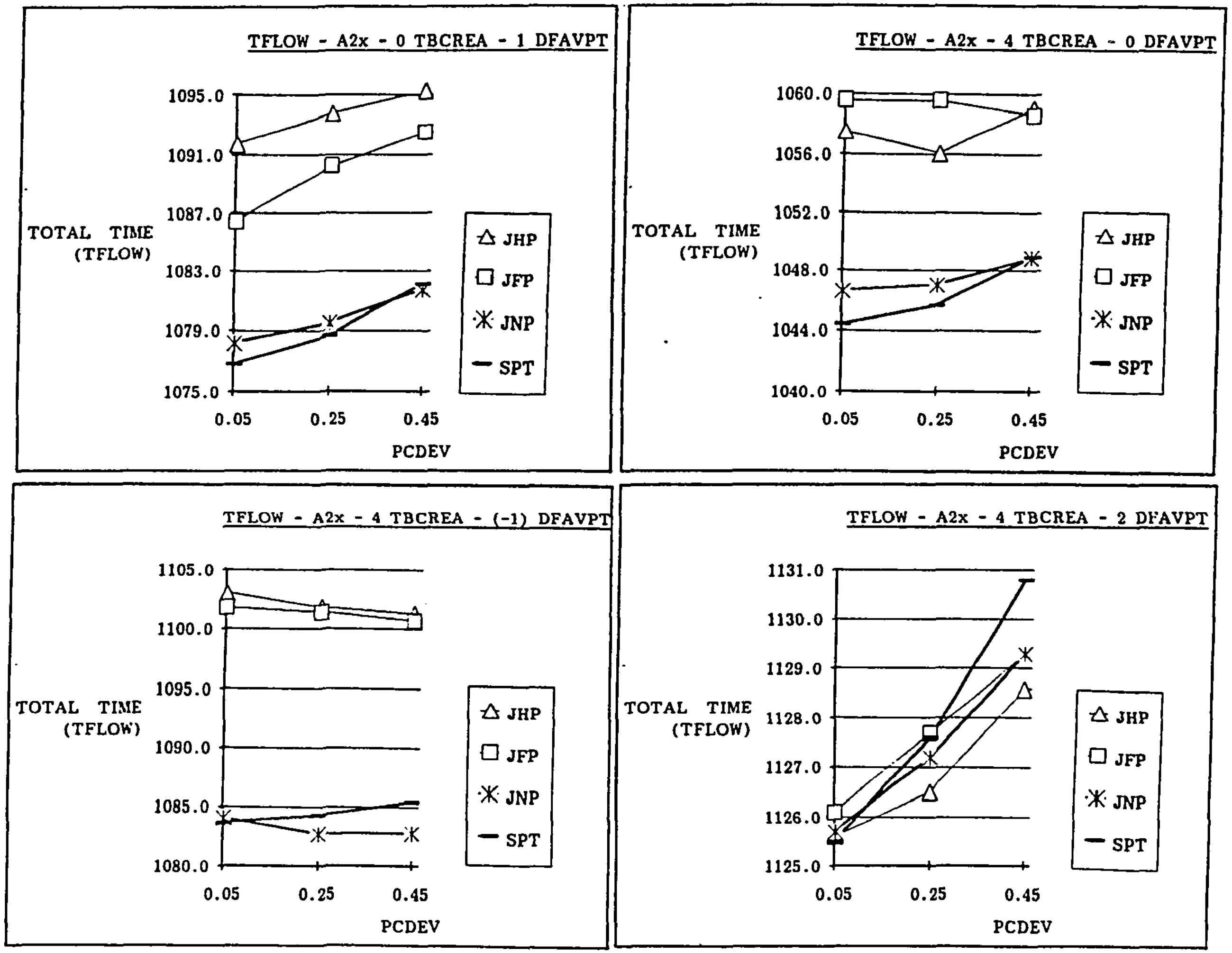


Figure 13. Effect of the three levels of PCDEV on the performance of the different sequencing rules

cases (0 TBCREA, 1 DFAVPT and 4 TBCREA, -1 DFAVPT). Both tests show that the interaction is not statistically significant at the 95% confidence level. The results of these two tests are shown in the appendix 7. As the test results show that there is no significant interaction in these extreme case, and that there is no change in rule preference in all other cases, we can conclude that the different levels of the factor PCDEV do not have an impact on the preferred sequencing rule, and therefore we can proceed with our analysis without taking into consideration the different levels of the factor PCDEV. We will conduct our study on the dataset where PCDEV assumes the value 0.25, which we consider to be a reasonable level.

Impact of the Levels of Time Between Job Creations

In this section we assess the impact of the two levels of the time between jobs creation on the preferred sequencing rule.

As previously stated, we use the Wilcoxon matched-pairs signed-ranks test to find any statistically significant difference in the performance measures due to the different sequencing rules. The Wilcoxon test was administered for the following three sets of pairs of rules: JNP/SPT, JNP/JHP, JNP/JFP. The results of these tests, at 95% confidence level, are shown in table 10 for the performance measure TFLOW, and in table 11 for the performance measure AVTIS. An entry in the tables showing one rule indicates that this rule is statistically dominant, while an entry showing both rules indicates that we failed to prove that there exits a statistically significant difference between the two rules.

Impact of the Time Between Job Creations on Total Flow Time

A study of table 10 shows that the JNP rule is non-dominated with the following two exceptions: model 1x where the non-dominated rule is SPT, and model 5x where the non-dominated rule is one of the Johnson priority rules, JHP or JFP. With these two exceptions, we can state that the JNP rule is a powerful one when trying to minimize the total flow time in an assembly job shop. We notice that the two exceptions stated above correspond to the two models where the bottleneck machines are on two consecutive stages.

The SPT rule performed best for model 1x because the parts output on the non-bottleneck branches (refer to

MODEL	TBCREA	DFAVPT	TFLOW STATISTICAL SIGNIFICANCE JNP/SPT	JNP/JHP	JNP/JFP
1X	0	-2	SPT	JNP/JHP.	JNP/JFP.
		-1	SPT	JNP/JHP.	JNP/JFP.
		0	SPT	JNP/JHP.	JNP/JFP.
		1	SPT/JNP	JNP/JHP	JNP/JFP.
		2	SPT/JNP	JNP/JHP.	JNP/JFP.
	4	-2	SPT	JNP/JHP.	JNP/JFP.
		-1	SPT	JNP/JHP.	JNP/JFP.
		0	SPT	JNP/JHP.	JNP/JFP.
		1	SPT/JNP	JNP/JHP.	JNP/JFP.
		2	SPT/JNP	JNP/JHP.	JNP/JFP.
2X	0	-2	JNP	JNP	JNP
		-1	JNP	JNP	JNP
		0	JNP	JNP	JNP
		1	JNP/SPT	JNP/JHP.	JNP/JFP.
		2	JNP/SPT	JNP/JHP.	JNP/JFP.
	4	-2	JNP/SPT	JNP/JHP.	JNP/JFP.
		-1	JNP/SPT	JNP/JHP.	JNP/JFP.
		0	JNP/SPT	JNP/JHP.	JNP/JFP.
		1	JNP/SPT	JNP/JHP.	JNP/JFP.
		2	JNP/SPT	JNP/JHP.	JNP/JFP.
3X	0	-2	JNP	JNP	JNP
		-1	JNP	JNP	JNP
		0	JNP	JNP	JNP/JFP.
		1	JNP/SPT	JNP/JHP.	JNP/JFP.
		2	JNP/SPT	JNP/JHP.	JNP/JFP.
	4	-2	JNP	JNP/JHP.	JNP/JFP.
		-1	JNP	JNP/JHP.	JNP/JFP.
		0	JNP	JNP/JHP.	JNP/JFP.
		1	JNP/SPT	JNP/JHP.	JNP/JFP.
		2	JNP/SPT	JNP/JHP.	JNP/JFP.

Table 10. Results of the Wilcoxon matched-pairs signed-ranks test (for TFLOW)

			TFLOW		
			STATISTICAL SIGNIFICANCE		
MODEL	TBCREA	DFAVPT	JNP/SPT	JNP/JHP	JNP/JFP
4X	0	-2	JNP	JNP/JHP.	JNP/JFP.
		-1	JNP	JNP/JHP.	JNP/JFP.
		0	JNP	JNP/JHP.	JNP/JFP.
		1	JNP	JNP/JHP.	JNP/JFP.
		2	JNP	JNP/JHP.	JNP/JFP.
	4	-2	JNP	JNP/JHP.	JNP/JFP.
		-1	JNP	JNP/JHP.	JNP/JFP.
		0	JNP	JNP/JHP.	JNP/JFP.
		1	JNP	JNP/JHP.	JNP/JFP.
		2	JNP	JNP/JHP.	JNP/JFP.
5X	0	-2	JNP	JHP	JFP
		-1	JNP	JHP	JFP
		0	JNP	JNP/JHP.	JNP/JFP.
		1	JNP	JNP/JHP.	JNP/JFP.
		2	JNP	JHP	JFP
	4	-2	JNP	JNP/JHP.	JNP/JFP.
		-1	JNP	JNP/JHP.	JNP/JFP.
		0	JNP/SPT	JNP/JHP.	JNP/JFP.
		1	JNP/SPT	JNP/JHP.	JNP/JFP.
		2	JNP/SPT	JNP/JHP.	JNP/JFP.
6X	0	-2	JNP	JNP/JHP	JNP/JFP
		-1	JNP	JNP	JNP
		0	JNP	JNP	JNP
		1	JNP/SPT	JNP/JHP.	JNP/JFP.
		2	JNP/SPT	JNP/JHP.	JNP/JFP.
	4	-2	JNP/SPT	JNP/JHP.	JNP/JFP.
		-1	JNP/SPT	JNP/JHP.	JNP/JFP.
		0	JNP/SPT	JNP/JHP.	JNP/JFP.
		1	JNP/SPT	JNP/JHP.	JNP/JFP.
		2	JNP/SPT	JNP/JHP.	JNP/JFP.

Table 10 (continued). Results of the Wilcoxon matched-pairs signed-ranks test (for TFLOW)

			AVTIS		
			STATISTICAL SIGNIFICANCE		
MODEL	TBCREA	DFAVPT	JNP/SPT	JNP/JHP	JNP/JFP
1X	0	-2	SPT	JNP	JNP
		-1	SPT	JNP	JNP
		0	SPT	JNP	JNP
		1	SPT	JNP	JNP
		2	SPT	JNP	JNP
	4	-2	SPT	JNP	JNP
		-1	SPT	JNP	JNP
		0	SPT	JNP	JNP
		1	SPT	JNP	JNP
		2	SPT	JNP	JNP
2X	0	-2	SPT	JNP	JNP
		-1	SPT	JNP	JNP
		0	SPT	JNP	JNP
		1	SPT	JNP	JNP
		2	SPT	JNP	JNP
	4	-2	SPT	JNP	JNP
		-1	SPT	JNP	JNP
		0	SPT	JNP	JNP
		1	SPT	JNP	JNP
		2	SPT	JNP	JNP
3X	0	-2	SPT/JNP	JNP	JNP/JFP.
		-1	SPT/JNP	JNP	JNP/JFP.
		0	SPT/JNP	JNP	JNP
		1	SPT/JNP	JNP	JNP
		2	SPT	JNP	JNP
	4	-2	SPT	JNP	JNP/JFP.
		-1	SPT	JNP	JNP/JFP.
		0	SPT	JNP	JNP/JFP.
		1	SPT	JNP	JNP/JFP.
		2	SPT	JNP	JNP/JFP.

Table 11. Results of the Wilcoxon matched-pairs signed-ranks test (for AVTIS)

			AVTIS		
			STATISTICAL SIGNIFICANCE		
MODEL	TBCREA	DFAVPT	JNP/SPT	JNP/JHP	JNP/JFP
4X	0	-2	JNP	JNP/JHP.	JNP/JFP.
		-1	JNP	JNP	JNP/JFP.
		0	JNP	JNP	JNP/JFP.
		1	JNP	JNP	JNP/JFP.
		2	JNP	JNP	JNP/JFP.
	4	-2	SPT	JNP	JNP/JFP.
		-1	SPT	JNP/JHP.	JNP/JFP.
		0	SPT	JNP/JHP.	JNP/JFP.
		1	SPT	JNP	JNP/JFP.
		2	SPT	JNP	JNP/JFP.
5X	0	-2	JNP/SPT	JHP	JFP
		-1	JNP/SPT	JHP	JFP
		0	JNP	JHP	JFP
		1	JNP	JHP	JFP
		2	JNP	JHP	JFP
	4	-2	SPT	JHP	JFP
		-1	SPT	JHP/JNP	JFP/JNP
		0	SPT	JHP	JFP
		1	SPT	JHP	JFP
		2	SPT	JHP	JFP
6X	0	-2	SPT	JNP/JHP	JNP/JFP
		-1	SPT/JNP	JNP	JNP
		0	SPT/JNP	JNP	JNP
		1	SPT	JNP	JNP
		2	SPT	JNP	JNP
	4	-2	SPT	JNP	JNP/JFP
		-1	SPT	JNP	JNP/JFP
		0	SPT	JNP/JHP	JNP/JFP
		1	SPT	JNP	JNP
		2	SPT	JNP	JNP

Table 11 (continued). Results of the Wilcoxon matched-pairs signed-ranks test (for AVTIS) figure 5 where we show all six models) is much higher than that on the bottleneck branches. Parts following the non-bottleneck branches are waiting for the other parts at the assembly point because they were not delayed by any bottleneck machine. The SPT rule will surely help in expediting bottleneck branches up to the assembly point.

The JHP (or JFP) performed best for model 5x because we want to process the parts on the bottleneck machines as soon as possible. The Johnson priority rules (JHP and JFP) synchronize the parts through the system and gets them to the bottleneck machines earlier than the Johnson rule without priority (JNP). When the two bottleneck machines are located after the assembly point, the two sequencing rules JHP and JFP are the same.

In comparing the performance measure TFLOW at the two levels of TBCREA we can conclude that an increase in TBCREA from zero to four never changes the non-dominating rule. However, we can state that for three models, the semi-dominated (meaning dominated at some levels of DFAVPT and not dominated at others) rule at TBCREA equal to zero becomes more competitive when TBCREA is increased to four. These three models are 2x, 5x, and 6x.

Looking at the results of the two models 2x and 6x, we notice that the JNP rule is the preferred rule when

TBCREA is zero because the JNP rule dominates in all non-positive values of the factor DFAVPT. In these non-positive values of DFAVPT, an "expediting" rule like the SPT hurts performance because it is pushing parts, which might not be needed at the assembly point, through the non-critical bottleneck machine M1, thus making the JNP rule the dominant one. This negative effect of the SPT rule is drastically reduced when the TBCREA value is increased to four because less parts are available to be pushed in the wrong sequence, therefore making the SPT rule much more competitive at all levels of DFAVPT.

Looking at the results of model 5x, we notice that the preferred rule is one of the two priority rules JHP or JFP when TBCREA is zero because they dominate in three of the five levels of DFAVPT. From the graphs in figure 9e, we can see that the magnitude of that domination is relatively small. When the value of TBCREA is increased to four, the JNP rule competes for domination with the two priority rules.

We can therefore summarize by saying that an increase in the value of TBCREA from zero to four does not change the non-dominated rule in any of the six models. However, in general, an increase in the value of TBCREA will improve the performance of the poorer rules to the extent that they become competitors of the dominating rule. This is found to be true in three of the six models.

Impact of the Time Between Job Creations on Average Time in System

A study of table 11 shows that the SPT rule is generally non-dominated with the following two exceptions: model 4x at the zero level of TBCREA, where the non-dominated rule is JNP, and model 5x at the zero level of TBCREA where the dominating rule is JHP or JFP. With these two exceptions, we can state that the SPT rule is a powerful one when trying to minimize the average time in the system in an assembly job shop.

The JNP rule performed best for model 4x (at the zero level of TBCREA) because of the poor performance of the SPT rule. In this model 4x the bottleneck machines are each preceded by a non-bottleneck machine. Parts on these non-bottleneck machines are sequenced according to the SPT rule, regardless of the priorities of the bottleneck machines. Such a setup has a double negative impact on performance. This negative effect disappears when the factor TBCREA is increased in value to four because there will be less parts to process in the wrong sequence before getting to the bottleneck machines.

The JHP (or JFP) performed best for model 5x (at the zero level of TBCREA) because we want to process the parts on the bottleneck machines as soon as possible. The Johnson priority rules (JHP and JFP) push the parts through the system and gets them to the bottleneck machines earlier than the Johnson rule without priority (JNP) or the SPT. When the factor TBCREA is increased to four, the SPT rule regains its dominance.

In comparing the performance measure AVTIS at the two levels of TBCREA we can certainly conclude that an increase in TBCREA from zero to four has a significant impact on the preferred rule for the two models 4x and 5x. In both cases, the SPT results improve when the value of TBCREA increases. This should be of no surprise as it is well established that the SPT rule is extremely powerful when it comes to minimizing the average time in the system under steady state conditions. As job shop simulation studies are usually conducted under steady state conditions, and not under the more appropriate transient condition, this could be the reason why the literature has typically emphasized the SPT rule over other rules.

Impact of the Levels of Difference in the Average Process Time

In this section we assess the impact of the difference in the average process time of the two bottleneck machines on the preferred sequencing rule. The same tabulated results of the Wilcoxon matched-pairs signed-ranks test are used for this purpose.

Impact of the Difference in the Average Process Time on Total Flow Time

It was previously found that an increase in the value of TBCREA from zero to four does not have an impact on the non-dominated rule when the performance measure is the total flow time. For this reason, we concentrate on the zero level of the factor TBCREA.

A study of table 10 show that SPT is the non-dominated rule for model 1x only, JHP or JFP for model 5x, and JNP for the remaining four models 2x, 3x, 4x, and 6x.

Model 1x results show that the SPT rule is the non-dominated rule in this case and that the JNP rule shares non-domination with the SPT rule at positive levels of DFAVPT. These results are explained by the fact that the presence of the bottleneck machines on the first two stages makes the SPT the most appropriate rule to use as it pushes, through the system, as many parts as possible at an early stage. In this model, when the SPT rule is used, the more critical bottleneck machine is working at almost full capacity at any level of DFAVPT, making the SPT rule the non-dominated rule. At the same time, there are no non-bottleneck machines preceding any of the two bottleneck machines, therefore the SPT sequence on the bottleneck machines is never disturbed. However, when the factor DFAVPT takes positive values, meaning that the first bottleneck machine is more of a bottleneck than the second one, then the JNP sequence gains some strength because, as we have previously seen in figure 10, the two sequences tend to be the same whenever there are no machines between the bottlenecks.

Models 2x, 3x, and 6x show that the JNP rule is the non-dominated rule in these three cases, and that the SPT rule shares dominance with the JNP rule at positive levels of DFAVPT. In all these three cases, only one bottleneck machine is preceded by a non-bottleneck machine; this situation disturbs the SPT sequence for the bottleneck machine and makes the JNP rule more efficient. As the value of DFAVPT increases to positive values, then the two sequences, SPT and JNP, tend to be the same, and the difference in performance between the two rules disappears.

In model 4x the JNP rule dominates the SPT rule. In this case, a non-bottleneck machine precedes each bottleneck machine, twice disturbing the SPT sequence before reaching the bottleneck machines. This situation makes the SPT rule quite inefficient, leaving the dominance for the Johnson based rule at all levels of DFAVPT. We notice from figure 9d that the SPT rule performs very inefficiently at the non-positive levels of DFAVPT; positive levels of DFAVPT tend to improve the performance of the SPT rule because the two rules tend to converge, however this improvement is not enough.

Model 5x shows that the Johnson based priority rules are non-dominated. This model has the bottleneck machines on the last two stages: any procedure accelerating the different parts forward to get to the bottleneck machines earlier would have a positive impact on the performance measure TFLOW. Both rules, JHP and JFP accelerate the movement of these parts. It is to be noted that these two rules are the same in this particular situation where the bottleneck machines are on the last two stages. The two bottleneck machines on the last two stages make the system act like a two-machine flow shop, where the Johnson rule is optimal. When the two bottleneck machines are close to being balanced, the JNP rule becomes as competitive as the Johnson priority rules. We also notice, from figure 9e that the SPT is far from being a competitor at all levels of DFAVPT because the SPT rule is getting parts to the bottleneck machines not in the appropriate sequence.

We can therefore conclude that, whenever the total flow time is the performance measure, it is more appropriate to use the SPT rule when the bottleneck machines are on the first two stages, the JHP (or JFP) when the bottleneck machines are on the last two stages, and the JNP rule for all other bottleneck machines locations. For the case where the two bottleneck machines are on the first two stages, the difference in performance between the SPT and all three Johnson rules is marginal at all levels of DFAVPT.

Figures 9a to 9f show that, except for model 5x, the performance of the SPT rule generally converges to the performance of the JNP rule as the value of the factor DFAVPT increases above zero. This is due to the two cases previously discussed in figure 10.

Impact of the Difference in the Average Process Time on Average Time in System

A study of table 11 shows that SPT is the non-dominated rule for all models except under two situations: model 4x at the zero level of TBCREA where the non-dominated rule is the JNP, and model 5x at the zero level of TBCREA where both JHP and JFP rules dominate (the two rules are equivalent for this model). In fact we can easily detect the strength of the SPT on all models when the factor TBCREA has a value of four, and on models 1x and 2x even at the zero level of the factor TBCREA. This should be of no surprise to us as we know that the SPT rule tends to move parts forward at an early stage, and therefore the average time of a job in the system tends to be minimized.

In model 4x, at the zero level of TBCREA, the JNP rule dominates the SPT rule. In this case, as previously stated, a non-bottleneck machine precedes each bottleneck machine, twice disturbing the SPT sequence before reaching the bottleneck machines. This situation makes the SPT rule quite inefficient, leaving the dominance for the Johnson rule at all levels of DFAVPT. We notice from figure 9d that the SPT rule performs very inefficiently at the non-positive levels of DFAVPT; positive levels of DFAVPT tend to improve the performance of the SPT rule because the two rules tend to converge.

Model 5x shows that, at the zero level of TBCREA, the Johnson based priority rules are non-dominated. This model has the bottleneck machines on the last two stages: any procedure accelerating the different parts forward to get early to the bottleneck machines would have a positive impact on the performance measure AVTIS. Both rules, JHP and JFP accelerate the movement of these parts. It is to be noted that these two rules are the same in this particular situation where the bottleneck machines are on the last two stages.

Impact of the Bottleneck Machines Location

In this section we assess the impact of the bottleneck machines location on the preferred sequencing rule. Results of another set of the Wilcoxon matched-pairs signed-ranks test are used for this purpose; the results are shown in table 12. These tests were described in detail in the Analysis Methodology section of chapter IV.

This study concentrates on the Johnson rule. We therefore find it most appropriate if we compare the different models based on their performance under the Johnson sequencing rule. At the zero level of TBCREA, zero level of DFAVPT, and 0.25 level of PCDEV, table 8 shows that the JNP rule performs best when applied to model 6x. For this reason, we consider our model 6x as base model for the bottleneck machines location, and

TFLOW				
TBCREA	DFAVPT	SUPERIOR TO MODEL 61	NO SIGNIFICANT DIFFERENCE FROM MODEL 61	INFERIOR TO MODEL 61
0	-2	11	61 21 51	31 41
	-1	11	61 21 51	31 41
	0		61 11	21 31 41 51
	1		61 41	11 21 31 51
	2		61 41	11 21 31 51
4	-2	11	61 21 51	31 41
	-1	11	61 21 51	31 41
	0		61 11 21	31 41 51
	1		61 11 21 41	31 51
	2		61 11 21 41	31 51

AVTIS				
TBCREA	DFAVPT	SUPERIOR TO MODEL 61	NO SIGNIFICANT DIFFERENCE FROM MODEL 61	INFERIOR TO MODEL 61
0	-2	11 21	61 51	31 41
	-1	11 21	61 51	31 41
	0	11	61 21 51	31 41
	1	11	61 21	31 41 51
	2	11	61 21	31 41 51
4	-2	11 21 51	61 31	41
	-1	11 21 51	61 31	41
	0	11 51	61 21 31	41
	1	11	61 21	31 41 51
	2	11	61 21	31 41 51

Table 12. Bottleneck machines location preference when the JNP rule is used

compare the other models with it.

Impact of the Bottleneck Machines Location on Total Flow Time

A study of table 12 at the zero level of TBCREA shows that, for negative values of DFAVPT, model 11 dominates model 61, there is no significant statistical difference between models 61, 21, and 51, and models 31 and 41 are dominated by model 61. For positive values of DFAVPT, there is no significant statistical difference between models 61 and 41, and models 11, 21, 31, and 51 are dominated by model 61. For a zero value of DFAVPT, there is no significant statistical difference between models 61 and 11, and models 21, 31, 41, and 51 are dominated by model 61.

From the above, we can clearly say that we have three different situations.

In the first situation, where the second bottleneck machine is the more critical (more loaded) one, it is preferable to have this critical bottleneck located right after the assembly point (models 21 and 61). In this first situation, it is also preferable to have the two bottleneck machines immediately after each other (models 11, 51, and 61): this makes efficient use of the

Johnson rule as there are no in-between machines to delay the process of parts. Having the two bottleneck machines immediately after each other when the second is more loaded than the first also keeps the two bottleneck machines busy whenever there are still parts to be processed.

In the second situation, where the two bottleneck machines have the same average load, it is also preferable to have the two bottleneck machines immediately after each other (models 11 and 61) which makes full use of the Johnson rule. Although the two bottleneck machines are next to each other in model 51, this particular model does not perform as well when using the JNP rule because the parts are not accelerated at the early stages. We have previously seen that in the case of model 51, a priority rule is more appropriate.

In the third situation, where the first bottleneck machine is the more critical (more loaded) one, it is preferable to have this critical bottleneck located right before the assembly point (models 41 and 61). This is also confirmed by model 11 when the value of DFAVPT is negative: in that particular case, machine 2 is more critical, and it is located right before the assembly point, resulting in a very efficient setup.

When the value of TBCREA increases to four, we notice that the classification of the different models remains the same with one exception: at the positive levels of DFAVPT, the two models 11 and 21 become more competitive with model 61.

It is noticed that model 31 is under no circumstances an efficient model.

From the above discussion, we can conclude that model 61, where the bottleneck machines are located just before and just after the assembly point, is the most efficient model. When the second bottleneck machine is more critical, then model 11, where the two bottleneck machines are located at the first and second stages, is more efficient. However, when the value of TBCREA is increased to four, then both models 11 (first and second stages) and 21 (first and third stages) are worth considering. Under any conditions, it is recommended to avoid locating the two bottleneck machines on the first and last stages.

Impact of the Bottleneck Machines Location on Average Time in System

We show a summary of the preferred models in table 12. We do not analyze these results as we have previously shown that the SPT rule is more appropriate when the performance measure is the average time in the system. As the comparison is made here on the basis of the JNP rule, it could be misleading to recommend a location for the bottleneck machines.

CHAPTER VI

FUTURE RESEARCH

In this chapter we recommend some research ideas based on the experience gained through the previously presented research and results.

Our research showed that the levels of deviation between the assumed and the actual process time does not have an impact on the relative performance of the different sequencing rules. However, can we assume that the performance measure TFLOW deteriorates as the deviation between the assumed and the actual process time increases? For a particular job shop setup, we can run different simulations at different deviation values to find a mathematical relationship between the level of deviation and the value of TFLOW. This can be done through a linear regression study.

Our study was conducted on a job shop with two bottleneck machines having an average load one and a half times the load on the non-bottleneck machines. It would be appropriate to conduct some experiments which will study the effect of increasing the load on the non-bottleneck machines to a level equal to 90% that of the bottleneck machines. Such a study will help in establishing a break point after which it would be more appropriate to buy new machinery instead of loading existing machines.

Whenever the SPT sequencing rule was employed in this research, it was applied on each machine in the shop independently. An alternative approach would be to use the SPT rule to sequence the different parts according to the assumed process time on the next bottleneck machine. Such an approach would help in guiding parts, having the smallest process time on bottleneck machines, to get to the bottleneck machines first. However, such an approach might also have a negative effect as it could be delaying parts in getting to the bottleneck machines. A study comparing the two approaches could shed additional light on the most commonly used sequencing rule whenever applied to a two bottleneck machine job shop.

Our research dealt with products all having product trees with four stages, with the assembly point after the second stage. Two bottleneck machine locations showed particular behavior: the first location is when the bottleneck machines are on the first two stages, and the second location is when the bottleneck machines are on the last two stages. In the first case, the SPT rule showed dominance when the second bottleneck machine is more loaded than the first. In the second case, the Johnson based rules showed dominance over the SPT rule. Because our product tree is made of four stages only, it was not possible for us to decide if the results of the first case will be similar when we have the bottleneck machines at any two stages before the assembly point in case we have a taller product tree. Similarly, it was not possible to decide if the results of the second case will be similar when we have the bottleneck machines at any two stages after the assembly point in case we have a taller product tree. While we speculate the results will be the same, a study which answers these two uncertainties will help in establishing efficient job shop procedures.

CHAPTER VII

CONCLUSION

In this chapter we summarize our results. As we have, during the course of this research, considered the total flow time to be our primary performance measure, we concentrate on that performance measure.

Our research showed that, within the limits of our study, the level of deviation between the assumed and the actual process time on the bottleneck machines does not have any significant impact on the relative performance of the four sequencing rules which are investigated. These four rules being the Shortest Process Time (SPT) rule, the Two-Machine Flow Shop Johnson (JNP) rule, and two priority variations (JHP and JFP) of the Two-Machine Flow Shop Johnson rule.

Our study of the impact of the time between job creations showed that the JNP rule is recommended when dealing with a job shop setup having two bottleneck machines. When all jobs are available before the start of operations, the JNP rule performed best in four of the six different models of bottleneck locations, a variation on the JNP rule performed best in the fifth model, and the SPT rule performed best in the sixth model; the difference in performance between the JNP and the SPT rules in this particular sixth model (model 1x) was marginal. When the time between jobs creations was increased, the preferred rule remained the same.

Our study of the difference in the average process time on the two machines shows that it is appropriate to use the SPT rule only when the bottleneck machines are on the first two stages and the first machine is less critical than the second machine: this, more or less guarantees that none of the two machines stays idle while there are still available parts to process. Even under these very particular conditions, the difference in performance between the SPT rule and the JNP rule is marginal. The Johnson based priority rules perform best when the two bottleneck machines are on the last two stages: the priority based rules accelerate the arrival of the different parts to the bottleneck machines. However, the JNP rule proves to be very effective for any other location of the two bottleneck machines. This is also true when the load on one bottleneck machine is different by up to twenty percent from the load of the other bottleneck machine (the non-bottleneck machines operating at 67% capacity). The SPT rule becomes very inefficient when there are more than one non-bottleneck machine between the two bottleneck machines.

This research also highlights the fact that a shop can be managed by managing only its bottleneck machines. Flow shop sequencing rules can be applied to manage job shops: when a job shop has two bottleneck machines, the Two-Machine Flow Shop Johnson rule can be used. This can only be applied to the case when the two bottleneck machines are on the same branch, and not on parallel branches.

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APPENDIXES

```
GEN,SABA BAHOUTH,M9 J3   JOHNSON,1/1/1991,20,Y,Y,Y/Y,Y,Y/F,72;
LIMITS,40,32,350;
EQUIVALENCE/ATRIB(1),TOC/ATRIB(2),NCREATED/ATRIB(3),PT1T/ATRIB(4),PT2T;
EQUIVALENCE/ATRIB(7),PT1A/ATRIB(8),PT2A;
EQUIVALENCE/ATRIB(9),PTPRIO/ATRIB(10),ASSEMBLY;
EQUIVALENCE/ATRIB(5),PRODUCT/ATRIB(6),REMOP/ATRIB(11),REMOPB/ATRIB(12),REMOPA;
EQUIVALENCE/ATRIB(21),QNEXT/ATRIB(22),BRANCH;
EQUIVALENCE/ATRIB(23),PT3T/ATRIB(24),PT4T/ATRIB(25),PT5T/ATRIB(26),PT6T;
EQUIVALENCE/ATRIB(27),PT7T/ATRIB(28),PT8T/ATRIB(29),PT9T;
EQUIVALENCE/ATRIB(13),PT3A/ATRIB(14),PT4A/ATRIB(15),PT5A/ATRIB(16),PT6A;
EQUIVALENCE/ATRIB(17),PT7A/ATRIB(18),PT8A/ATRIB(19),PT9A;
EQUIVALENCE/XX(1),LO1/XX(2),HI1/XX(3),LO2/XX(4),HI2;
EQUIVALENCE/XX(5),NCREA/XX(6),PCDEV/XX(7),TBCREA;
EQUIVALENCE/XX(8),INC_TBC/XX(9),INC_DEV/XX(10),INC_AVPT;
EQUIVALENCE/XX(11),INI_LO1/XX(12),INI_HI1/XX(13),INI_LO2/XX(14),INI_HI2;
EQUIVALENCE/XX(16),FLR_TBC/XX(17),FLR_DEV/XX(15),FLR_AVPT;
EQUIVALENCE/XX(18),CLG_TBC/XX(19),CLG_DEV/XX(20),CLG_AVPT;
EQUIVALENCE/XX(21),ARRPOINT/XX(22),TRTM_NUM/XX(23),ARRP3_9;
EQUIVALENCE/XX(24),ROWP_NQ/XX(27),MODEL;
EQUIVALENCE/XX(28),TRIDIS;
ARRAY(1,500);
ARRAY(2,500);
ARRAY(3,100);
ARRAY(4,100);
ARRAY(5,100);
ARRAY(6,100);
ARRAY(7,100);
ARRAY(8,100);
ARRAY(9,100);
ARRAY(10,100);
ARRAY(21,500);
ARRAY(22,500);
ARRAY(23,100);
ARRAY(24,100);
ARRAY(25,100);
ARRAY(26,100);
ARRAY(27,100);
ARRAY(28,100);
ARRAY(29,100);
;FOLLOWING ARRAYS ARE INVERTED DUE TO REMOP
ARRAY(31,2)/5,9;
ARRAY(32,2)/3,7;
ARRAY(33,2)/8,6;
ARRAY(34,2)/7,4;
ARRAY(35,2)/6,3;
ARRAY(36,1)/8;
ARRAY(37,2)/9,4;
ARRAY(38,1)/5;
ARRAY(41,2)/2,1;
ARRAY(42,2)/2,1;
ARRAY(43,2)/2,1;
```

Appendix.1. The Slamsystem simulation control file

```
PRIORITY/1,LVF(9)/2,LVF(9)/3,LVF(9)/4,LVF(9)/5,LVF(9)/6,LVF(9)/7,LVF(9)/8,LVF(
9)/9,LVF(9);
PRIORITY/11,LVF(3)/12,LVF(4)/13,LVF(23)/14,LVF(24)/15,LVF(25)/16,LVF(26)/17,LVF(
27)/18,LVF(28)/19,LVF(29);
INTLC,INC_TBC=4.,INC_DEV=.20,INC_AVPT=.5;
INTLC,FLR_TBC=0.0001,FLR_DEV=.05;
INTLC,CLG_TBC=4.0001,CLG_DEV=0.449,CLG_AVPT=11.;
INTLC,LO1=6.,HI1=12.,LO2=8.,HI2=14.;
INTLC,INI_LO1=6.,INI_HI1=12.,INI_LO2=8.,INI_HI2=14.;
INTLC,TBCREA=0.0001,PCDEV=.05,NCREA=100;
INTLC,MODEL=52;
NETWORK;
INITIALIZE,,,Y;
FIN;
```

```
;
CREIN CREATE,,,,1,1;
      ACTIVITY/81;
ARR   EVENT,4,1;
      ACTIVITY;
INASS ASSIGN,II=0,ARRPOINT=0,ARRP3_9=0,TRTM_NUM=0,1;
      ACTIVITY;
INTER TERMINATE;
;
GO2   GOON,1;
      ACTIVITY/25,,PT1T.LE.PT2T,JFA1;
      ACTIVITY/26,,PT1T.GT.PT2T,JFA2;
JFA1  ASSIGN,PTPRIO=PT1T,1;
      ACTIVITY;
GOJ1  GOON,1;
      ACTIVITY,,QNEXT.EQ.1;
      ACTIVITY,,QNEXT.EQ.2,Q2J;
      ACTIVITY,,QNEXT.EQ.3,Q3J;
      ACTIVITY,,QNEXT.EQ.4,Q4J;
      ACTIVITY,,QNEXT.EQ.5,Q5J;
      ACTIVITY,,QNEXT.EQ.6,Q6J;
      ACTIVITY,,QNEXT.EQ.7,Q7J;
      ACTIVITY,,QNEXT.EQ.8,Q8J;
      ACTIVITY,,QNEXT.EQ.9,Q9J;
Q1J   QUEUE(1),,,;
      ACTIVITY(1)/1,PT1A;
GOJ2  GOON,1;
      ACTIVITY,,REMOPB.GT.1.AND.ASSEMBLY.EQ.0;
      ACTIVITY,,REMOPB.LE.1.AND.ASSEMBLY.EQ.0,ZAAE;
      ACTIVITY,,REMOPB.LE.1.AND.REMOPA.GT.1.AND.ASSEMBLY.EQ.1,ZAAF;
      ACTIVITY/87,,REMOPB.LE.1.AND.REMOPA.LE.1.AND.ASSEMBLY.EQ.1,CJF1;
      ASSIGN,REMOPB=REMOPB-1,ROWP_NQ=BRANCH+30,QNEXT=ARRAY(ROWP_NQ,REMOPB),
      PTPRIO=PTPRIO-1000,1;
      ACTIVITY,,,GOJ1;
ZAAE  ASSIGN,ASSEMBLY=1,REMOPA=REMOPA+1,PTPRIO=PTPRIO+1000,1;
      ACTIVITY,,BRANCH.EQ.1;
      ACTIVITY,,BRANCH.EQ.2,Q22;
      ACTIVITY,,BRANCH.EQ.3,Q23;
      ACTIVITY,,BRANCH.EQ.4,Q24;
      ACTIVITY,,BRANCH.EQ.5,Q25;
      ACTIVITY,,BRANCH.EQ.6,Q26;
      ACTIVITY,,BRANCH.EQ.7,Q27;
      ACTIVITY,,BRANCH.EQ.8,Q28;
Q21   QUEUE(21),,,,ZAAB ;
ZAAB  SELECT,ASM,,,Q21 ,Q22 ,Q23 ;
      ACTIVITY(1),,,GOJ2;
Q22   QUEUE(22),,,,ZAAB ;
Q23   QUEUE(23),,,,ZAAB ;
Q24   QUEUE(24),,,,ZAAC ;
ZAAC  SELECT,ASM,,,Q24 ,Q25 ;
      ACTIVITY(1),,,GOJ2;
```

Appendix 2. The Slamsystem simulation network file in statement form

```
Q25   QUEUE(25),,,,ZAAC ;
Q26   QUEUE(26),,,,ZAAD ;
ZAAD  SELECT,ASM,,,Q26 ,Q27 ,Q28 ;
      ACTIVITY(1);
      ASSIGN,PTPRIO=PTPRIO-1000,1;
      ACTIVITY,,,GOJ2;
Q27   QUEUE(27),,,,ZAAD ;
Q28   QUEUE(28),,,,ZAAD ;
ZAAF  ASSIGN,REMOPA=REMOPA-1,ROWP_NQ=PRODUCT+40,QNEXT=ARRAY(ROWP_NQ,REMOPA),1;
      ACTIVITY,,,GOJ1;
CJF1  COLCT(1),INT(1),TISJF,,1;
      ACTIVITY/27;
AJF1  ACCUMULATE,NCREATED,NCREATED,LOW(1),1;
      ACTIVITY;
CJF2  COLCT(2),INT(1),TFLOWJF,,1;
      ACTIVITY/32;
EVT1  EVENT,1,1;
      ACTIVITY/71;
ACC2  ACCUMULATE,,,,1;
      ACTIVITY/73;
EVT3  EVENT,3,1;
      ACTIVITY/33;
PTASS ASSIGN,LO1=LO1+INC_AVPT,HI1=HI1+INC_AVPT,LO2=LO2-INC_AVPT,HI2=HI2-
      INC_AVPT,1;
      ACTIVITY/41,,,GO10;
Q2J   QUEUE(2),,,;
      ACTIVITY(1)/2,PT2A,,GOJ2;
Q3J   QUEUE(3),,,;
      ACTIVITY(1)/3,PT3A,,GOJ2;
Q4J   QUEUE(4),,,;
      ACTIVITY(1)/4,PT4A,,GOJ2;
Q5J   QUEUE(5),,,;
      ACTIVITY(1)/5,PT5A,,GOJ2;
Q6J   QUEUE(6),,,;
      ACTIVITY(1)/6,PT6A,,GOJ2;
Q7J   QUEUE(7),,,;
      ACTIVITY(1)/7,PT7A,,GOJ2;
Q8J   QUEUE(8),,,;
      ACTIVITY(1)/8,PT8A,,GOJ2;
Q9J   QUEUE(9),,,;
      ACTIVITY(1)/9,PT9A,,GOJ2;
JFA2  ASSIGN,PTPRIO=100-PT2T,1;
      ACTIVITY,,,GOJ1;
;
GOS1  GOON,1;
      ACTIVITY,,QNEXT.EQ.1;
      ACTIVITY,,QNEXT.EQ.2,Q2S;
      ACTIVITY,,QNEXT.EQ.3,Q3S;
      ACTIVITY,,QNEXT.EQ.4,Q4S;
      ACTIVITY,,QNEXT.EQ.5,Q5S;
      ACTIVITY,,QNEXT.EQ.6,Q6S;
```

```
       ACTIVITY,,QNEXT.EQ.7,Q7S;
       ACTIVITY,,QNEXT.EQ.8,Q8S;
       ACTIVITY,,QNEXT.EQ.9,Q9S;
Q1S    QUEUE(11),,,;
       ACTIVITY(1)/11,PT1A;
GOS2   GOON,1;
       ACTIVITY/89,,REMOPB.LE.1.AND.REMOPA.LE.1.AND.ASSEMBLY.EQ.1,CSS1;
       ACTIVITY,,REMOPB.LE.1.AND.REMOPA.GT.1.AND.ASSEMBLY.EQ.1,ZAAG;
       ACTIVITY,,REMOPB.LE.1.AND.ASSEMBLY.EQ.0,ZAAK;
       ACTIVITY/88,,REMOPB.GT.1.AND.ASSEMBLY.EQ.0,ZAAL;
CSS1   COLCT(3),INT(1),TISSS,,1;
       ACTIVITY;
ASS1   ACCUMULATE,NCREATED,NCREATED,LOW(1),1;
       ACTIVITY;
CSS2   COLCT(4),INT(1),TFLOWSS,,1;
       ACTIVITY;
EVT2   EVENT,2,1;
       ACTIVITY/72,,,ACC2;
ZAAG   ASSIGN,REMOPA=REMOPA-1,ROWP_NQ=PRODUCT+40,QNEXT=ARRAY(ROWP_NQ,REMOPA),1;
       ACTIVITY,,,GOS1;
ZAAK   ASSIGN,REMOPA=REMOPA+1,ASSEMBLY=1,1;
       ACTIVITY,,BRANCH.EQ.1;
       ACTIVITY,,BRANCH.EQ.2,Q32;
       ACTIVITY,,BRANCH.EQ.3,Q33;
       ACTIVITY,,BRANCH.EQ.4,Q34;
       ACTIVITY,,BRANCH.EQ.5,Q35;
       ACTIVITY,,BRANCH.EQ.6,Q36;
       ACTIVITY,,BRANCH.EQ.7,Q37;
       ACTIVITY,,BRANCH.EQ.8,Q38;
Q31    QUEUE(31),,,,ZAAH ;
ZAAH   SELECT,ASM,,,Q31 ,Q32 ,Q33 ;
       ACTIVITY(1),,,GOS2;
Q32    QUEUE(32),,,,ZAAH ;
Q33    QUEUE(33),,,,ZAAH ;
Q34    QUEUE(34),,,,ZAAI ;
ZAAI   SELECT,ASM,,,Q34 ,Q35 ;
       ACTIVITY,,,GOS2;
Q35    QUEUE(35),,,,ZAAI ;
Q36    QUEUE(36),,,,ZAAJ ;
ZAAJ   SELECT,ASM,,,Q36 ,Q37 ,Q38 ;
       ACTIVITY,,,GOS2;
Q37    QUEUE(37),,,,ZAAJ ;
Q38    QUEUE(38),,,,ZAAJ ;
ZAAL   ASSIGN,REMOPB=REMOPB-1,ROWP_NQ=BRANCH+30,QNEXT=ARRAY(ROWP_NQ,REMOPB),1;
       ACTIVITY,,,GOS1;
Q2S    QUEUE(12),,,;
       ACTIVITY(1)/12,PT2A,,GOS2;
Q3S    QUEUE(13),,,;
       ACTIVITY(1)/13,PT3A,,GOS2;
Q4S    QUEUE(14),,,;
       ACTIVITY(1)/14,PT4A,,GOS2;
```

```
Q5S   QUEUE(15),,,;
      ACTIVITY(1)/15,PT5A,,GOS2;
Q6S   QUEUE(16),,,;
      ACTIVITY(1)/16,PT6A,,GOS2;
Q7S   QUEUE(17),,,;
      ACTIVITY(1)/17,PT7A,,GOS2;
Q8S   QUEUE(18),,,;
      ACTIVITY(1)/18,PT8A,,GOS2;
Q9S   QUEUE(19),,,;
      ACTIVITY(1)/19,PT9A,,GOS2;
;
GO10  GOON,1;
      ACTIVITY/52,,LO1/2+HI1/2.LE.CLG_AVPT,ASS2;
      ACTIVITY/51,,LO1/2+HI1/2.GT.CLG_AVPT,TTL;
ASS2  ASSIGN,II=0,ARRP3_9=0,1;
      ACTIVITY,,,CRE1;
CRE1  CREATE,,,1,1,1;
      ACTIVITY/99;
PN    ASSIGN,II=II+1,ARRPOINT=ARRPOINT+1,ARRP3_9=ARRP3_9+1,ASSEMBLY=0,PRODUCT=
      ARRAY(10,II),2;
      ACTIVITY;
      ACTIVITY,,,ZAAU;
      GOON,1;
      ACTIVITY,,II.GE.NCREA;
      ACTIVITY,TBCREA,II.LT.NCREA,CRE1;
      ASSIGN,TRTM_NUM=TRTM_NUM+1,1;
      ACTIVITY;
TER2  TERMINATE;
ZAAU  GOON,1;
      ACTIVITY/91,,PRODUCT.EQ.1;
      ACTIVITY/92,,PRODUCT.EQ.2,ZAAQ;
      ACTIVITY/93,,PRODUCT.EQ.3,ZAAT;
      GOON,3;
      ACTIVITY;
      ACTIVITY,,,ZAAN;
      ACTIVITY,,,ZAAO;
      ASSIGN,REMOPB=2,REMOPA=2,QNEXT=ARRAY(31,REMOPB),BRANCH=1,1;
      ACTIVITY;
ZAAM  ASSIGN,PT1T=ARRAY(1,ARRPOINT),TRIDIS=ARRAY(21,ARRPOINT),PT1A=TRIDIS*PT1T*
      PCDEV+PT1T,PT2T=ARRAY(2,ARRPOINT),TRIDIS=ARRAY(22,ARRPOINT),PT2A=TRIDIS*
      PT2T*PCDEV+PT2T,NCREATED=NCREA,1;
      ACTIVITY;
      ASSIGN,PT3T=ARRAY(3,ARRP3_9),TRIDIS=ARRAY(23,ARRP3_9),PT3A=TRIDIS*PT3T*
      PCDEV+PT3T,1;
      ACTIVITY;
      ASSIGN,PT4T=ARRAY(4,ARRP3_9),TRIDIS=ARRAY(24,ARRP3_9),PT4A=TRIDIS*PT4T*
      PCDEV+PT4T,1;
      ACTIVITY;
      ASSIGN,PT5T=ARRAY(5,ARRP3_9),TRIDIS=ARRAY(25,ARRP3_9),PT5A=TRIDIS*PT5T*
      PCDEV+PT5T,1;
      ACTIVITY;
```

```
      ASSIGN,PT6T=ARRAY(6,ARRP3_9),TRIDIS=ARRAY(26,ARRP3_9),PT6A=TRIDIS*PT6T*
      PCDEV+PT6T,1;
      ACTIVITY;
      ASSIGN,PT7T=ARRAY(7,ARRP3_9),TRIDIS=ARRAY(27,ARRP3_9),PT7A=TRIDIS*PT7T*
      PCDEV+PT7T,1;
      ACTIVITY;
      ASSIGN,PT8T=ARRAY(8,ARRP3_9),TRIDIS=ARRAY(28,ARRP3_9),PT8A=TRIDIS*PT8T*
      PCDEV+PT8T,1;
      ACTIVITY;
      ASSIGN,PT9T=ARRAY(9,ARRP3_9),TRIDIS=ARRAY(29,ARRP3_9),PT9A=TRIDIS*PT9T*
      PCDEV+PT9T,1;
      ACTIVITY;
GO1   GOON,1;
      ACTIVITY/24,,,GO2;
      ACTIVITY/45,,0,GOS1;
ZAAN  ASSIGN,REMOPB=2,REMOPA=2,QNEXT=ARRAY(32,REMOPB),BRANCH=2,1;
      ACTIVITY,,,ZAAM;
ZAAO  ASSIGN,REMOPB=2,REMOPA=2,QNEXT=ARRAY(33,REMOPB),BRANCH=3,1;
      ACTIVITY,,,ZAAM;
ZAAQ  GOON,2;
      ACTIVITY;
      ACTIVITY,,,ZAAP;
      ASSIGN,REMOPB=2,REMOPA=2,QNEXT=ARRAY(34,REMOPB),BRANCH=4,1;
      ACTIVITY,,,ZAAM;
ZAAP  ASSIGN,REMOPB=2,REMOPA=2,QNEXT=ARRAY(35,REMOPB),BRANCH=5,1;
      ACTIVITY,,,ZAAM;
ZAAT  GOON,3;
      ACTIVITY;
      ACTIVITY,,,ZAAR;
      ACTIVITY,,,ZAAS;
      ASSIGN,REMOPB=1,REMOPA=2,QNEXT=ARRAY(36,REMOPB),BRANCH=6,1;
      ACTIVITY,,,ZAAM;
ZAAR  ASSIGN,REMOPB=2,REMOPA=2,QNEXT=ARRAY(37,REMOPB),BRANCH=7,1;
      ACTIVITY,,,ZAAM;
ZAAS  ASSIGN,REMOPB=1,REMOPA=2,QNEXT=ARRAY(38,REMOPB),BRANCH=8,1;
      ACTIVITY,,,ZAAM;
TTL   EVENT,9,1;
      ACTIVITY/60;
ARRC  ASSIGN,ARRPOINT=0,ARRP3_9=0,1;
      ACTIVITY;
GO9   GOON,1;
      ACTIVITY/67,,TBCREA.LT.CLG_TBC.OR.PCDEV.LT.CLG_DEV;
      ACTIVITY/68,,TBCREA.GE.CLG_TBC.AND.PCDEV.GE.CLG_DEV,END;
GO8   GOON,1;
      ACTIVITY/65,,PCDEV.LT.CLG_DEV;
      ACTIVITY/66,,PCDEV.GE.CLG_DEV,ASS5;
ASS6  ASSIGN,II=0,PCDEV=PCDEV+INC_DEV,LO1=INI_LO1,HI1=INI_HI1,LO2=INI_LO2,HI2=
      INI_HI2,1;
      ACTIVITY,,,CRE1;
ASS5  ASSIGN,II=0,TBCREA=TBCREA+INC_TBC,PCDEV=FLR_DEV,LO1=INI_LO1,HI1=INI_HI1,
      LO2=INI_LO2,HI2=INI_HI2,1;
```

```
      ACTIVITY,,,CRE1;
END   TERMINATE;
      END;
```

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

C TO DIMENSION ARRAYS AND OPEN A DATA OUTPUT FILE
      DIMENSION ARRM1T(500)
      DIMENSION ARRM2T(500)
      DIMENSION ARRM3T(100)
      DIMENSION ARRM4T(100)
      DIMENSION ARRM5T(100)
      DIMENSION ARRM6T(100)
      DIMENSION ARRM7T(100)
      DIMENSION ARRM8T(100)
      DIMENSION ARRM9T(100)
      DIMENSION ARRM1AF(500)
      DIMENSION ARRM2AF(500)
      DIMENSION ARRM3AF(100)
      DIMENSION ARRM4AF(100)
      DIMENSION ARRM5AF(100)
      DIMENSION ARRM6AF(100)
      DIMENSION ARRM7AF(100)
      DIMENSION ARRM8AF(100)
      DIMENSION ARRM9AF(100)
      DIMENSION ARRPROON(100)
      OPEN(UNIT=30,FILE='TEMPOF',STATUS='OLD')

C TO DECLARE VARIABLES THAT COULD BE OF USE LOOPING CONTROL
      NJOBS=100
      NLEVELS=5
      NJOBSXLV=NJOBS*NLEVELS

C TO DECLARE VARIABLES THAT WILL BE USED IN THIS SUBROUTINE
      AVPT1=(XX(1)+XX(2))/2
      AVPT2=(XX(3)+XX(4))/2
      ZNCREA=XX(5)
      PCDEV=XX(6)
      TBCREA=XX(7)
      FLR_DEV=XX(17)
      CLG_TBC=XX(18)
      CLG_DEV=XX(19)
      DFAVPT=AVPT1-AVPT2
      ARRPOINT=XX(21)
      TRTM_NUM=XX(22)
      ZMODEL=XX(27)


C                                          CONTROL STATEMENT
      GO TO (10,20,30,40,50,60,70,80,90),I

C TO COLLECT STATISTICS FOR JOHNSON RULE AND WRITE IN DATA FILE
   10 AVTISJF=CCAVG(1)
```

Appendix 3. The Fortran user inserts file

```
      ZMXTISJF=CCMAX(1)
      TFLOWJF=TNOW-ATRIB(1)
      SDTISJF=CCSTD(1)
C       AVQ1JF=FFAVG(1)
C       SDQ1JF=FFSTD(1)
C       ZMXQ1JF=FFMAX(1)
C       AVWQ1JF=FFAWT(1)
C       AVQ2JF=FFAVG(2)
C       SDQ2JF=FFSTD(2)
C       ZMXQ2JF=FFMAX(2)
C       AVWQ2JF=FFAWT(2)
      UTM1JF=AAAVG(1)
      UTM2JF=AAAVG(2)
      UTM3JF=AAAVG(3)
      UTM4JF=AAAVG(4)
      UTM5JF=AAAVG(5)
      UTM6JF=AAAVG(6)
      UTM7JF=AAAVG(7)
      UTM8JF=AAAVG(8)
      UTM9JF=AAAVG(9)
      WRITE(30,110) TRTM_NUM,NNRUN,AVPT1,AVPT2,
     +AVTISJF,ZMXTISJF,TFLOWJF,SDTISJF,
C     +AVQ1JF,SDQ1JF,ZMXQ1JF,AVWQ1JF,
C     +AVQ2JF,SDQ2JF,ZMXQ2JF,AVWQ2JF,
     +DFAVPT,TBCREA,PCDEV,
     +UTM1JF,UTM2JF,
     +UTM3JF,UTM4JF,UTM5JF,UTM6JF,UTM7JF,UTM8JF,UTM9JF,
     +ZMODEL
  110 FORMAT(F4.0,1X,I3,1X,' JF2',1X,F5.1,1X,F5.1,1X,
     +F8.2,1X,F8.2,1X,F10.2,1X,F7.2,1X,
C     +F6.2,1X,F5.1,1X,F4.0,1X,F6.1,1X,
C     +F6.2,1X,F5.1,1X,F4.0,1X,F6.1,1X,
     +F6.1,1X,F6.0,1X,F5.2,2X,
     +F4.2,1X,F4.2,1X,
     +F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,
     +F3.0)
      RETURN

C TO COLLECT STATISTICS FOR SPT RULE AND WRITE IN DATA FILE
   20 AVTISSS=CCAVG(3)
      ZMXTISSS=CCMAX(3)
      TFLOWSS=TNOW-ATRIB(1)
      SDTISSS=CCSTD(3)
C       AVQ1SS=FFAVG(3)
C       SDQ1SS=FFSTD(3)
C       ZMXQ1SS=FFMAX(3)
C       AVWQ1SS=FFAWT(3)
C       AVQ2SS=FFAVG(4)
C       SDQ2SS=FFSTD(4)
C       ZMXQ2SS=FFMAX(4)
C       AVWQ2SS=FFAWT(4)
```

```
      UTM1SS=AAAVG(11)
      UTM2SS=AAAVG(12)
      UTM3SS=AAAVG(13)
      UTM4SS=AAAVG(14)
      UTM5SS=AAAVG(15)
      UTM6SS=AAAVG(16)
      UTM7SS=AAAVG(17)
      UTM8SS=AAAVG(18)
      UTM9SS=AAAVG(19)
      WRITE(30,210) TRTM_NUM,NNRUN,AVPT1,AVPT2,
     +AVTISSS,ZMXTISSS,TFLOWSS,SDTISSS,
C     +AVQ1SS,SDQ1SS,ZMXQ1SS,AVWQ1SS,
C     +AVQ2SS,SDQ2SS,ZMXQ2SS,AVWQ2SS,
     +DFAVPT,TBCREA,PCDEV,
     +UTM1SS,UTM2SS,
     +UTM3SS,UTM4SS,UTM5SS,UTM6SS,UTM7SS,UTM8SS,UTM9SS,
     +ZMODEL
  210 FORMAT(F4.0,1X,I3,1X,' SS2',1X,F5.1,1X,F5.1,1X,
     +F8.2,1X,F8.2,1X,F10.2,1X,F7.2,1X,
C     +F6.2,1X,F5.1,1X,F4.0,1X,F6.1,1X,
C     +F6.2,1X,F5.1,1X,F4.0,1X,F6.1,1X,
     +F6.1,1X,F6.0,1X,F5.2,2X,
     +F4.2,1X,F4.2,1X,
     +F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,F4.2,1X,
     +F3.0)
      RETURN


C TO SHOW SIMULATION PROGRSS ON COMPUTER SCREEN AND CLEAR ARRAYS
   30 PRINT 310, TRTM_NUM,NNRUN
  310 FORMAT('+','TREATMENT: ',F4.0,7X,'RUN: ',I3)
      CALL CLEAR
      RETURN

C TO INITIALIZE PROCESS TIME ARRAYS(1-9 & 21-29) AND PRODUCT NUMBER ARRAY(10)
C AT BEGINNING OF EACH RUN
   40 I1=1
      DO 410 I1=1,NJOBS
         I2=(1*NJOBS)+I1
         I3=(2*NJOBS)+I1
         I4=(3*NJOBS)+I1
         I5=(4*NJOBS)+I1
         ARRM1T(I1)=UNFRM(06.0,12.0,3)
         ARRM1AF(I1)=TRIAG(-1.,0.,1.,4)
         ARRM1T(I2)=ARRM1T(I1)+0.5
         ARRM1AF(I2)=ARRM1AF(I1)
         ARRM1T(I3)=ARRM1T(I1)+1.0
         ARRM1AF(I3)=ARRM1AF(I1)
         ARRM1T(I4)=ARRM1T(I1)+1.5
         ARRM1AF(I4)=ARRM1AF(I1)
         ARRM1T(I5)=ARRM1T(I1)+2.0
```

```
      ARRM1AF(I5)=ARRM1AF(I1)
410 CONTINUE
    CALL SETARY(1,ARRM1T)
    CALL SETARY(21,ARRM1AF)

    I1=1
    DO 420 I1=1,NJOBS
      I2=(1*NJOBS)+I1
      I3=(2*NJOBS)+I1
      I4=(3*NJOBS)+I1
      I5=(4*NJOBS)+I1
      ARRM2T(I1)=UNFRM(08.0,14.0,3)
      ARRM2AF(I1)=TRIAG(-1.,0.,1.,4)
      ARRM2T(I2)=ARRM2T(I1)-0.5
      ARRM2AF(I2)=ARRM2AF(I1)
      ARRM2T(I3)=ARRM2T(I1)-1.0
      ARRM2AF(I3)=ARRM2AF(I1)
      ARRM2T(I4)=ARRM2T(I1)-1.5
      ARRM2AF(I4)=ARRM2AF(I1)
      ARRM2T(I5)=ARRM2T(I1)-2.0
      ARRM2AF(I5)=ARRM2AF(I1)
420 CONTINUE
    CALL SETARY(2,ARRM2T)
    CALL SETARY(22,ARRM2AF)

    I1=1
    DO 430 I1=1,NJOBS
      ARRM3T(I1)=UNFRM(7.0,13.0,3)
      ARRM3AF(I1)=TRIAG(-1.,0.,1.,4)
430 CONTINUE
    CALL SETARY(3,ARRM3T)
    CALL SETARY(23,ARRM3AF)

    I1=1
    DO 440 I1=1,NJOBS
      ARRM4T(I1)=UNFRM(7.0,13.0,3)
      ARRM4AF(I1)=TRIAG(-1.,0.,1.,4)
440 CONTINUE
    CALL SETARY(4,ARRM4T)
    CALL SETARY(24,ARRM4AF)

    I1=1
    DO 450 I1=1,NJOBS
      ARRM5T(I1)=UNFRM(7.0,13.0,3)
      ARRM5AF(I1)=TRIAG(-1.,0.,1.,4)
450 CONTINUE
    CALL SETARY(5,ARRM5T)
    CALL SETARY(25,ARRM5AF)

    I1=1
    DO 460 I1=1,NJOBS
```

```
         ARRM6T(I1)=UNFRM(7.0,13.0,3)
         ARRM6AF(I1)=TRIAG(-1.,0.,1.,4)
  460 CONTINUE
      CALL SETARY(6,ARRM6T)
      CALL SETARY(26,ARRM6AF)

      I1=1
      DO 470 I1=1,NJOBS
         ARRM7T(I1)=UNFRM(7.0,13.0,3)
         ARRM7AF(I1)=TRIAG(-1.,0.,1.,4)
  470 CONTINUE
      CALL SETARY(7,ARRM7T)
      CALL SETARY(27,ARRM7AF)

      I1=1
      DO 480 I1=1,NJOBS
         ARRM8T(I1)=UNFRM(7.0,13.0,3)
         ARRM8AF(I1)=TRIAG(-1.,0.,1.,4)
  480 CONTINUE
      CALL SETARY(8,ARRM8T)
      CALL SETARY(28,ARRM8AF)

      I1=1
      DO 490 I1=1,NJOBS
         ARRM9T(I1)=UNFRM(7.0,13.0,3)
         ARRM9AF(I1)=TRIAG(-1.,0.,1.,4)
  490 CONTINUE
      CALL SETARY(9,ARRM9T)
      CALL SETARY(29,ARRM9AF)

      I1=1
      DO 492 I1=1,NJOBS
         TEMP_PN1=UNFRM(1.0,3.999999,5)
         TEMP_PN2=AINT(TEMP_PN1)
         ARRPRODN(I1)=TEMP_PN2
  492 CONTINUE
      CALL SETARY(10,ARRPRODN)
      RETURN

C FOR POSSIBLE FUTURE USE
   50 return
   60 return
   70 return
   80 return

C TO BE USED FOR HEADINGS, WHEN NEEDED, IN OUTPUT DATA FILE
C   90 WRITE(30,*)
C      WRITE(30,910)
CCCCCCCCCC   THE FOLLOWING FORMAT 910 NEEDS TO BE REWRITEN    CCCCCCC
C  910 FORMAT('TRTM',1X,'RUN',1X,'RULE',1X,'AVPT1',1X,'AVPT2',1X,
C     +'   AVTIS',1X,'   MXTIS',1X,'     TFLOW',1X,'  SDTIS',1X,
```

```
C     +'  AVQ1',1X,' SDQ1',1X,'MXQ1',1X,' AVWQ1',1X,
C     +'  AVQ2',1X,' SDQ2',1X,'MXQ2',1X,' AVWQ2',1X,
C     +'DFAVPT',1X,'TBCREA',1X,'PCDEV',2X,
C     +' UT1',1X,' UT2')
C      WRITE(30,920)
C  920 FORMAT(2X,'TBCREA',2X,'PCDEV',4X,'CLG_TBC',2X,
C     +'CLG_DEV',4X,'NCREA')
C      WRITE(30,930) TBCREA,PCDEV,CLG_TBC,
C     +CLG_DEV,ZNCREA
C  930 FORMAT(2X,F10.6,2X,F5.2,4X,F7.0,2X,
C     +F7.2,4X,F5.0)
C      WRITE(30,*)'---------------------------------------------'
C  990 RETURN
   90 RETURN
      END
```

TRTM	RUN	RULE	AVPT1	AVPT2	AVTIS	MXTIS	TFLOW	SDTIS	DFAVPT	TBCREA	PCDEV	UTM1	UTM2	UTM3	UTM4	UTM5	UTM6	UTM7	UTM8	UTM9	MDL
1.	1	JF2	9.0	11.0	598.49	1113.63	1113.63	320.54	-2.0	0.	.05	.82	.96	.58	.53	.68	.60	.61	.66	.67	31.
2.	1	JF2	9.5	10.5	584.54	1066.28	1066.29	308.20	-1.0	0.	.05	.90	.96	.60	.55	.71	.62	.64	.69	.70	31.
3.	1	JF2	10.0	10.0	573.75	1042.20	1042.20	294.58	.0	0.	.05	.97	.93	.62	.56	.73	.64	.65	.71	.71	31.
4.	1	JF2	10.5	9.5	575.61	1087.30	1087.30	301.29	1.0	0.	.05	.97	.85	.59	.54	.70	.61	.62	.68	.68	31.
5.	1	JF2	11.0	9.0	595.51	1135.28	1135.28	316.19	2.0	0.	.05	.98	.77	.57	.52	.67	.59	.60	.65	.65	31.
6.	1	JF2	9.0	11.0	603.34	1123.82	1123.82	323.27	-2.0	0.	.25	.82	.96	.58	.52	.68	.59	.61	.66	.66	31.
7.	1	JF2	9.5	10.5	590.27	1076.93	1076.93	310.86	-1.0	0.	.25	.90	.96	.61	.54	.71	.61	.64	.69	.69	31.
8.	1	JF2	10.0	10.0	578.33	1052.02	1052.02	296.95	.0	0.	.25	.97	.93	.62	.55	.73	.63	.65	.70	.70	31.
9.	1	JF2	10.5	9.5	581.69	1097.52	1097.52	304.53	1.0	0.	.25	.97	.85	.60	.53	.70	.60	.62	.68	.67	31.
10.	1	JF2	11.0	9.0	604.16	1145.88	1145.88	317.75	2.0	0.	.25	.98	.77	.57	.51	.67	.57	.60	.65	.65	31.
11.	1	JF2	9.0	11.0	608.15	1134.00	1134.00	326.05	-2.0	0.	.45	.82	.96	.58	.51	.69	.57	.61	.66	.65	31.
12.	1	JF2	9.5	10.5	593.52	1085.01	1085.01	313.36	-1.0	0.	.45	.90	.96	.61	.54	.72	.60	.64	.69	.68	31.
13.	1	JF2	10.0	10.0	583.02	1061.83	1061.83	299.38	.0	0.	.45	.97	.93	.62	.55	.73	.61	.65	.70	.69	31.
14.	1	JF2	10.5	9.5	588.13	1107.76	1107.76	308.17	1.0	0.	.45	.97	.85	.60	.53	.70	.59	.62	.67	.66	31.
15.	1	JF2	11.0	9.0	610.08	1156.48	1156.48	323.62	2.0	0.	.45	.98	.77	.57	.50	.67	.56	.60	.65	.64	31.
16.	1	JF2	9.0	11.0	405.78	1075.71	1120.03	315.57	-2.0	4.	.05	.81	.96	.58	.52	.68	.59	.61	.66	.66	31.
17.	1	JF2	9.5	10.5	406.60	1041.86	1085.66	309.57	-1.0	4.	.05	.88	.94	.59	.54	.70	.61	.63	.68	.68	31.
18.	1	JF2	10.0	10.0	388.34	991.58	1042.20	290.74	.0	4.	.05	.97	.93	.62	.56	.73	.64	.65	.71	.71	31.
19.	1	JF2	10.5	9.5	386.01	1036.21	1087.30	289.98	1.0	4.	.05	.97	.85	.59	.54	.70	.61	.62	.68	.68	31.
20.	1	JF2	11.0	9.0	398.04	1082.05	1135.28	309.71	2.0	4.	.05	.98	.77	.57	.52	.67	.59	.60	.65	.65	31.
21.	1	JF2	9.0	11.0	414.73	1087.57	1133.11	320.01	-2.0	4.	.25	.81	.96	.58	.52	.68	.58	.60	.65	.65	31.
22.	1	JF2	9.5	10.5	403.21	1042.21	1087.14	304.10	-1.0	4.	.25	.89	.95	.60	.54	.71	.61	.63	.68	.68	31.
23.	1	JF2	10.0	10.0	396.35	1000.32	1052.02	295.36	.0	4.	.25	.97	.93	.62	.55	.73	.63	.65	.71	.70	31.
24.	1	JF2	10.5	9.5	394.78	1045.46	1097.52	294.65	1.0	4.	.25	.97	.85	.60	.53	.70	.60	.62	.68	.67	31.
25.	1	JF2	11.0	9.0	407.01	1091.68	1145.88	310.91	2.0	4.	.25	.98	.77	.57	.51	.67	.57	.60	.65	.65	31.
26.	1	JF2	9.0	11.0	425.11	1099.48	1146.24	322.19	-2.0	4.	.45	.81	.95	.58	.51	.68	.57	.60	.65	.64	31.
27.	1	JF2	9.5	10.5	415.85	1057.65	1103.73	314.03	-1.0	4.	.45	.88	.94	.60	.53	.71	.59	.63	.68	.67	31.
28.	1	JF2	10.0	10.0	397.38	1009.05	1061.83	294.13	.0	4.	.45	.97	.93	.62	.55	.73	.61	.65	.70	.69	31.
29.	1	JF2	10.5	9.5	402.56	1054.75	1107.78	297.58	1.0	4.	.45	.97	.85	.60	.53	.70	.59	.62	.67	.66	31.
30.	1	JF2	11.0	9.0	417.11	1102.77	1156.48	313.05	2.0	4.	.45	.98	.77	.57	.50	.67	.56	.60	.65	.64	31.

Appendix 4. A sample of the data output file (file A31)

1.	2	JF2	9.0	11.0	608.37	1136.27	1136.27	328.03	-2.0	0.	.05	.81	.96	.59	.61	.56	.61	.60	.55	.55	31.
2.	2	JF2	9.5	10.5	591.62	1086.74	1086.75	316.18	-1.0	0.	.05	.89	.96	.62	.63	.59	.63	.62	.57	.57	31.
3.	2	JF2	10.0	10.0	576.23	1046.03	1046.03	300.54	.0	0.	.05	.97	.95	.64	.66	.61	.66	.65	.59	.59	31.
4.	2	JF2	10.5	9.5	573.93	1094.98	1094.98	303.90	1.0	0.	.05	.97	.86	.61	.63	.58	.63	.62	.57	.57	31.
5.	2	JF2	11.0	9.0	593.49	1143.93	1143.93	317.58	2.0	0.	.05	.98	.78	.59	.60	.56	.60	.59	.54	.54	31.
6.	2	JF2	9.0	11.0	611.11	1141.49	1141.49	330.68	-2.0	0.	.25	.80	.96	.59	.61	.56	.60	.61	.54	.54	31.
7.	2	JF2	9.5	10.5	594.98	1091.88	1091.88	319.34	-1.0	0.	.25	.88	.96	.61	.64	.58	.63	.64	.57	.56	31.
8.	2	JF2	10.0	10.0	587.03	1049.42	1049.42	304.25	.0	0.	.25	.96	.95	.64	.67	.60	.66	.66	.59	.58	31.
9.	2	JF2	10.5	9.5	583.12	1086.79	1086.79	300.37	1.0	0.	.25	.97	.87	.62	.64	.58	.63	.64	.57	.56	31.
10.	2	JF2	11.0	9.0	593.02	1135.54	1135.54	314.98	2.0	0.	.25	.98	.79	.59	.62	.56	.61	.61	.54	.54	31.
11.	2	JF2	9.0	11.0	625.41	1159.24	1159.24	334.90	-2.0	0.	.45	.78	.95	.58	.61	.54	.60	.62	.53	.52	31.
12.	2	JF2	9.5	10.5	613.54	1113.33	1113.33	324.34	-1.0	0.	.45	.85	.94	.60	.64	.57	.62	.64	.55	.54	31.
13.	2	JF2	10.0	10.0	592.95	1055.66	1055.66	306.65	.0	0.	.45	.95	.95	.63	.67	.60	.65	.68	.58	.57	31.
14.	2	JF2	10.5	9.5	588.67	1078.59	1078.59	299.58	1.0	0.	.45	.97	.88	.62	.66	.59	.64	.66	.57	.56	31.
15.	2	JF2	11.0	9.0	594.75	1127.14	1127.14	312.11	2.0	0.	.45	.98	.80	.59	.63	.56	.61	.63	.55	.54	31.
16.	2	JF2	9.0	11.0	404.73	1051.67	1133.88	316.31	-2.0	4.	.05	.81	.96	.59	.61	.56	.61	.60	.55	.55	31.
17.	2	JF2	9.5	10.5	391.94	1000.98	1087.56	301.10	-1.0	4.	.05	.89	.96	.62	.63	.59	.63	.62	.57	.57	31.
18.	2	JF2	10.0	10.0	376.56	954.56	1046.04	293.50	.0	4.	.05	.97	.95	.64	.66	.61	.66	.65	.59	.59	31.
19.	2	JF2	10.5	9.5	370.68	998.92	1094.98	296.95	1.0	4.	.05	.97	.86	.61	.63	.58	.63	.62	.57	.57	31.
20.	2	JF2	11.0	9.0	391.34	1046.41	1143.92	311.54	2.0	4.	.05	.98	.78	.59	.60	.56	.60	.59	.54	.54	31.
21.	2	JF2	9.0	11.0	408.91	1059.03	1140.27	316.89	-2.0	4.	.25	.80	.96	.59	.61	.56	.60	.61	.54	.54	31.
22.	2	JF2	9.5	10.5	400.08	1012.64	1097.77	304.18	-1.0	4.	.25	.87	.95	.61	.64	.58	.63	.63	.56	.56	31.
23.	2	JF2	10.0	10.0	378.06	957.66	1039.32	294.17	.0	4.	.25	.97	.96	.65	.67	.61	.66	.67	.59	.59	31.
24.	2	JF2	10.5	9.5	369.01	988.37	1086.78	295.26	1.0	4.	.25	.97	.87	.62	.64	.58	.63	.64	.57	.56	31.
25.	2	JF2	11.0	9.0	393.06	1036.54	1135.54	307.68	2.0	4.	.25	.98	.79	.59	.62	.56	.61	.61	.54	.54	31.
26.	2	JF2	9.0	11.0	410.75	1064.94	1145.21	318.82	-2.0	4.	.45	.79	.96	.58	.62	.55	.60	.62	.54	.53	31.
27.	2	JF2	9.5	10.5	409.80	1026.76	1110.43	308.62	-1.0	4.	.45	.86	.95	.60	.64	.57	.62	.64	.55	.55	31.
28.	2	JF2	10.0	10.0	383.27	964.99	1045.10	296.25	.0	4.	.45	.96	.96	.64	.68	.60	.66	.68	.59	.58	31.
29.	2	JF2	10.5	9.5	373.63	983.58	1078.59	296.04	1.0	4.	.45	.97	.88	.62	.66	.59	.64	.66	.57	.56	31.
30.	2	JF2	11.0	9.0	391.80	1029.52	1127.15	304.15	2.0	4.	.45	.98	.80	.59	.63	.56	.61	.63	.55	.54	31.

1.	3	JF2	9.0	11.0	613.39	1152.40	1152.40	333.63	-2.0	0.	.05	.75	.96	.60	.57	.58	.61	.60	.59	.56	31.
2.	3	JF2	9.5	10.5	594.14	1104.37	1104.38	320.96	-1.0	0.	.05	.83	.96	.62	.59	.61	.64	.62	.61	.58	31.
3.	3	JF2	10.0	10.0	584.09	1056.36	1056.36	307.78	.0	0.	.05	.92	.96	.65	.62	.64	.66	.65	.64	.61	31.
4.	3	JF2	10.5	9.5	572.68	1047.53	1047.53	296.23	1.0	0.	.05	.97	.92	.66	.63	.64	.67	.66	.64	.61	31.
5.	3	JF2	11.0	9.0	569.36	1095.58	1095.58	305.77	2.0	0.	.05	.98	.83	.63	.60	.61	.64	.63	.62	.59	31.
6.	3	JF2	9.0	11.0	615.01	1157.30	1157.30	334.90	-2.0	0.	.25	.76	.96	.60	.57	.59	.61	.59	.59	.56	31.
7.	3	JF2	9.5	10.5	597.42	1110.92	1110.92	322.52	-1.0	0.	.25	.83	.96	.62	.60	.62	.64	.62	.62	.58	31.
8.	3	JF2	10.0	10.0	590.90	1062.81	1062.81	310.22	.0	0.	.25	.92	.95	.65	.62	.64	.67	.64	.65	.60	31.
9.	3	JF2	10.5	9.5	578.54	1053.38	1053.38	298.30	1.0	0.	.25	.97	.92	.66	.63	.65	.67	.65	.65	.61	31.
10.	3	JF2	11.0	9.0	575.10	1101.62	1101.62	306.05	2.0	0.	.25	.98	.83	.63	.60	.62	.64	.62	.62	.58	31.
11.	3	JF2	9.0	11.0	614.00	1159.51	1159.51	336.08	-2.0	0.	.45	.76	.96	.60	.58	.60	.61	.59	.60	.55	31.
12.	3	JF2	9.5	10.5	600.71	1117.46	1117.46	324.11	-1.0	0.	.45	.83	.96	.62	.60	.62	.64	.61	.63	.57	31.
13.	3	JF2	10.0	10.0	597.73	1069.27	1069.27	312.67	.0	0.	.45	.92	.95	.65	.63	.65	.67	.64	.65	.60	31.
14.	3	JF2	10.5	9.5	584.70	1059.22	1059.22	300.44	1.0	0.	.45	.97	.91	.65	.63	.66	.67	.64	.66	.61	31.
15.	3	JF2	11.0	9.0	578.91	1107.66	1107.66	307.77	2.0	0.	.45	.98	.83	.63	.60	.63	.64	.62	.63	.58	31.
16.	3	JF2	9.0	11.0	411.90	1085.24	1149.82	324.30	-2.0	4.	.05	.76	.97	.60	.57	.59	.61	.60	.59	.56	31.
17.	3	JF2	9.5	10.5	392.05	1030.96	1101.80	307.96	-1.0	4.	.05	.84	.96	.62	.60	.61	.64	.63	.61	.58	31.
18.	3	JF2	10.0	10.0	380.80	985.30	1050.86	297.86	.0	4.	.05	.92	.96	.65	.62	.64	.67	.66	.64	.61	31.
19.	3	JF2	10.5	9.5	376.43	971.98	1047.52	287.54	1.0	4.	.05	.97	.92	.66	.63	.64	.67	.66	.64	.61	31.
20.	3	JF2	11.0	9.0	383.91	1019.07	1095.58	287.93	2.0	4.	.05	.98	.83	.63	.60	.61	.64	.63	.62	.59	31.
21.	3	JF2	9.0	11.0	415.64	1096.35	1160.50	323.90	-2.0	4.	.25	.75	.96	.59	.57	.59	.61	.59	.59	.55	31.
22.	3	JF2	9.5	10.5	399.91	1044.40	1115.21	312.87	-1.0	4.	.25	.83	.95	.62	.59	.61	.63	.61	.62	.58	31.
23.	3	JF2	10.0	10.0	393.39	999.74	1065.38	302.92	.0	4.	.25	.92	.95	.65	.62	.64	.66	.64	.65	.60	31.
24.	3	JF2	10.5	9.5	377.83	968.71	1053.37	289.84	1.0	4.	.25	.97	.92	.66	.63	.65	.67	.65	.65	.61	31.
25.	3	JF2	11.0	9.0	381.48	1017.03	1101.63	291.62	2.0	4.	.25	.98	.83	.63	.60	.62	.64	.62	.62	.58	31.
26.	3	JF2	9.0	11.0	420.79	1108.26	1171.96	325.50	-2.0	4.	.45	.75	.95	.59	.57	.59	.61	.58	.60	.55	31.
27.	3	JF2	9.5	10.5	394.99	1046.43	1117.21	310.88	-1.0	4.	.45	.83	.96	.62	.60	.62	.64	.61	.63	.57	31.
28.	3	JF2	10.0	10.0	395.22	1001.00	1066.73	307.01	.0	4.	.45	.92	.95	.65	.63	.65	.67	.64	.66	.60	31.
29.	3	JF2	10.5	9.5	384.20	974.55	1059.22	297.98	1.0	4.	.45	.97	.91	.65	.63	.66	.67	.64	.66	.61	31.
30.	3	JF2	11.0	9.0	380.31	1020.58	1107.65	296.07	2.0	4.	.45	.98	.83	.63	.60	.63	.64	.62	.63	.58	31.

1.	4	JF2	9.0	11.0	610.93	1151.10	1151.11	332.95	-2.0	0.	.05	.79	.97	.60	.55	.58	.59	.59	.57	.59	31.
2.	4	JF2	9.5	10.5	594.81	1104.36	1104.37	321.15	-1.0	0.	.05	.86	.96	.62	.58	.60	.62	.61	.59	.61	31.
3.	4	JF2	10.0	10.0	577.98	1052.04	1052.04	307.16	.0	0.	.05	.96	.96	.65	.60	.63	.65	.64	.62	.64	31.
4.	4	JF2	10.5	9.5	570.44	1083.58	1083.58	305.25	1.0	0.	.05	.97	.89	.64	.59	.62	.63	.62	.61	.63	31.
5.	4	JF2	11.0	9.0	585.39	1133.26	1133.26	320.95	2.0	0.	.05	.98	.81	.61	.56	.59	.60	.60	.58	.60	31.
6.	4	JF2	9.0	11.0	609.51	1153.45	1153.45	332.60	-2.0	0.	.25	.80	.97	.60	.55	.58	.62	.59	.57	.58	31.
7.	4	JF2	9.5	10.5	589.83	1102.91	1102.91	320.80	-1.0	0.	.25	.88	.97	.63	.58	.61	.65	.61	.59	.61	31.
8.	4	JF2	10.0	10.0	574.80	1053.25	1053.25	306.58	.0	0.	.25	.97	.96	.66	.60	.64	.68	.64	.62	.64	31.
9.	4	JF2	10.5	9.5	572.05	1097.74	1097.74	310.97	1.0	0.	.25	.97	.88	.63	.58	.61	.65	.62	.59	.61	31.
10.	4	JF2	11.0	9.0	590.01	1148.11	1148.11	328.53	2.0	0.	.25	.98	.80	.60	.55	.58	.62	.59	.57	.58	31.
11.	4	JF2	9.0	11.0	608.31	1156.03	1156.03	332.27	-2.0	0.	.45	.80	.97	.60	.55	.58	.64	.58	.56	.57	31.
12.	4	JF2	9.5	10.5	587.61	1104.24	1104.24	320.51	-1.0	0.	.45	.89	.97	.63	.57	.61	.67	.61	.59	.60	31.
13.	4	JF2	10.0	10.0	571.93	1060.82	1060.82	306.51	.0	0.	.45	.97	.96	.66	.60	.63	.70	.64	.61	.62	31.
14.	4	JF2	10.5	9.5	575.32	1111.88	1111.88	317.66	1.0	0.	.45	.98	.87	.63	.57	.60	.67	.61	.58	.59	31.
15.	4	JF2	11.0	9.0	597.81	1162.96	1162.96	333.96	2.0	0.	.45	.98	.79	.60	.54	.58	.64	.58	.56	.57	31.
16.	4	JF2	9.0	11.0	413.07	995.48	1149.44	309.88	-2.0	4.	.05	.79	.97	.60	.55	.58	.59	.59	.57	.59	31.
17.	4	JF2	9.5	10.5	407.10	1005.92	1113.68	306.30	-1.0	4.	.05	.86	.96	.62	.57	.60	.61	.61	.59	.61	31.
18.	4	JF2	10.0	10.0	390.80	956.33	1060.54	282.39	.0	4.	.05	.95	.96	.65	.60	.63	.64	.64	.62	.64	31.
19.	4	JF2	10.5	9.5	378.32	944.82	1083.59	278.64	1.0	4.	.05	.97	.89	.64	.59	.62	.63	.62	.61	.63	31.
20.	4	JF2	11.0	9.0	389.08	990.48	1133.27	288.23	2.0	4.	.05	.98	.81	.61	.56	.59	.60	.60	.58	.60	31.
21.	4	JF2	9.0	11.0	413.31	995.18	1153.04	310.84	-2.0	4.	.25	.80	.97	.60	.55	.58	.62	.59	.57	.58	31.
22.	4	JF2	9.5	10.5	405.26	1004.82	1115.86	301.65	-1.0	4.	.25	.87	.95	.62	.57	.60	.64	.61	.58	.60	31.
23.	4	JF2	10.0	10.0	382.87	949.68	1056.96	275.42	.0	4.	.25	.96	.96	.66	.60	.63	.67	.64	.62	.63	31.
24.	4	JF2	10.5	9.5	378.24	928.60	1097.73	277.87	1.0	4.	.25	.97	.88	.63	.58	.61	.65	.62	.59	.61	31.
25.	4	JF2	11.0	9.0	399.07	977.57	1148.11	289.47	2.0	4.	.25	.98	.80	.60	.55	.58	.62	.59	.57	.58	31.
26.	4	JF2	9.0	11.0	417.35	998.17	1159.93	312.23	-2.0	4.	.45	.80	.96	.60	.55	.58	.64	.58	.56	.57	31.
27.	4	JF2	9.5	10.5	399.32	996.26	1110.57	295.47	-1.0	4.	.45	.88	.96	.63	.57	.61	.67	.61	.58	.59	31.
28.	4	JF2	10.0	10.0	390.01	957.63	1067.98	277.45	.0	4.	.45	.97	.95	.65	.59	.63	.70	.63	.61	.62	31.
29.	4	JF2	10.5	9.5	381.45	945.05	1111.87	280.54	1.0	4.	.45	.98	.87	.63	.57	.60	.67	.61	.58	.59	31.
30.	4	JF2	11.0	9.0	404.03	994.44	1162.96	295.74	2.0	4.	.45	.98	.79	.60	.54	.58	.64	.58	.56	.57	31.

1.	5	JF2	9.0	11.0	601.31	1118.61	1118.62	318.99	-2.0	0.	.05	.81	.96	.65	.59	.54	.64	.65	.56	.54	31.
2.	5	JF2	9.5	10.5	588.79	1070.61	1070.62	306.93	-1.0	0.	.05	.89	.95	.68	.62	.57	.67	.68	.59	.57	31.
3.	5	JF2	10.0	10.0	582.79	1032.62	1032.62	290.44	.0	0.	.05	.97	.94	.70	.64	.59	.69	.71	.61	.59	31.
4.	5	JF2	10.5	9.5	581.70	1080.55	1080.55	296.75	1.0	0.	.05	.97	.85	.67	.62	.56	.66	.68	.58	.56	31.
5.	5	JF2	11.0	9.0	604.84	1128.50	1128.50	306.59	2.0	0.	.05	.98	.77	.64	.59	.54	.64	.65	.56	.54	31.
6.	5	JF2	9.0	11.0	605.84	1123.27	1123.27	319.32	-2.0	0.	.25	.80	.95	.65	.60	.54	.64	.65	.56	.54	31.
7.	5	JF2	9.5	10.5	592.87	1073.75	1073.75	307.62	-1.0	0.	.25	.88	.95	.68	.63	.56	.67	.68	.58	.56	31.
8.	5	JF2	10.0	10.0	585.02	1031.21	1031.21	290.35	.0	0.	.25	.97	.94	.71	.65	.58	.70	.71	.61	.59	31.
9.	5	JF2	10.5	9.5	584.96	1076.94	1076.94	294.60	1.0	0.	.25	.97	.85	.68	.63	.56	.67	.68	.58	.56	31.
10.	5	JF2	11.0	9.0	603.76	1123.11	1123.11	306.72	2.0	0.	.25	.98	.77	.65	.60	.54	.64	.65	.56	.54	31.
11.	5	JF2	9.0	11.0	604.58	1122.23	1122.23	319.81	-2.0	0.	.45	.80	.95	.66	.61	.53	.64	.65	.56	.53	31.
12.	5	JF2	9.5	10.5	593.69	1073.75	1073.75	308.52	-1.0	0.	.45	.88	.95	.69	.64	.56	.67	.68	.58	.56	31.
13.	5	JF2	10.0	10.0	583.92	1033.51	1033.51	291.81	.0	0.	.45	.96	.94	.72	.66	.58	.70	.71	.60	.58	31.
14.	5	JF2	10.5	9.5	585.33	1076.77	1076.77	294.56	1.0	0.	.45	.97	.85	.69	.63	.55	.67	.68	.58	.56	31.
15.	5	JF2	11.0	9.0	601.82	1122.28	1122.28	308.30	2.0	0.	.45	.97	.77	.66	.61	.53	.64	.65	.56	.53	31.
16.	5	JF2	9.0	11.0	410.99	1108.05	1124.38	306.06	-2.0	4.	.05	.80	.95	.65	.59	.54	.64	.65	.56	.54	31.
17.	5	JF2	9.5	10.5	401.42	1047.60	1078.03	289.27	-1.0	4.	.05	.88	.95	.67	.62	.56	.66	.68	.58	.56	31.
18.	5	JF2	10.0	10.0	381.26	970.10	1032.63	261.29	.0	4.	.05	.97	.94	.70	.64	.59	.69	.71	.61	.59	31.
19.	5	JF2	10.5	9.5	383.79	1015.37	1080.55	258.64	1.0	4.	.05	.97	.85	.67	.62	.56	.66	.68	.58	.56	31.
20.	5	JF2	11.0	9.0	407.36	1062.34	1128.51	266.36	2.0	4.	.05	.98	.77	.64	.59	.54	.64	.65	.56	.54	31.
21.	5	JF2	9.0	11.0	411.32	1108.92	1125.61	307.15	-2.0	4.	.25	.80	.95	.65	.60	.53	.64	.65	.56	.54	31.
22.	5	JF2	9.5	10.5	393.70	1039.78	1069.93	286.89	-1.0	4.	.25	.89	.95	.69	.63	.56	.67	.68	.59	.56	31.
23.	5	JF2	10.0	10.0	378.35	968.51	1031.21	262.05	.0	4.	.25	.97	.94	.71	.65	.58	.70	.71	.61	.59	31.
24.	5	JF2	10.5	9.5	382.37	1013.16	1076.94	259.19	1.0	4.	.25	.97	.85	.68	.63	.56	.67	.68	.58	.56	31.
25.	5	JF2	11.0	9.0	403.40	1059.99	1123.11	265.07	2.0	4.	.25	.98	.77	.65	.60	.54	.64	.65	.56	.54	31.
26.	5	JF2	9.0	11.0	413.70	1109.80	1126.85	306.06	-2.0	4.	.45	.79	.95	.66	.61	.53	.64	.65	.55	.53	31.
27.	5	JF2	9.5	10.5	396.49	1039.73	1069.61	287.42	-1.0	4.	.45	.88	.95	.70	.64	.56	.67	.69	.58	.56	31.
28.	5	JF2	10.0	10.0	378.49	966.88	1033.51	261.72	.0	4.	.45	.96	.94	.72	.66	.58	.70	.71	.60	.58	31.
29.	5	JF2	10.5	9.5	388.66	1010.95	1076.76	256.43	1.0	4.	.45	.97	.85	.69	.63	.55	.67	.68	.58	.56	31.
30.	5	JF2	11.0	9.0	409.04	1057.65	1122.29	263.39	2.0	4.	.45	.97	.77	.66	.61	.53	.64	.65	.56	.53	31.

1.	6	JF2	9.0	11.0	600.15	1129.74	1129.74	321.41	-2.0	0.	.05	.81	.95	.62	.53	.61	.61	.64	.62	.62	31.
2.	6	JF2	9.5	10.5	588.49	1076.85	1076.85	310.89	-1.0	0.	.05	.89	.95	.65	.55	.64	.64	.67	.65	.65	31.
3.	6	JF2	10.0	10.0	579.79	1049.86	1049.86	295.76	.0	0.	.05	.97	.93	.67	.57	.65	.66	.68	.67	.67	31.
4.	6	JF2	10.5	9.5	581.67	1093.84	1093.84	307.39	1.0	0.	.05	.97	.85	.64	.54	.63	.63	.66	.64	.64	31.
5.	6	JF2	11.0	9.0	602.32	1141.56	1141.56	322.48	2.0	0.	.05	.98	.77	.61	.52	.60	.60	.63	.61	.61	31.
6.	6	JF2	9.0	11.0	597.71	1129.06	1129.06	322.14	-2.0	0.	.25	.81	.95	.62	.52	.60	.61	.64	.62	.62	31.
7.	6	JF2	9.5	10.5	590.15	1079.56	1079.56	312.04	-1.0	0.	.25	.89	.95	.65	.54	.63	.64	.67	.64	.65	31.
8.	6	JF2	10.0	10.0	576.56	1050.85	1050.85	297.04	.0	0.	.25	.96	.93	.67	.56	.65	.65	.69	.66	.67	31.
9.	6	JF2	10.5	9.5	581.53	1094.71	1094.71	306.26	1.0	0.	.25	.97	.85	.64	.53	.62	.63	.66	.64	.64	31.
10.	6	JF2	11.0	9.0	600.37	1141.94	1141.94	321.84	2.0	0.	.25	.97	.77	.62	.51	.59	.60	.63	.61	.62	31.
11.	6	JF2	9.0	11.0	595.12	1128.23	1128.23	322.87	-2.0	0.	.45	.81	.96	.63	.51	.59	.61	.64	.61	.63	31.
12.	6	JF2	9.5	10.5	591.36	1082.09	1082.09	313.60	-1.0	0.	.45	.89	.95	.65	.53	.62	.63	.67	.64	.65	31.
13.	6	JF2	10.0	10.0	577.60	1051.83	1051.83	297.86	.0	0.	.45	.96	.93	.67	.55	.64	.65	.69	.66	.67	31.
14.	6	JF2	10.5	9.5	582.38	1099.37	1099.37	305.46	1.0	0.	.45	.97	.84	.64	.52	.61	.62	.66	.63	.64	31.
15.	6	JF2	11.0	9.0	598.14	1142.79	1142.79	321.18	2.0	0.	.45	.97	.77	.62	.50	.59	.60	.63	.60	.62	31.
16.	6	JF2	9.0	11.0	397.41	1094.76	1123.67	306.36	-2.0	4.	.05	.81	.96	.62	.53	.61	.61	.64	.62	.62	31.
17.	6	JF2	9.5	10.5	394.38	1009.48	1076.36	289.43	-1.0	4.	.05	.90	.95	.65	.55	.64	.64	.67	.65	.65	31.
18.	6	JF2	10.0	10.0	383.79	946.25	1049.87	275.81	.0	4.	.05	.97	.93	.67	.57	.65	.66	.68	.67	.67	31.
19.	6	JF2	10.5	9.5	393.06	992.22	1093.84	289.04	1.0	4.	.05	.97	.85	.64	.54	.63	.63	.66	.64	.64	31.
20.	6	JF2	11.0	9.0	407.13	1038.21	1141.56	306.12	2.0	4.	.05	.98	.77	.61	.52	.60	.60	.63	.61	.61	31.
21.	6	JF2	9.0	11.0	394.04	1092.86	1120.85	306.12	-2.0	4.	.25	.81	.96	.63	.52	.61	.61	.64	.62	.63	31.
22.	6	JF2	9.5	10.5	391.41	1008.00	1073.58	288.41	-1.0	4.	.25	.90	.96	.66	.55	.63	.64	.67	.65	.65	31.
23.	6	JF2	10.0	10.0	388.83	946.76	1050.86	278.24	.0	4.	.25	.96	.93	.67	.56	.65	.65	.69	.66	.67	31.
24.	6	JF2	10.5	9.5	386.93	992.66	1094.71	286.00	1.0	4.	.25	.97	.85	.64	.53	.62	.63	.66	.64	.64	31.
25.	6	JF2	11.0	9.0	403.75	1046.13	1141.93	303.19	2.0	4.	.25	.97	.77	.62	.51	.59	.60	.63	.61	.62	31.
26.	6	JF2	9.0	11.0	399.36	1102.85	1129.92	308.81	-2.0	4.	.45	.81	.95	.63	.51	.59	.60	.64	.61	.63	31.
27.	6	JF2	9.5	10.5	397.07	1016.24	1080.52	290.21	-1.0	4.	.45	.89	.95	.65	.53	.62	.63	.67	.64	.65	31.
28.	6	JF2	10.0	10.0	400.86	960.37	1052.84	282.40	.0	4.	.45	.96	.93	.67	.55	.64	.65	.69	.66	.67	31.
29.	6	JF2	10.5	9.5	388.73	1001.05	1099.36	284.21	1.0	4.	.45	.97	.84	.64	.52	.61	.62	.66	.63	.64	31.
30.	6	JF2	11.0	9.0	402.74	1046.77	1142.78	301.37	2.0	4.	.45	.97	.77	.62	.50	.59	.60	.63	.60	.62	31.

1.	7	JF2	9.0	11.0	607.87	1146.70	1146.71	329.29	-2.0	0.	.05	.78	.96	.60	.57	.58	.58	.58	.55	.60	31.
2.	7	JF2	9.5	10.5	593.74	1098.14	1098.15	317.96	-1.0	0.	.05	.86	.96	.63	.59	.60	.60	.61	.59	.62	31.
3.	7	JF2	10.0	10.0	582.02	1049.30	1049.30	304.37	.0	0.	.05	.95	.95	.66	.62	.63	.63	.64	.61	.65	31.
4.	7	JF2	10.5	9.5	585.51	1076.60	1076.60	295.87	1.0	0.	.05	.98	.88	.64	.61	.61	.61	.62	.60	.64	31.
5.	7	JF2	11.0	9.0	597.23	1126.07	1126.07	309.84	2.0	0.	.05	.98	.80	.61	.58	.59	.59	.59	.57	.61	31.
6.	7	JF2	9.0	11.0	601.71	1140.32	1140.32	328.57	-2.0	0.	.25	.79	.96	.61	.57	.57	.58	.58	.57	.59	31.
7.	7	JF2	9.5	10.5	586.87	1092.00	1092.00	316.92	-1.0	0.	.25	.87	.96	.63	.60	.59	.61	.61	.60	.62	31.
8.	7	JF2	10.0	10.0	576.24	1044.48	1044.48	303.53	.0	0.	.25	.96	.96	.66	.62	.62	.64	.63	.62	.64	31.
9.	7	JF2	10.5	9.5	577.35	1076.58	1076.58	296.11	1.0	0.	.25	.97	.88	.64	.60	.60	.62	.61	.60	.62	31.
10.	7	JF2	11.0	9.0	590.98	1125.42	1125.42	312.20	2.0	0.	.25	.98	.80	.61	.58	.58	.59	.59	.58	.60	31.
11.	7	JF2	9.0	11.0	595.55	1133.92	1133.92	327.85	-2.0	0.	.45	.79	.97	.61	.57	.56	.59	.58	.58	.58	31.
12.	7	JF2	9.5	10.5	581.34	1087.25	1087.25	316.01	-1.0	0.	.45	.87	.96	.64	.60	.59	.62	.60	.60	.61	31.
13.	7	JF2	10.0	10.0	570.64	1040.02	1040.02	302.97	.0	0.	.45	.96	.96	.67	.62	.61	.65	.63	.63	.64	31.
14.	7	JF2	10.5	9.5	570.64	1076.86	1076.86	296.55	1.0	0.	.45	.97	.88	.64	.60	.59	.62	.61	.61	.61	31.
15.	7	JF2	11.0	9.0	587.24	1125.58	1125.58	312.46	2.0	0.	.45	.97	.80	.62	.58	.57	.60	.58	.58	.59	31.
16.	7	JF2	9.0	11.0	390.35	990.77	1134.29	310.51	-2.0	4.	.05	.79	.97	.61	.58	.58	.58	.59	.57	.60	31.
17.	7	JF2	9.5	10.5	377.95	995.26	1085.79	297.03	-1.0	4.	.05	.87	.97	.63	.60	.61	.61	.62	.59	.63	31.
18.	7	JF2	10.0	10.0	380.24	944.25	1046.79	287.35	.0	4.	.05	.96	.96	.66	.62	.63	.63	.64	.62	.65	31.
19.	7	JF2	10.5	9.5	383.45	953.91	1076.60	276.94	1.0	4.	.05	.98	.88	.64	.61	.61	.61	.62	.60	.64	31.
20.	7	JF2	11.0	9.0	399.28	999.83	1126.06	287.09	2.0	4.	.05	.98	.80	.61	.58	.59	.59	.59	.57	.61	31.
21.	7	JF2	9.0	11.0	388.72	986.80	1130.46	309.09	-2.0	4.	.25	.80	.97	.61	.57	.57	.59	.58	.58	.59	31.
22.	7	JF2	9.5	10.5	386.27	1001.27	1092.02	304.14	-1.0	4.	.25	.87	.96	.63	.60	.59	.61	.61	.60	.62	31.
23.	7	JF2	10.0	10.0	375.77	940.13	1043.47	286.68	.0	4.	.25	.96	.96	.66	.62	.62	.64	.63	.62	.64	31.
24.	7	JF2	10.5	9.5	374.11	952.13	1076.59	273.61	1.0	4.	.25	.97	.88	.64	.60	.60	.62	.61	.60	.62	31.
25.	7	JF2	11.0	9.0	392.89	997.80	1125.42	289.97	2.0	4.	.25	.98	.80	.61	.58	.58	.59	.59	.58	.60	31.
26.	7	JF2	9.0	11.0	410.31	1064.09	1149.53	317.41	-2.0	4.	.45	.78	.95	.60	.56	.55	.58	.57	.57	.57	31.
27.	7	JF2	9.5	10.5	384.87	998.35	1089.31	302.18	-1.0	4.	.45	.87	.96	.64	.59	.59	.62	.60	.60	.61	31.
28.	7	JF2	10.0	10.0	371.71	936.55	1040.71	290.50	.0	4.	.45	.96	.96	.67	.62	.61	.65	.63	.63	.63	31.
29.	7	JF2	10.5	9.5	378.19	950.33	1076.85	278.51	1.0	4.	.45	.97	.88	.64	.60	.59	.62	.61	.61	.61	31.
30.	7	JF2	11.0	9.0	392.67	995.77	1125.57	290.17	2.0	4.	.45	.97	.80	.62	.58	.57	.60	.58	.58	.59	31.

1.	8	JF2	9.0	11.0	605.24	1144.20	1144.21	329.81	-2.0	0.	.05	.77	.97	.59	.50	.68	.60	.57	.67	.66	31.
2.	8	JF2	9.5	10.5	583.25	1094.70	1094.71	317.02	-1.0	0.	.05	.85	.97	.62	.52	.71	.63	.59	.70	.69	31.
3.	8	JF2	10.0	10.0	572.85	1047.89	1047.89	305.09	.0	0.	.05	.94	.96	.65	.54	.74	.66	.62	.73	.72	31.
4.	8	JF2	10.5	9.5	568.18	1059.55	1059.55	296.69	1.0	0.	.05	.98	.90	.64	.54	.73	.65	.61	.73	.71	31.
5.	8	JF2	11.0	9.0	585.68	1108.89	1108.89	310.65	2.0	0.	.05	.98	.82	.61	.51	.70	.62	.59	.69	.68	31.
6.	8	JF2	9.0	11.0	612.53	1145.52	1145.52	330.38	-2.0	0.	.25	.76	.97	.60	.49	.67	.61	.57	.66	.66	31.
7.	8	JF2	9.5	10.5	590.15	1096.00	1096.00	317.41	-1.0	0.	.25	.84	.97	.62	.52	.70	.64	.60	.69	.69	31.
8.	8	JF2	10.0	10.0	576.91	1046.48	1046.48	304.49	.0	0.	.25	.93	.96	.65	.54	.74	.67	.63	.73	.72	31.
9.	8	JF2	10.5	9.5	569.09	1044.30	1044.30	292.04	1.0	0.	.25	.98	.92	.65	.54	.74	.67	.63	.73	.72	31.
10.	8	JF2	11.0	9.0	580.90	1092.95	1092.95	304.55	2.0	0.	.25	.98	.83	.62	.52	.71	.64	.60	.69	.69	31.
11.	8	JF2	9.0	11.0	619.82	1146.83	1146.83	330.99	-2.0	0.	.45	.75	.97	.60	.49	.67	.61	.58	.65	.66	31.
12.	8	JF2	9.5	10.5	597.03	1097.29	1097.29	317.90	-1.0	0.	.45	.83	.97	.62	.51	.70	.64	.60	.68	.69	31.
13.	8	JF2	10.0	10.0	583.35	1047.76	1047.76	304.44	.0	0.	.45	.91	.96	.65	.54	.73	.67	.63	.71	.72	31.
14.	8	JF2	10.5	9.5	570.61	1029.03	1029.03	287.70	1.0	0.	.45	.98	.93	.66	.55	.74	.68	.64	.73	.74	31.
15.	8	JF2	11.0	9.0	577.88	1077.02	1077.02	298.32	2.0	0.	.45	.98	.84	.63	.52	.71	.65	.61	.69	.70	31.
16.	8	JF2	9.0	11.0	409.87	1059.50	1145.30	324.33	-2.0	4.	.05	.77	.97	.59	.50	.68	.60	.57	.67	.66	31.
17.	8	JF2	9.5	10.5	390.94	1017.20	1099.54	308.79	-1.0	4.	.05	.85	.96	.62	.52	.71	.63	.59	.70	.68	31.
18.	8	JF2	10.0	10.0	379.63	959.91	1053.53	289.51	.0	4.	.05	.93	.96	.65	.54	.74	.66	.62	.73	.71	31.
19.	8	JF2	10.5	9.5	379.54	932.10	1059.55	275.31	1.0	4.	.05	.98	.90	.64	.54	.73	.65	.61	.73	.71	31.
20.	8	JF2	11.0	9.0	389.71	977.14	1108.89	289.44	2.0	4.	.05	.98	.82	.61	.51	.70	.62	.59	.69	.68	31.
21.	8	JF2	9.0	11.0	412.45	1059.99	1143.42	324.42	-2.0	4.	.25	.76	.97	.60	.49	.67	.61	.57	.66	.66	31.
22.	8	JF2	9.5	10.5	395.03	1019.02	1099.13	310.09	-1.0	4.	.25	.84	.96	.62	.51	.70	.63	.60	.69	.69	31.
23.	8	JF2	10.0	10.0	387.84	966.75	1058.00	290.95	.0	4.	.25	.92	.95	.64	.53	.73	.66	.62	.72	.71	31.
24.	8	JF2	10.5	9.5	373.03	923.20	1044.29	271.59	1.0	4.	.25	.98	.92	.65	.54	.74	.67	.63	.73	.72	31.
25.	8	JF2	11.0	9.0	390.36	961.75	1092.95	277.67	2.0	4.	.25	.98	.83	.62	.52	.71	.64	.60	.69	.69	31.
26.	8	JF2	9.0	11.0	417.21	1060.07	1141.13	321.36	-2.0	4.	.45	.75	.97	.60	.49	.67	.62	.58	.66	.66	31.
27.	8	JF2	9.5	10.5	395.06	1014.02	1091.90	306.13	-1.0	4.	.45	.83	.97	.63	.52	.70	.64	.61	.68	.69	31.
28.	8	JF2	10.0	10.0	388.41	964.59	1053.48	286.47	.0	4.	.45	.91	.96	.65	.53	.73	.67	.63	.71	.72	31.
29.	8	JF2	10.5	9.5	374.97	917.73	1029.03	270.16	1.0	4.	.45	.98	.93	.66	.55	.74	.68	.64	.73	.74	31.
30.	8	JF2	11.0	9.0	388.23	953.01	1077.03	280.04	2.0	4.	.45	.98	.84	.63	.52	.71	.65	.61	.69	.70	31.

1.	9	JF2	9.0	11.0	613.40	1171.26	1171.27	338.14	-2.0	0.	.05	.77	.97	.53	.60	.58	.54	.51	.56	.56	31.
2.	9	JF2	9.5	10.5	595.04	1125.53	1125.54	325.40	-1.0	0.	.05	.84	.96	.55	.63	.60	.56	.53	.59	.58	31.
3.	9	JF2	10.0	10.0	582.02	1076.14	1076.14	313.48	.0	0.	.05	.93	.96	.58	.66	.63	.58	.56	.61	.61	31.
4.	9	JF2	10.5	9.5	584.03	1070.41	1070.41	301.43	1.0	0.	.05	.98	.92	.58	.66	.63	.59	.56	.62	.61	31.
5.	9	JF2	11.0	9.0	592.81	1119.74	1119.74	316.70	2.0	0.	.05	.98	.83	.55	.63	.60	.56	.54	.59	.58	31.
6.	9	JF2	9.0	11.0	610.30	1160.69	1160.69	334.23	-2.0	0.	.25	.79	.96	.53	.61	.59	.54	.51	.57	.56	31.
7.	9	JF2	9.5	10.5	588.87	1112.16	1112.16	321.67	-1.0	0.	.25	.87	.96	.55	.64	.61	.56	.53	.60	.59	31.
8.	9	JF2	10.0	10.0	575.91	1064.14	1064.14	309.33	.0	0.	.25	.95	.96	.58	.67	.64	.58	.55	.63	.61	31.
9.	9	JF2	10.5	9.5	584.25	1086.04	1086.04	305.30	1.0	0.	.25	.98	.89	.57	.65	.63	.57	.54	.61	.60	31.
10.	9	JF2	11.0	9.0	599.65	1136.11	1136.11	322.81	2.0	0.	.25	.98	.81	.54	.63	.60	.55	.52	.59	.58	31.
11.	9	JF2	9.0	11.0	606.24	1149.10	1149.10	330.28	-2.0	0.	.45	.81	.96	.53	.62	.60	.54	.50	.58	.57	31.
12.	9	JF2	9.5	10.5	585.41	1101.46	1101.46	317.93	-1.0	0.	.45	.89	.96	.56	.65	.62	.56	.52	.61	.60	31.
13.	9	JF2	10.0	10.0	576.28	1058.78	1058.78	305.47	.0	0.	.45	.97	.95	.58	.68	.65	.58	.54	.63	.62	31.
14.	9	JF2	10.5	9.5	587.48	1101.66	1101.66	311.48	1.0	0.	.45	.98	.87	.56	.65	.62	.56	.52	.61	.60	31.
15.	9	JF2	11.0	9.0	607.87	1152.49	1152.49	329.10	2.0	0.	.45	.98	.79	.53	.62	.60	.53	.50	.58	.57	31.
16.	9	JF2	9.0	11.0	423.61	1115.32	1177.56	335.09	-2.0	4.	.05	.76	.96	.53	.60	.57	.53	.51	.56	.55	31.
17.	9	JF2	9.5	10.5	402.58	1060.55	1128.47	320.12	-1.0	4.	.05	.84	.96	.55	.62	.60	.56	.53	.59	.58	31.
18.	9	JF2	10.0	10.0	406.29	1015.54	1095.09	312.79	.0	4.	.05	.91	.94	.57	.64	.62	.57	.55	.60	.60	31.
19.	9	JF2	10.5	9.5	402.71	965.94	1070.42	295.45	1.0	4.	.05	.98	.92	.58	.66	.63	.59	.56	.62	.61	31.
20.	9	JF2	11.0	9.0	402.93	1008.61	1119.74	306.03	2.0	4.	.05	.98	.83	.55	.63	.60	.56	.54	.59	.58	31.
21.	9	JF2	9.0	11.0	419.25	1103.89	1165.54	333.31	-2.0	4.	.25	.78	.96	.53	.61	.58	.53	.50	.57	.56	31.
22.	9	JF2	9.5	10.5	397.65	1048.91	1116.10	316.13	-1.0	4.	.25	.86	.96	.55	.64	.61	.56	.53	.60	.59	31.
23.	9	JF2	10.0	10.0	410.30	1014.74	1093.20	313.20	.0	4.	.25	.93	.93	.56	.65	.62	.57	.54	.61	.60	31.
24.	9	JF2	10.5	9.5	405.74	982.76	1086.03	295.96	1.0	4.	.25	.98	.89	.57	.65	.63	.57	.54	.61	.60	31.
25.	9	JF2	11.0	9.0	411.24	1022.94	1136.12	309.67	2.0	4.	.25	.98	.81	.54	.63	.60	.55	.52	.59	.58	31.
26.	9	JF2	9.0	11.0	418.73	1094.68	1155.72	329.98	-2.0	4.	.45	.80	.96	.53	.62	.59	.53	.50	.58	.57	31.
27.	9	JF2	9.5	10.5	398.14	1042.05	1108.50	315.05	-1.0	4.	.45	.88	.96	.55	.65	.62	.56	.52	.61	.59	31.
28.	9	JF2	10.0	10.0	392.38	994.11	1071.50	303.28	.0	4.	.45	.96	.94	.57	.67	.64	.57	.54	.63	.61	31.
29.	9	JF2	10.5	9.5	396.02	1003.05	1101.65	301.88	1.0	4.	.45	.98	.87	.56	.65	.62	.56	.52	.61	.60	31.
30.	9	JF2	11.0	9.0	418.22	1043.29	1152.47	321.63	2.0	4.	.45	.98	.79	.53	.62	.60	.53	.50	.58	.57	31.

1.	10	JF2	9.0	11.0	606.39	1142.09	1142.09	328.13	-2.0	0.	.05	.77	.96	.59	.56	.59	.59	.59	.58	.61	31.
2.	10	JF2	9.5	10.5	587.72	1094.59	1094.60	315.91	-1.0	0.	.05	.85	.96	.62	.59	.62	.61	.61	.60	.64	31.
3.	10	JF2	10.0	10.0	571.39	1046.85	1046.85	302.05	.0	0.	.05	.94	.96	.65	.61	.64	.64	.64	.63	.67	31.
4.	10	JF2	10.5	9.5	571.52	1061.99	1061.99	294.86	1.0	0.	.05	.97	.90	.64	.61	.63	.63	.63	.62	.66	31.
5.	10	JF2	11.0	9.0	588.55	1110.93	1110.93	306.48	2.0	0.	.05	.97	.81	.61	.58	.61	.60	.60	.59	.63	31.
6.	10	JF2	9.0	11.0	602.66	1137.58	1137.58	328.50	-2.0	0.	.25	.77	.97	.59	.57	.59	.59	.60	.58	.62	31.
7.	10	JF2	9.5	10.5	587.20	1094.40	1094.40	316.01	-1.0	0.	.25	.85	.96	.62	.59	.61	.62	.62	.60	.64	31.
8.	10	JF2	10.0	10.0	568.25	1045.56	1045.56	301.75	.0	0.	.25	.94	.95	.64	.61	.64	.65	.65	.63	.67	31.
9.	10	JF2	10.5	9.5	568.89	1061.19	1061.19	294.32	1.0	0.	.25	.97	.89	.64	.61	.63	.64	.64	.62	.66	31.
10.	10	JF2	11.0	9.0	582.57	1109.86	1109.86	307.47	2.0	0.	.25	.97	.81	.61	.58	.60	.61	.61	.59	.63	31.
11.	10	JF2	9.0	11.0	608.89	1143.05	1143.05	328.96	-2.0	0.	.45	.77	.96	.59	.56	.58	.59	.60	.57	.62	31.
12.	10	JF2	9.5	10.5	586.92	1094.08	1094.08	315.52	-1.0	0.	.45	.84	.96	.61	.59	.61	.62	.63	.60	.65	31.
13.	10	JF2	10.0	10.0	567.86	1046.86	1046.86	301.20	.0	0.	.45	.93	.95	.64	.61	.63	.65	.65	.62	.68	31.
14.	10	JF2	10.5	9.5	571.39	1060.39	1060.39	292.09	1.0	0.	.45	.96	.89	.63	.61	.63	.64	.65	.62	.67	31.
15.	10	JF2	11.0	9.0	581.34	1108.80	1108.80	305.09	2.0	0.	.45	.97	.81	.61	.58	.60	.61	.62	.59	.64	31.
16.	10	JF2	9.0	11.0	403.30	1107.95	1136.19	330.88	-2.0	4.	.05	.78	.97	.59	.57	.59	.59	.59	.58	.62	31.
17.	10	JF2	9.5	10.5	384.21	1059.98	1087.71	311.04	-1.0	4.	.05	.86	.97	.62	.59	.62	.62	.62	.61	.64	31.
18.	10	JF2	10.0	10.0	368.14	1012.50	1039.72	296.95	.0	4.	.05	.95	.96	.65	.62	.65	.65	.64	.63	.67	31.
19.	10	JF2	10.5	9.5	375.87	1033.57	1061.99	291.79	1.0	4.	.05	.97	.90	.64	.61	.63	.63	.63	.62	.66	31.
20.	10	JF2	11.0	9.0	394.25	1082.52	1110.92	296.15	2.0	4.	.05	.97	.81	.61	.58	.61	.60	.60	.59	.63	31.
21.	10	JF2	9.0	11.0	403.07	1104.54	1133.46	331.88	-2.0	4.	.25	.78	.97	.59	.57	.59	.60	.60	.58	.62	31.
22.	10	JF2	9.5	10.5	383.75	1056.69	1085.06	308.59	-1.0	4.	.25	.86	.97	.62	.59	.62	.62	.62	.60	.65	31.
23.	10	JF2	10.0	10.0	365.10	1009.27	1037.10	297.98	.0	4.	.25	.94	.96	.65	.62	.64	.65	.65	.63	.68	31.
24.	10	JF2	10.5	9.5	371.63	1031.21	1061.20	289.93	1.0	4.	.25	.97	.89	.64	.61	.63	.64	.64	.62	.66	31.
25.	10	JF2	11.0	9.0	387.82	1079.98	1109.86	295.98	2.0	4.	.25	.97	.81	.61	.58	.60	.61	.61	.59	.63	31.
26.	10	JF2	9.0	11.0	403.42	1101.09	1130.70	328.27	-2.0	4.	.45	.77	.97	.59	.57	.59	.60	.61	.58	.63	31.
27.	10	JF2	9.5	10.5	385.09	1058.30	1087.32	307.64	-1.0	4.	.45	.85	.96	.62	.59	.61	.63	.63	.60	.65	31.
28.	10	JF2	10.0	10.0	364.16	1006.87	1035.29	293.77	.0	4.	.45	.94	.96	.65	.62	.64	.66	.66	.63	.68	31.
29.	10	JF2	10.5	9.5	367.61	1028.84	1060.39	285.50	1.0	4.	.45	.96	.89	.63	.61	.63	.64	.65	.62	.67	31.
30.	10	JF2	11.0	9.0	384.18	1077.44	1108.79	292.71	2.0	4.	.45	.97	.81	.61	.58	.60	.61	.62	.59	.64	31.

1.	11	JF2	9.0	11.0	606.97	1154.86	1154.86	330.28	-2.0	0.	.05	.78	.97	.66	.61	.48	.65	.64	.49	.46	31.
2.	11	JF2	9.5	10.5	594.98	1106.39	1106.39	320.91	-1.0	0.	.05	.86	.97	.69	.64	.50	.68	.67	.52	.48	31.
3.	11	JF2	10.0	10.0	581.89	1057.93	1057.93	307.89	.0	0.	.05	.94	.96	.72	.66	.52	.71	.70	.54	.50	31.
4.	11	JF2	10.5	9.5	578.87	1075.17	1075.17	300.97	1.0	0.	.05	.97	.90	.71	.65	.52	.70	.69	.53	.50	31.
5.	11	JF2	11.0	9.0	586.77	1124.57	1124.57	317.58	2.0	0.	.05	.98	.82	.68	.63	.49	.67	.66	.51	.47	31.
6.	11	JF2	9.0	11.0	605.84	1152.42	1152.42	326.20	-2.0	0.	.25	.77	.97	.66	.60	.48	.65	.65	.50	.46	31.
7.	11	JF2	9.5	10.5	593.81	1104.09	1104.09	317.06	-1.0	0.	.25	.85	.96	.69	.63	.50	.68	.67	.52	.48	31.
8.	11	JF2	10.0	10.0	580.59	1055.76	1055.76	304.16	.0	0.	.25	.94	.96	.72	.65	.53	.71	.71	.54	.50	31.
9.	11	JF2	10.5	9.5	574.39	1067.86	1067.86	297.59	1.0	0.	.25	.97	.90	.71	.65	.52	.71	.70	.54	.50	31.
10.	11	JF2	11.0	9.0	583.00	1114.54	1114.54	314.87	2.0	0.	.25	.98	.82	.68	.62	.50	.68	.67	.51	.48	31.
11.	11	JF2	9.0	11.0	604.59	1149.98	1149.98	322.30	-2.0	0.	.45	.77	.97	.66	.59	.49	.66	.65	.50	.46	31.
12.	11	JF2	9.5	10.5	592.56	1101.79	1101.79	313.36	-1.0	0.	.45	.85	.96	.69	.62	.51	.69	.68	.52	.48	31.
13.	11	JF2	10.0	10.0	579.24	1053.61	1053.61	300.55	.0	0.	.45	.93	.96	.72	.64	.53	.72	.71	.55	.50	31.
14.	11	JF2	10.5	9.5	569.21	1063.48	1063.48	295.41	1.0	0.	.45	.97	.90	.71	.64	.52	.71	.70	.54	.50	31.
15.	11	JF2	11.0	9.0	579.09	1109.01	1109.01	313.90	2.0	0.	.45	.97	.82	.69	.61	.50	.68	.67	.52	.48	31.
16.	11	JF2	9.0	11.0	419.84	1128.76	1161.69	330.08	-2.0	4.	.05	.77	.96	.66	.61	.48	.65	.64	.49	.46	31.
17.	11	JF2	9.5	10.5	410.13	1060.66	1114.88	325.75	-1.0	4.	.05	.85	.96	.69	.63	.50	.67	.67	.51	.48	31.
18.	11	JF2	10.0	10.0	395.08	1014.70	1065.89	304.80	.0	4.	.05	.94	.96	.72	.66	.52	.71	.70	.54	.50	31.
19.	11	JF2	10.5	9.5	386.74	997.13	1075.17	291.38	1.0	4.	.05	.97	.90	.71	.65	.52	.70	.69	.53	.50	31.
20.	11	JF2	11.0	9.0	390.21	1042.57	1124.58	303.57	2.0	4.	.05	.98	.82	.68	.63	.49	.67	.66	.51	.47	31.
21.	11	JF2	9.0	11.0	419.37	1126.28	1162.02	336.22	-2.0	4.	.25	.77	.96	.66	.59	.48	.65	.64	.49	.46	31.
22.	11	JF2	9.5	10.5	402.56	1049.36	1105.88	323.41	-1.0	4.	.25	.85	.96	.69	.62	.50	.68	.67	.52	.48	31.
23.	11	JF2	10.0	10.0	387.49	1003.61	1056.95	298.62	.0	4.	.25	.94	.96	.72	.65	.53	.71	.70	.54	.50	31.
24.	11	JF2	10.5	9.5	377.90	989.31	1066.17	288.30	1.0	4.	.25	.97	.91	.71	.65	.52	.71	.70	.54	.50	31.
25.	11	JF2	11.0	9.0	387.07	1034.56	1114.54	301.23	2.0	4.	.25	.98	.82	.68	.62	.50	.68	.67	.51	.48	31.
26.	11	JF2	9.0	11.0	411.58	1114.22	1152.77	330.82	-2.0	4.	.45	.77	.96	.66	.59	.48	.66	.65	.50	.46	31.
27.	11	JF2	9.5	10.5	403.07	1047.59	1106.42	323.52	-1.0	4.	.45	.84	.96	.69	.61	.50	.68	.67	.52	.48	31.
28.	11	JF2	10.0	10.0	386.74	1002.03	1057.52	300.70	.0	4.	.45	.93	.96	.72	.64	.53	.71	.70	.54	.50	31.
29.	11	JF2	10.5	9.5	374.61	982.77	1063.49	281.85	1.0	4.	.45	.97	.90	.71	.64	.52	.71	.70	.54	.50	31.
30.	11	JF2	11.0	9.0	384.74	1027.80	1109.02	298.95	2.0	4.	.45	.97	.82	.69	.61	.50	.68	.67	.52	.48	31.

1.	12	JF2	9.0	11.0	602.54	1125.43	1125.43	322.10	-2.0	0.	.05	.79	.96	.54	.64	.61	.55	.54	.59	.58	31.
2.	12	JF2	9.5	10.5	586.48	1077.76	1077.76	310.57	-1.0	0.	.05	.87	.96	.56	.67	.63	.57	.57	.61	.61	31.
3.	12	JF2	10.0	10.0	572.95	1029.07	1029.07	296.39	.0	0.	.05	.96	.95	.59	.70	.66	.60	.59	.64	.64	31.
4.	12	JF2	10.5	9.5	566.81	1071.48	1071.48	293.24	1.0	0.	.05	.97	.87	.56	.68	.64	.57	.57	.61	.61	31.
5.	12	JF2	11.0	9.0	582.96	1118.87	1118.87	307.75	2.0	0.	.05	.97	.79	.54	.65	.61	.55	.55	.59	.59	31.
6.	12	JF2	9.0	11.0	602.89	1133.51	1133.51	324.15	-2.0	0.	.25	.80	.96	.53	.63	.60	.54	.53	.58	.58	31.
7.	12	JF2	9.5	10.5	587.12	1084.67	1084.67	313.29	-1.0	0.	.25	.88	.96	.56	.66	.63	.57	.55	.61	.60	31.
8.	12	JF2	10.0	10.0	575.62	1043.82	1043.82	299.73	.0	0.	.25	.96	.95	.58	.69	.65	.59	.57	.63	.63	31.
9.	12	JF2	10.5	9.5	575.21	1091.31	1091.31	298.31	1.0	0.	.25	.97	.86	.55	.66	.62	.56	.55	.60	.60	31.
10.	12	JF2	11.0	9.0	591.51	1140.37	1140.37	313.77	2.0	0.	.25	.97	.78	.53	.63	.60	.54	.52	.58	.57	31.
11.	12	JF2	9.0	11.0	603.21	1141.59	1141.59	326.25	-2.0	0.	.45	.81	.96	.53	.62	.59	.54	.51	.58	.57	31.
12.	12	JF2	9.5	10.5	588.63	1092.48	1092.48	316.07	-1.0	0.	.45	.89	.96	.55	.65	.62	.57	.53	.61	.59	31.
13.	12	JF2	10.0	10.0	582.73	1062.86	1062.86	303.28	.0	0.	.45	.97	.94	.57	.67	.64	.58	.55	.62	.61	31.
14.	12	JF2	10.5	9.5	586.29	1111.30	1111.30	302.59	1.0	0.	.45	.97	.85	.54	.64	.61	.56	.53	.60	.58	31.
15.	12	JF2	11.0	9.0	603.02	1161.87	1161.87	317.70	2.0	0.	.45	.97	.77	.52	.61	.58	.53	.50	.57	.56	31.
16.	12	JF2	9.0	11.0	405.96	1120.22	1128.22	311.07	-2.0	4.	.05	.79	.96	.54	.64	.60	.54	.54	.58	.58	31.
17.	12	JF2	9.5	10.5	387.28	1071.87	1079.87	303.88	-1.0	4.	.05	.87	.95	.56	.67	.63	.57	.56	.61	.61	31.
18.	12	JF2	10.0	10.0	374.27	1022.88	1030.88	282.63	.0	4.	.05	.96	.95	.59	.70	.66	.60	.59	.64	.64	31.
19.	12	JF2	10.5	9.5	372.68	1063.48	1071.48	272.75	1.0	4.	.05	.97	.87	.56	.68	.64	.57	.57	.61	.61	31.
20.	12	JF2	11.0	9.0	384.04	1110.87	1118.87	280.66	2.0	4.	.05	.97	.79	.54	.65	.61	.55	.55	.59	.59	31.
21.	12	JF2	9.0	11.0	404.73	1126.22	1134.22	312.24	-2.0	4.	.25	.80	.96	.53	.63	.60	.54	.53	.58	.58	31.
22.	12	JF2	9.5	10.5	389.47	1079.36	1087.36	305.58	-1.0	4.	.25	.88	.96	.56	.66	.63	.57	.55	.61	.60	31.
23.	12	JF2	10.0	10.0	377.84	1035.83	1043.83	280.47	.0	4.	.25	.96	.95	.58	.69	.65	.59	.57	.63	.63	31.
24.	12	JF2	10.5	9.5	380.20	1083.31	1091.31	276.26	1.0	4.	.25	.97	.86	.55	.66	.62	.56	.55	.60	.60	31.
25.	12	JF2	11.0	9.0	395.10	1132.38	1140.38	284.30	2.0	4.	.25	.97	.78	.53	.63	.60	.54	.52	.58	.57	31.
26.	12	JF2	9.0	11.0	412.02	1142.61	1150.61	323.98	-2.0	4.	.45	.80	.95	.52	.62	.59	.54	.51	.58	.56	31.
27.	12	JF2	9.5	10.5	400.25	1094.41	1102.41	313.59	-1.0	4.	.45	.88	.95	.55	.64	.61	.56	.53	.60	.59	31.
28.	12	JF2	10.0	10.0	392.37	1054.86	1062.86	288.93	.0	4.	.45	.97	.94	.57	.67	.64	.58	.55	.62	.61	31.
29.	12	JF2	10.5	9.5	388.11	1103.31	1111.31	282.12	1.0	4.	.45	.97	.85	.54	.64	.61	.56	.53	.60	.58	31.
30.	12	JF2	11.0	9.0	406.59	1153.87	1161.87	287.42	2.0	4.	.45	.97	.77	.52	.61	.58	.53	.50	.57	.56	31.

1.	13	JF2	9.0	11.0	599.50	1119.27	1119.27	320.06	-2.0	0.	.05	.79	.96	.46	.68	.57	.49	.47	.60	.58	31.
2.	13	JF2	9.5	10.5	583.08	1070.25	1070.25	308.70	-1.0	0.	.05	.87	.96	.49	.71	.60	.51	.50	.63	.61	31.
3.	13	JF2	10.0	10.0	570.80	1022.35	1022.35	293.97	.0	0.	.05	.96	.96	.51	.74	.63	.53	.52	.66	.63	31.
4.	13	JF2	10.5	9.5	561.72	1068.36	1068.36	294.45	1.0	0.	.05	.97	.87	.49	.71	.60	.51	.50	.63	.61	31.
5.	13	JF2	11.0	9.0	578.63	1117.43	1117.43	307.46	2.0	0.	.05	.97	.79	.47	.68	.57	.49	.48	.60	.58	31.
6.	13	JF2	9.0	11.0	595.86	1117.65	1117.65	320.00	-2.0	0.	.25	.80	.96	.46	.68	.57	.48	.48	.60	.58	31.
7.	13	JF2	9.5	10.5	579.45	1068.57	1068.57	308.58	-1.0	0.	.25	.88	.96	.48	.71	.59	.50	.50	.63	.60	31.
8.	13	JF2	10.0	10.0	565.51	1024.77	1024.77	293.75	.0	0.	.25	.97	.95	.50	.74	.62	.52	.52	.66	.63	31.
9.	13	JF2	10.5	9.5	562.82	1074.14	1074.14	296.39	1.0	0.	.25	.97	.86	.48	.70	.59	.50	.50	.63	.60	31.
10.	13	JF2	11.0	9.0	582.95	1123.51	1123.51	309.55	2.0	0.	.25	.98	.78	.46	.67	.56	.48	.48	.60	.57	31.
11.	13	JF2	9.0	11.0	602.31	1126.29	1126.29	320.25	-2.0	0.	.45	.80	.96	.45	.67	.56	.47	.48	.60	.57	31.
12.	13	JF2	9.5	10.5	585.91	1077.16	1077.16	308.75	-1.0	0.	.45	.88	.95	.47	.70	.58	.49	.50	.62	.59	31.
13.	13	JF2	10.0	10.0	570.56	1032.97	1032.97	293.84	.0	0.	.45	.97	.95	.49	.73	.61	.51	.52	.65	.62	31.
14.	13	JF2	10.5	9.5	567.58	1079.96	1079.96	297.21	1.0	0.	.45	.98	.86	.47	.70	.58	.49	.50	.62	.59	31.
15.	13	JF2	11.0	9.0	586.98	1129.63	1129.63	311.65	2.0	0.	.45	.98	.78	.45	.67	.56	.47	.48	.59	.57	31.
16.	13	JF2	9.0	11.0	397.93	1092.97	1116.97	313.29	-2.0	4.	.05	.79	.96	.47	.68	.57	.49	.48	.60	.58	31.
17.	13	JF2	9.5	10.5	383.37	1036.60	1068.38	300.63	-1.0	4.	.05	.88	.96	.49	.71	.60	.51	.50	.63	.61	31.
18.	13	JF2	10.0	10.0	375.89	985.24	1023.62	280.22	.0	4.	.05	.96	.95	.51	.74	.63	.53	.52	.66	.63	31.
19.	13	JF2	10.5	9.5	364.70	1021.47	1068.36	276.59	1.0	4.	.05	.97	.87	.49	.71	.60	.51	.50	.63	.61	31.
20.	13	JF2	11.0	9.0	375.34	1069.54	1117.43	286.32	2.0	4.	.05	.97	.79	.47	.68	.57	.49	.48	.60	.58	31.
21.	13	JF2	9.0	11.0	395.51	1093.94	1117.94	312.42	-2.0	4.	.25	.80	.96	.46	.68	.57	.48	.48	.60	.58	31.
22.	13	JF2	9.5	10.5	378.40	1035.30	1067.84	297.73	-1.0	4.	.25	.88	.96	.48	.71	.59	.50	.50	.63	.60	31.
23.	13	JF2	10.0	10.0	372.81	988.93	1028.11	280.19	.0	4.	.25	.97	.95	.50	.74	.62	.52	.52	.65	.63	31.
24.	13	JF2	10.5	9.5	360.68	1029.76	1074.13	276.24	1.0	4.	.25	.97	.86	.48	.70	.59	.50	.50	.63	.60	31.
25.	13	JF2	11.0	9.0	380.26	1077.91	1123.50	287.56	2.0	4.	.25	.98	.78	.46	.67	.56	.48	.48	.60	.57	31.
26.	13	JF2	9.0	11.0	397.50	1100.51	1124.51	313.79	-2.0	4.	.45	.80	.96	.45	.67	.56	.47	.48	.60	.57	31.
27.	13	JF2	9.5	10.5	381.51	1042.89	1076.19	300.48	-1.0	4.	.45	.89	.96	.47	.70	.58	.49	.50	.62	.59	31.
28.	13	JF2	10.0	10.0	370.40	993.00	1032.98	279.90	.0	4.	.45	.97	.95	.49	.73	.61	.51	.52	.65	.62	31.
29.	13	JF2	10.5	9.5	369.55	1040.28	1079.95	276.65	1.0	4.	.45	.98	.86	.47	.70	.58	.49	.50	.62	.59	31.
30.	13	JF2	11.0	9.0	389.28	1087.60	1129.63	287.64	2.0	4.	.45	.98	.78	.45	.67	.56	.47	.48	.59	.57	31.

1.	14	JF2	9.0	11.0	624.18	1155.46	1155.47	330.68	-2.0	0.	.05	.81	.95	.60	.55	.60	.59	.62	.64	.60	31.
2.	14	JF2	9.5	10.5	605.12	1105.32	1105.34	317.74	-1.0	0.	.05	.89	.95	.62	.57	.63	.62	.65	.67	.63	31.
3.	14	JF2	10.0	10.0	594.01	1063.32	1063.32	300.71	.0	0.	.05	.98	.94	.65	.59	.65	.64	.67	.70	.65	31.
4.	14	JF2	10.5	9.5	595.96	1111.86	1111.86	306.92	1.0	0.	.05	.98	.85	.62	.57	.62	.62	.64	.66	.62	31.
5.	14	JF2	11.0	9.0	612.51	1160.56	1160.56	326.34	2.0	0.	.05	.98	.77	.59	.54	.60	.59	.62	.64	.60	31.
6.	14	JF2	9.0	11.0	628.45	1165.72	1165.72	335.04	-2.0	0.	.25	.81	.95	.59	.53	.60	.59	.61	.63	.59	31.
7.	14	JF2	9.5	10.5	608.80	1115.04	1115.04	321.84	-1.0	0.	.25	.89	.95	.62	.56	.62	.62	.64	.66	.62	31.
8.	14	JF2	10.0	10.0	598.22	1067.64	1067.64	304.28	.0	0.	.25	.98	.95	.64	.58	.65	.64	.67	.69	.65	31.
9.	14	JF2	10.5	9.5	599.30	1116.80	1116.80	308.26	1.0	0.	.25	.98	.86	.61	.55	.62	.62	.64	.66	.62	31.
10.	14	JF2	11.0	9.0	615.82	1165.96	1165.96	327.22	2.0	0.	.25	.98	.78	.59	.53	.60	.59	.61	.63	.59	31.
11.	14	JF2	9.0	11.0	632.72	1175.97	1175.97	339.40	-2.0	0.	.45	.81	.95	.58	.51	.59	.59	.61	.63	.59	31.
12.	14	JF2	9.5	10.5	612.50	1124.74	1124.74	325.91	-1.0	0.	.45	.89	.95	.61	.54	.62	.61	.64	.66	.61	31.
13.	14	JF2	10.0	10.0	602.72	1075.20	1075.20	308.16	.0	0.	.45	.97	.95	.64	.56	.65	.64	.67	.69	.64	31.
14.	14	JF2	10.5	9.5	603.69	1122.07	1122.07	309.73	1.0	0.	.45	.98	.86	.61	.54	.62	.62	.64	.66	.61	31.
15.	14	JF2	11.0	9.0	621.00	1171.36	1171.36	327.00	2.0	0.	.45	.98	.78	.58	.52	.59	.59	.61	.63	.59	31.
16.	14	JF2	9.0	11.0	424.53	1061.42	1149.84	332.90	-2.0	4.	.05	.82	.95	.60	.55	.60	.60	.62	.64	.60	31.
17.	14	JF2	9.5	10.5	400.82	1008.23	1095.15	314.03	-1.0	4.	.05	.90	.96	.63	.58	.63	.63	.65	.67	.63	31.
18.	14	JF2	10.0	10.0	390.95	975.39	1063.31	296.14	.0	4.	.05	.98	.94	.65	.59	.65	.64	.67	.70	.65	31.
19.	14	JF2	10.5	9.5	394.95	1023.42	1111.86	303.21	1.0	4.	.05	.98	.85	.62	.57	.62	.62	.64	.66	.62	31.
20.	14	JF2	11.0	9.0	417.86	1071.45	1160.56	320.51	2.0	4.	.05	.98	.77	.59	.54	.60	.59	.62	.64	.60	31.
21.	14	JF2	9.0	11.0	432.47	1075.34	1163.79	339.91	-2.0	4.	.25	.81	.95	.59	.53	.60	.59	.62	.63	.59	31.
22.	14	JF2	9.5	10.5	405.80	1019.04	1105.98	319.56	-1.0	4.	.25	.90	.96	.62	.56	.63	.62	.65	.67	.62	31.
23.	14	JF2	10.0	10.0	393.89	979.18	1067.63	296.38	.0	4.	.25	.98	.95	.64	.58	.65	.64	.67	.69	.65	31.
24.	14	JF2	10.5	9.5	398.12	1027.33	1116.82	305.58	1.0	4.	.25	.98	.86	.61	.55	.62	.62	.64	.66	.62	31.
25.	14	JF2	11.0	9.0	419.96	1075.45	1165.97	326.40	2.0	4.	.25	.98	.78	.59	.53	.60	.59	.61	.63	.59	31.
26.	14	JF2	9.0	11.0	439.95	1089.28	1177.75	345.80	-2.0	4.	.45	.80	.95	.58	.51	.59	.59	.61	.63	.58	31.
27.	14	JF2	9.5	10.5	409.82	1030.15	1117.12	322.76	-1.0	4.	.45	.89	.96	.61	.54	.62	.62	.64	.66	.62	31.
28.	14	JF2	10.0	10.0	399.77	982.98	1072.79	302.18	.0	4.	.45	.98	.95	.64	.56	.65	.64	.67	.69	.64	31.
29.	14	JF2	10.5	9.5	410.20	1031.20	1122.07	307.20	1.0	4.	.45	.98	.86	.61	.54	.62	.62	.64	.66	.61	31.
30.	14	JF2	11.0	9.0	426.59	1079.45	1171.38	324.69	2.0	4.	.45	.98	.78	.58	.52	.59	.59	.61	.63	.59	31.

1.	15	JF2	9.0	11.0	613.99	1141.27	1141.28	325.00	-2.0	0.	.05	.78	.95	.53	.63	.59	.50	.48	.61	.61	31.
2.	15	JF2	9.5	10.5	598.25	1091.34	1091.35	314.02	-1.0	0.	.05	.86	.95	.55	.66	.62	.53	.50	.64	.64	31.
3.	15	JF2	10.0	10.0	583.49	1041.42	1041.42	298.92	.0	0.	.05	.95	.95	.58	.69	.65	.55	.52	.67	.67	31.
4.	15	JF2	10.5	9.5	582.42	1075.33	1075.33	292.83	1.0	0.	.05	.97	.87	.56	.67	.63	.53	.51	.64	.65	31.
5.	15	JF2	11.0	9.0	590.18	1122.31	1122.31	309.35	2.0	0.	.05	.97	.79	.54	.64	.60	.51	.48	.62	.62	31.
6.	15	JF2	9.0	11.0	619.43	1141.32	1141.32	326.28	-2.0	0.	.25	.78	.95	.54	.62	.60	.50	.48	.61	.61	31.
7.	15	JF2	9.5	10.5	605.63	1093.50	1093.50	315.19	-1.0	0.	.25	.86	.95	.56	.65	.63	.53	.50	.64	.64	31.
8.	15	JF2	10.0	10.0	592.65	1045.68	1045.68	299.73	.0	0.	.25	.94	.94	.59	.68	.66	.55	.52	.66	.67	31.
9.	15	JF2	10.5	9.5	586.43	1075.70	1075.70	291.62	1.0	0.	.25	.96	.87	.57	.66	.64	.53	.51	.65	.65	31.
10.	15	JF2	11.0	9.0	592.00	1122.58	1122.58	307.67	2.0	0.	.25	.97	.79	.55	.63	.61	.51	.49	.62	.62	31.
11.	15	JF2	9.0	11.0	620.86	1137.32	1137.32	327.51	-2.0	0.	.45	.78	.95	.55	.62	.61	.51	.48	.61	.61	31.
12.	15	JF2	9.5	10.5	607.03	1089.64	1089.64	316.34	-1.0	0.	.45	.86	.95	.57	.64	.64	.53	.50	.64	.64	31.
13.	15	JF2	10.0	10.0	593.69	1041.85	1041.85	300.60	.0	0.	.45	.94	.94	.60	.67	.67	.55	.52	.67	.67	31.
14.	15	JF2	10.5	9.5	590.81	1075.57	1075.57	291.36	1.0	0.	.45	.96	.87	.58	.65	.65	.53	.51	.65	.65	31.
15.	15	JF2	11.0	9.0	591.27	1122.33	1122.33	308.35	2.0	0.	.45	.97	.79	.56	.62	.62	.51	.49	.62	.62	31.
16.	15	JF2	9.0	11.0	404.55	1073.72	1125.68	316.64	-2.0	4.	.05	.79	.97	.53	.64	.60	.51	.48	.62	.62	31.
17.	15	JF2	9.5	10.5	389.13	993.63	1075.74	302.29	-1.0	4.	.05	.87	.97	.56	.67	.63	.53	.51	.64	.65	31.
18.	15	JF2	10.0	10.0	373.55	972.64	1028.37	283.86	.0	4.	.05	.96	.96	.59	.70	.66	.56	.53	.67	.68	31.
19.	15	JF2	10.5	9.5	373.35	1008.63	1075.34	284.46	1.0	4.	.05	.97	.87	.56	.67	.63	.53	.51	.64	.65	31.
20.	15	JF2	11.0	9.0	388.78	1056.09	1122.30	297.13	2.0	4.	.05	.97	.79	.54	.64	.60	.51	.48	.62	.62	31.
21.	15	JF2	9.0	11.0	408.68	1072.49	1122.38	316.46	-2.0	4.	.25	.79	.97	.55	.63	.61	.51	.49	.62	.62	31.
22.	15	JF2	9.5	10.5	393.42	992.86	1072.72	302.91	-1.0	4.	.25	.87	.96	.57	.66	.64	.54	.51	.65	.65	31.
23.	15	JF2	10.0	10.0	377.75	970.59	1028.82	283.30	.0	4.	.25	.96	.96	.60	.69	.67	.56	.53	.68	.68	31.
24.	15	JF2	10.5	9.5	376.42	1007.60	1075.71	285.11	1.0	4.	.25	.96	.87	.57	.66	.64	.53	.51	.65	.65	31.
25.	15	JF2	11.0	9.0	386.69	1054.90	1122.57	297.15	2.0	4.	.25	.97	.79	.55	.63	.61	.51	.49	.62	.62	31.
26.	15	JF2	9.0	11.0	413.01	1071.58	1119.41	317.43	-2.0	4.	.45	.79	.97	.56	.63	.62	.51	.49	.62	.62	31.
27.	15	JF2	9.5	10.5	397.91	992.41	1070.04	301.39	-1.0	4.	.45	.87	.96	.58	.66	.65	.54	.51	.65	.65	31.
28.	15	JF2	10.0	10.0	383.01	969.42	1028.80	281.41	.0	4.	.45	.96	.96	.61	.68	.68	.56	.53	.68	.68	31.
29.	15	JF2	10.5	9.5	379.67	1006.57	1075.57	285.20	1.0	4.	.45	.96	.87	.58	.65	.65	.53	.51	.65	.65	31.
30.	15	JF2	11.0	9.0	391.56	1053.71	1122.35	294.76	2.0	4.	.45	.97	.79	.56	.62	.62	.51	.49	.62	.62	31.

1.	16	JF2	9.0	11.0	599.52	1110.94	1110.94	315.89	-2.0	0.	.05	.77	.95	.64	.60	.54	.65	.64	.53	.53	31.
2.	16	JF2	9.5	10.5	582.13	1063.59	1063.59	303.70	-1.0	0.	.05	.86	.95	.67	.63	.56	.68	.67	.55	.55	31.
3.	16	JF2	10.0	10.0	574.27	1016.24	1016.24	288.74	.0	0.	.05	.94	.94	.70	.66	.59	.71	.70	.58	.58	31.
4.	16	JF2	10.5	9.5	569.27	1048.38	1048.38	281.83	1.0	0.	.05	.96	.87	.67	.64	.57	.69	.68	.56	.56	31.
5.	16	JF2	11.0	9.0	576.52	1096.21	1096.21	294.16	2.0	0.	.05	.97	.78	.65	.61	.54	.66	.65	.53	.53	31.
6.	16	JF2	9.0	11.0	589.65	1098.34	1098.34	313.70	-2.0	0.	.25	.77	.95	.64	.61	.54	.66	.64	.52	.54	31.
7.	16	JF2	9.5	10.5	573.06	1051.57	1051.57	301.77	-1.0	0.	.25	.85	.95	.67	.64	.56	.68	.67	.55	.56	31.
8.	16	JF2	10.0	10.0	565.04	1004.80	1004.80	286.76	.0	0.	.25	.94	.94	.70	.67	.59	.72	.70	.57	.59	31.
9.	16	JF2	10.5	9.5	559.62	1039.05	1039.05	280.80	1.0	0.	.25	.96	.87	.68	.64	.57	.69	.68	.55	.57	31.
10.	16	JF2	11.0	9.0	567.34	1086.17	1086.17	293.71	2.0	0.	.25	.96	.78	.65	.62	.55	.66	.65	.53	.54	31.
11.	16	JF2	9.0	11.0	579.81	1085.74	1085.74	311.47	-2.0	0.	.45	.77	.95	.64	.62	.54	.66	.64	.52	.55	31.
12.	16	JF2	9.5	10.5	564.03	1039.55	1039.55	299.78	-1.0	0.	.45	.85	.95	.67	.64	.57	.69	.67	.54	.57	31.
13.	16	JF2	10.0	10.0	555.51	993.05	993.05	284.73	.0	0.	.45	.94	.94	.70	.67	.59	.72	.70	.57	.60	31.
14.	16	JF2	10.5	9.5	552.08	1033.08	1033.08	278.74	1.0	0.	.45	.95	.86	.67	.65	.57	.69	.67	.55	.58	31.
15.	16	JF2	11.0	9.0	561.62	1079.50	1079.50	290.66	2.0	0.	.45	.96	.78	.65	.62	.55	.66	.64	.52	.55	31.
16.	16	JF2	9.0	11.0	408.95	1100.95	1120.95	317.88	-2.0	4.	.05	.77	.95	.63	.60	.53	.65	.63	.52	.52	31.
17.	16	JF2	9.5	10.5	380.29	1039.77	1059.77	299.93	-1.0	4.	.05	.86	.95	.67	.63	.56	.69	.67	.55	.55	31.
18.	16	JF2	10.0	10.0	365.79	985.78	1005.78	267.81	.0	4.	.05	.95	.95	.70	.67	.59	.72	.71	.58	.58	31.
19.	16	JF2	10.5	9.5	372.19	1029.44	1049.44	255.82	1.0	4.	.05	.96	.87	.67	.64	.57	.69	.68	.56	.56	31.
20.	16	JF2	11.0	9.0	384.07	1076.20	1096.20	266.78	2.0	4.	.05	.97	.78	.65	.61	.54	.66	.65	.53	.53	31.
21.	16	JF2	9.0	11.0	394.40	1080.85	1100.85	310.23	-2.0	4.	.25	.77	.95	.64	.61	.54	.65	.64	.52	.54	31.
22.	16	JF2	9.5	10.5	375.68	1029.69	1049.69	291.35	-1.0	4.	.25	.86	.95	.67	.64	.57	.69	.67	.55	.56	31.
23.	16	JF2	10.0	10.0	354.82	972.93	992.93	261.63	.0	4.	.25	.95	.96	.71	.67	.60	.72	.71	.58	.59	31.
24.	16	JF2	10.5	9.5	373.02	1023.99	1043.99	251.40	1.0	4.	.25	.95	.86	.67	.64	.57	.69	.67	.55	.57	31.
25.	16	JF2	11.0	9.0	373.42	1066.17	1086.17	263.24	2.0	4.	.25	.96	.78	.65	.62	.55	.66	.65	.53	.54	31.
26.	16	JF2	9.0	11.0	388.25	1069.86	1089.86	304.56	-2.0	4.	.45	.77	.95	.64	.61	.54	.65	.64	.52	.55	31.
27.	16	JF2	9.5	10.5	369.95	1019.61	1039.61	287.75	-1.0	4.	.45	.85	.95	.67	.64	.57	.69	.67	.54	.57	31.
28.	16	JF2	10.0	10.0	346.18	962.91	982.91	256.88	.0	4.	.45	.95	.95	.71	.68	.60	.73	.71	.58	.60	31.
29.	16	JF2	10.5	9.5	368.59	1008.14	1028.14	244.37	1.0	4.	.45	.96	.86	.68	.65	.57	.69	.68	.55	.58	31.
30.	16	JF2	11.0	9.0	367.10	1050.79	1070.79	258.76	2.0	4.	.45	.96	.78	.65	.62	.55	.67	.65	.53	.56	31.

1.	17	JF2	9.0	11.0	635.34	1170.64	1170.64	330.99	-2.0	0.	.05	.76	.95	.57	.61	.53	.57	.58	.54	.51	31.
2.	17	JF2	9.5	10.5	614.90	1121.70	1121.71	318.49	-1.0	0.	.05	.83	.95	.60	.63	.55	.60	.60	.57	.54	31.
3.	17	JF2	10.0	10.0	598.97	1068.93	1068.93	304.59	.0	0.	.05	.92	.95	.63	.66	.58	.63	.63	.60	.56	31.
4.	17	JF2	10.5	9.5	586.44	1066.72	1066.72	291.68	1.0	0.	.05	.97	.90	.63	.67	.58	.63	.63	.60	.56	31.
5.	17	JF2	11.0	9.0	586.63	1115.27	1115.27	304.24	2.0	0.	.05	.97	.82	.60	.64	.56	.60	.61	.57	.54	31.
6.	17	JF2	9.0	11.0	631.46	1163.56	1163.56	329.82	-2.0	0.	.25	.76	.95	.57	.62	.53	.58	.58	.56	.52	31.
7.	17	JF2	9.5	10.5	610.68	1114.33	1114.33	317.41	-1.0	0.	.25	.84	.95	.59	.64	.55	.61	.60	.58	.54	31.
8.	17	JF2	10.0	10.0	595.47	1061.35	1061.35	303.82	.0	0.	.25	.93	.95	.62	.68	.58	.64	.63	.61	.57	31.
9.	17	JF2	10.5	9.5	584.63	1070.18	1070.18	292.73	1.0	0.	.25	.97	.90	.62	.67	.58	.63	.63	.60	.56	31.
10.	17	JF2	11.0	9.0	585.50	1119.45	1119.45	306.16	2.0	0.	.25	.97	.81	.59	.64	.55	.61	.60	.58	.54	31.
11.	17	JF2	9.0	11.0	634.49	1163.56	1163.56	328.95	-2.0	0.	.45	.77	.95	.56	.62	.53	.59	.57	.56	.51	31.
12.	17	JF2	9.5	10.5	614.71	1115.41	1115.41	316.68	-1.0	0.	.45	.84	.94	.58	.65	.55	.62	.60	.59	.54	31.
13.	17	JF2	10.0	10.0	601.62	1063.72	1063.72	303.65	.0	0.	.45	.93	.94	.61	.68	.58	.65	.63	.61	.56	31.
14.	17	JF2	10.5	9.5	584.39	1073.99	1073.99	293.58	1.0	0.	.45	.97	.89	.61	.67	.57	.64	.62	.61	.56	31.
15.	17	JF2	11.0	9.0	585.46	1123.49	1123.49	307.76	2.0	0.	.45	.97	.81	.58	.64	.55	.61	.59	.58	.53	31.
16.	17	JF2	9.0	11.0	426.31	1045.19	1157.62	314.76	-2.0	4.	.05	.76	.96	.58	.61	.54	.58	.58	.55	.52	31.
17.	17	JF2	9.5	10.5	404.68	984.20	1108.17	294.64	-1.0	4.	.05	.84	.96	.60	.64	.56	.60	.61	.58	.54	31.
18.	17	JF2	10.0	10.0	393.31	912.13	1060.13	277.92	.0	4.	.05	.93	.95	.63	.67	.59	.63	.64	.60	.57	31.
19.	17	JF2	10.5	9.5	381.10	922.73	1066.73	261.54	1.0	4.	.05	.97	.90	.63	.67	.58	.63	.63	.60	.56	31.
20.	17	JF2	11.0	9.0	385.44	971.27	1115.27	270.60	2.0	4.	.05	.97	.82	.60	.64	.56	.60	.61	.57	.54	31.
21.	17	JF2	9.0	11.0	420.47	1037.91	1149.43	316.13	-2.0	4.	.25	.77	.96	.58	.62	.54	.59	.58	.56	.52	31.
22.	17	JF2	9.5	10.5	399.26	977.73	1100.23	299.20	-1.0	4.	.25	.85	.96	.60	.65	.56	.62	.61	.59	.55	31.
23.	17	JF2	10.0	10.0	389.07	903.04	1051.04	276.14	.0	4.	.25	.94	.96	.63	.68	.59	.65	.64	.61	.57	31.
24.	17	JF2	10.5	9.5	385.64	926.17	1070.17	265.65	1.0	4.	.25	.97	.90	.62	.67	.58	.63	.63	.60	.56	31.
25.	17	JF2	11.0	9.0	383.95	975.44	1119.44	272.09	2.0	4.	.25	.97	.81	.59	.64	.55	.61	.60	.58	.54	31.
26.	17	JF2	9.0	11.0	416.50	1032.12	1142.74	315.14	-2.0	4.	.45	.78	.97	.57	.63	.54	.60	.58	.57	.52	31.
27.	17	JF2	9.5	10.5	398.18	972.75	1093.78	295.49	-1.0	4.	.45	.86	.96	.60	.66	.56	.63	.61	.60	.55	31.
28.	17	JF2	10.0	10.0	397.29	949.41	1053.79	278.10	.0	4.	.45	.94	.95	.62	.69	.58	.65	.63	.62	.57	31.
29.	17	JF2	10.5	9.5	383.79	925.98	1073.98	262.60	1.0	4.	.45	.97	.89	.61	.67	.57	.64	.62	.61	.56	31.
30.	17	JF2	11.0	9.0	384.03	975.48	1123.48	272.93	2.0	4.	.45	.97	.81	.58	.64	.55	.61	.59	.58	.53	31.

1.	18	JF2	9.0	11.0	612.13	1129.70	1129.71	324.89	-2.0	0.	.05	.82	.96	.70	.52	.59	.63	.67	.57	.57	31.
2.	18	JF2	9.5	10.5	597.07	1081.96	1081.97	312.25	-1.0	0.	.05	.90	.96	.73	.54	.61	.66	.70	.59	.59	31.
3.	18	JF2	10.0	10.0	583.21	1047.77	1047.77	297.64	.0	0.	.05	.97	.94	.76	.56	.63	.68	.73	.61	.61	31.
4.	18	JF2	10.5	9.5	582.15	1098.60	1098.60	300.40	1.0	0.	.05	.98	.85	.72	.53	.60	.65	.69	.59	.59	31.
5.	18	JF2	11.0	9.0	593.19	1144.97	1144.97	317.43	2.0	0.	.05	.98	.77	.69	.51	.58	.62	.66	.56	.56	31.
6.	18	JF2	9.0	11.0	599.29	1106.73	1106.73	317.64	-2.0	0.	.25	.84	.96	.71	.53	.60	.64	.68	.59	.58	31.
7.	18	JF2	9.5	10.5	585.29	1060.05	1060.05	305.72	-1.0	0.	.25	.92	.95	.74	.56	.63	.67	.71	.62	.60	31.
8.	18	JF2	10.0	10.0	575.27	1050.30	1050.30	294.44	.0	0.	.25	.98	.92	.75	.56	.64	.67	.72	.62	.61	31.
9.	18	JF2	10.5	9.5	579.14	1098.25	1098.25	301.32	1.0	0.	.25	.98	.83	.71	.54	.61	.64	.69	.60	.58	31.
10.	18	JF2	11.0	9.0	592.76	1148.34	1148.34	320.18	2.0	0.	.25	.98	.75	.68	.51	.58	.62	.66	.57	.56	31.
11.	18	JF2	9.0	11.0	586.30	1083.75	1083.75	310.58	-2.0	0.	.45	.86	.96	.72	.55	.62	.65	.69	.61	.58	31.
12.	18	JF2	9.5	10.5	573.46	1038.11	1038.11	299.24	-1.0	0.	.45	.94	.95	.75	.58	.65	.68	.73	.64	.61	31.
13.	18	JF2	10.0	10.0	569.01	1052.50	1052.50	292.64	.0	0.	.45	.98	.90	.74	.57	.64	.67	.72	.63	.60	31.
14.	18	JF2	10.5	9.5	578.21	1101.63	1101.63	303.42	1.0	0.	.45	.98	.81	.71	.54	.61	.64	.68	.60	.57	31.
15.	18	JF2	11.0	9.0	594.49	1151.88	1151.88	322.06	2.0	0.	.45	.98	.74	.68	.52	.58	.61	.65	.58	.55	31.
16.	18	JF2	9.0	11.0	414.46	1084.88	1129.10	312.56	-2.0	4.	.05	.82	.96	.70	.52	.59	.63	.67	.57	.57	31.
17.	18	JF2	9.5	10.5	400.82	1039.43	1083.14	304.60	-1.0	4.	.05	.90	.95	.73	.54	.61	.66	.70	.59	.59	31.
18.	18	JF2	10.0	10.0	392.22	997.76	1047.76	288.02	.0	4.	.05	.97	.94	.76	.56	.63	.68	.73	.61	.61	31.
19.	18	JF2	10.5	9.5	386.38	1042.98	1098.60	289.71	1.0	4.	.05	.98	.85	.72	.53	.60	.65	.69	.59	.59	31.
20.	18	JF2	11.0	9.0	398.23	1096.95	1144.97	298.72	2.0	4.	.05	.98	.77	.69	.51	.58	.62	.66	.56	.56	31.
21.	18	JF2	9.0	11.0	399.32	1059.49	1104.12	309.19	-2.0	4.	.25	.84	.96	.71	.53	.60	.64	.69	.59	.58	31.
22.	18	JF2	9.5	10.5	383.33	1010.87	1054.97	300.85	-1.0	4.	.25	.92	.96	.74	.56	.63	.67	.72	.62	.60	31.
23.	18	JF2	10.0	10.0	379.82	1000.80	1050.31	284.80	.0	4.	.25	.98	.92	.75	.56	.64	.67	.72	.62	.61	31.
24.	18	JF2	10.5	9.5	380.12	1048.13	1098.26	292.01	1.0	4.	.25	.98	.83	.71	.54	.61	.64	.69	.60	.58	31.
25.	18	JF2	11.0	9.0	397.48	1093.98	1148.33	303.96	2.0	4.	.25	.98	.75	.68	.51	.58	.62	.66	.57	.56	31.
26.	18	JF2	9.0	11.0	387.23	1038.37	1083.41	299.99	-2.0	4.	.45	.86	.96	.72	.55	.62	.65	.69	.61	.58	31.
27.	18	JF2	9.5	10.5	370.37	989.81	1034.30	290.53	-1.0	4.	.45	.95	.96	.75	.58	.65	.68	.73	.64	.61	31.
28.	18	JF2	10.0	10.0	374.63	1003.48	1052.50	281.41	.0	4.	.45	.98	.90	.74	.57	.64	.67	.72	.63	.60	31.
29.	18	JF2	10.5	9.5	379.63	1051.08	1101.63	289.11	1.0	4.	.45	.98	.81	.71	.54	.61	.64	.68	.60	.57	31.
30.	18	JF2	11.0	9.0	399.02	1098.66	1151.87	307.45	2.0	4.	.45	.98	.74	.68	.52	.58	.61	.65	.58	.55	31.

1.	19	JF2	9.0	11.0	625.93	1146.58	1146.59	324.64	-2.0	0.	.05	.79	.95	.55	.58	.60	.60	.58	.60	.59	31.
2.	19	JF2	9.5	10.5	606.99	1098.07	1098.08	311.34	-1.0	0.	.05	.87	.95	.57	.60	.62	.62	.60	.63	.62	31.
3.	19	JF2	10.0	10.0	594.44	1045.49	1045.49	294.73	.0	0.	.05	.96	.95	.60	.63	.66	.65	.63	.66	.65	31.
4.	19	JF2	10.5	9.5	584.97	1091.84	1091.84	295.50	1.0	0.	.05	.96	.86	.58	.61	.63	.62	.61	.63	.62	31.
5.	19	JF2	11.0	9.0	593.18	1139.44	1139.44	313.57	2.0	0.	.05	.97	.78	.55	.58	.60	.60	.58	.60	.60	31.
6.	19	JF2	9.0	11.0	627.50	1148.48	1148.48	326.72	-2.0	0.	.25	.79	.95	.55	.57	.60	.60	.57	.60	.59	31.
7.	19	JF2	9.5	10.5	607.89	1100.44	1100.44	312.83	-1.0	0.	.25	.87	.95	.58	.60	.62	.63	.60	.63	.62	31.
8.	19	JF2	10.0	10.0	597.14	1054.49	1054.49	295.85	.0	0.	.25	.96	.94	.60	.63	.65	.65	.63	.66	.65	31.
9.	19	JF2	10.5	9.5	593.22	1102.48	1102.48	296.48	1.0	0.	.25	.96	.86	.58	.60	.62	.62	.60	.63	.62	31.
10.	19	JF2	11.0	9.0	604.50	1150.47	1150.47	312.95	2.0	0.	.25	.97	.78	.55	.57	.59	.60	.57	.60	.59	31.
11.	19	JF2	9.0	11.0	630.24	1151.40	1151.40	328.61	-2.0	0.	.45	.80	.95	.56	.57	.59	.60	.57	.61	.59	31.
12.	19	JF2	9.5	10.5	609.44	1103.33	1103.33	314.11	-1.0	0.	.45	.88	.95	.58	.59	.62	.63	.60	.63	.62	31.
13.	19	JF2	10.0	10.0	603.47	1064.74	1064.74	297.85	.0	0.	.45	.96	.93	.60	.62	.64	.65	.62	.66	.64	31.
14.	19	JF2	10.5	9.5	597.66	1113.12	1113.12	299.38	1.0	0.	.45	.96	.85	.58	.59	.61	.62	.59	.63	.61	31.
15.	19	JF2	11.0	9.0	610.89	1162.26	1162.26	316.61	2.0	0.	.45	.97	.77	.55	.56	.59	.60	.57	.60	.59	31.
16.	19	JF2	9.0	11.0	407.47	1041.96	1130.39	320.88	-2.0	4.	.05	.80	.97	.56	.59	.61	.60	.58	.61	.60	31.
17.	19	JF2	9.5	10.5	394.75	1011.81	1087.81	308.47	-1.0	4.	.05	.88	.96	.58	.61	.63	.63	.61	.63	.63	31.
18.	19	JF2	10.0	10.0	385.62	955.71	1044.24	291.82	.0	4.	.05	.96	.95	.60	.64	.66	.65	.63	.66	.65	31.
19.	19	JF2	10.5	9.5	378.79	1000.78	1091.84	293.71	1.0	4.	.05	.96	.86	.58	.61	.63	.62	.61	.63	.62	31.
20.	19	JF2	11.0	9.0	388.50	1048.37	1139.44	309.87	2.0	4.	.05	.97	.78	.55	.58	.60	.60	.58	.60	.60	31.
21.	19	JF2	9.0	11.0	417.58	1054.54	1140.60	323.27	-2.0	4.	.25	.80	.96	.56	.58	.60	.60	.58	.61	.60	31.
22.	19	JF2	9.5	10.5	396.95	1015.68	1091.68	307.88	-1.0	4.	.25	.88	.96	.58	.60	.63	.63	.60	.64	.62	31.
23.	19	JF2	10.0	10.0	388.58	962.14	1054.50	293.94	.0	4.	.25	.96	.94	.60	.63	.65	.65	.63	.66	.65	31.
24.	19	JF2	10.5	9.5	382.98	1010.07	1102.48	296.51	1.0	4.	.25	.96	.86	.58	.60	.62	.62	.60	.63	.62	31.
25.	19	JF2	11.0	9.0	395.33	1058.00	1150.47	312.92	2.0	4.	.25	.97	.78	.55	.57	.59	.60	.57	.60	.59	31.
26.	19	JF2	9.0	11.0	415.86	1056.18	1139.85	329.52	-2.0	4.	.45	.81	.96	.56	.57	.60	.61	.58	.61	.60	31.
27.	19	JF2	9.5	10.5	401.30	1022.20	1098.20	312.90	-1.0	4.	.45	.88	.95	.58	.60	.62	.63	.60	.64	.62	31.
28.	19	JF2	10.0	10.0	398.55	972.04	1064.73	297.09	.0	4.	.45	.96	.93	.60	.62	.64	.65	.62	.66	.64	31.
29.	19	JF2	10.5	9.5	389.81	1020.34	1113.13	298.97	1.0	4.	.45	.96	.85	.58	.59	.61	.62	.59	.63	.61	31.
30.	19	JF2	11.0	9.0	403.55	1069.37	1162.27	315.23	2.0	4.	.45	.97	.77	.55	.56	.59	.60	.57	.60	.59	31.

1.	20	JF2	9.0	11.0	627.20	1147.76	1147.76	327.03	-2.0	0.	.05	.78	.95	.62	.55	.54	.61	.61	.57	.58	31.
2.	20	JF2	9.5	10.5	612.70	1099.35	1099.35	314.62	-1.0	0.	.05	.86	.95	.64	.58	.56	.64	.64	.60	.60	31.
3.	20	JF2	10.0	10.0	597.67	1050.94	1050.94	299.17	.0	0.	.05	.94	.94	.67	.61	.59	.67	.66	.63	.63	31.
4.	20	JF2	10.5	9.5	582.21	1075.56	1075.56	295.23	1.0	0.	.05	.97	.87	.66	.59	.58	.65	.65	.61	.62	31.
5.	20	JF2	11.0	9.0	588.56	1124.00	1124.00	308.04	2.0	0.	.05	.97	.79	.63	.57	.55	.62	.62	.59	.59	31.
6.	20	JF2	9.0	11.0	624.34	1140.19	1140.19	325.40	-2.0	0.	.25	.78	.95	.61	.55	.53	.62	.61	.58	.59	31.
7.	20	JF2	9.5	10.5	609.02	1092.15	1092.15	313.71	-1.0	0.	.25	.86	.95	.64	.58	.55	.65	.64	.60	.62	31.
8.	20	JF2	10.0	10.0	594.79	1043.32	1043.32	297.46	.0	0.	.25	.94	.94	.67	.60	.58	.68	.67	.63	.65	31.
9.	20	JF2	10.5	9.5	583.86	1067.45	1067.45	292.23	1.0	0.	.25	.97	.88	.65	.59	.56	.66	.65	.62	.63	31.
10.	20	JF2	11.0	9.0	586.34	1115.62	1115.62	304.59	2.0	0.	.25	.97	.79	.62	.56	.54	.63	.63	.59	.60	31.
11.	20	JF2	9.0	11.0	626.59	1138.81	1138.81	325.07	-2.0	0.	.45	.77	.95	.60	.55	.51	.63	.61	.58	.60	31.
12.	20	JF2	9.5	10.5	612.80	1090.44	1090.44	312.76	-1.0	0.	.45	.85	.94	.63	.57	.54	.66	.64	.60	.63	31.
13.	20	JF2	10.0	10.0	598.67	1042.71	1042.71	296.19	.0	0.	.45	.93	.94	.66	.60	.56	.69	.67	.63	.66	31.
14.	20	JF2	10.5	9.5	586.14	1059.34	1059.34	288.27	1.0	0.	.45	.97	.88	.65	.59	.55	.68	.66	.62	.65	31.
15.	20	JF2	11.0	9.0	584.13	1107.26	1107.26	300.95	2.0	0.	.45	.97	.79	.62	.56	.53	.65	.63	.59	.62	31.
16.	20	JF2	9.0	11.0	426.17	1104.85	1140.98	327.88	-2.0	4.	.05	.78	.96	.62	.56	.54	.61	.61	.58	.58	31.
17.	20	JF2	9.5	10.5	411.23	1056.91	1091.56	305.35	-1.0	4.	.05	.86	.95	.65	.58	.57	.64	.64	.60	.61	31.
18.	20	JF2	10.0	10.0	395.79	1002.09	1042.15	283.97	.0	4.	.05	.95	.95	.68	.61	.60	.67	.67	.63	.63	31.
19.	20	JF2	10.5	9.5	384.10	1000.46	1075.56	275.37	1.0	4.	.05	.97	.87	.66	.59	.58	.65	.65	.61	.62	31.
20.	20	JF2	11.0	9.0	384.03	1048.36	1123.99	287.81	2.0	4.	.05	.97	.79	.63	.57	.55	.62	.62	.59	.59	31.
21.	20	JF2	9.0	11.0	421.95	1099.06	1133.83	323.97	-2.0	4.	.25	.78	.96	.61	.55	.53	.62	.62	.58	.59	31.
22.	20	JF2	9.5	10.5	410.17	1051.61	1084.98	304.25	-1.0	4.	.25	.86	.95	.64	.58	.55	.65	.64	.61	.62	31.
23.	20	JF2	10.0	10.0	390.14	975.50	1033.60	277.35	.0	4.	.25	.95	.95	.67	.61	.58	.68	.68	.64	.65	31.
24.	20	JF2	10.5	9.5	380.54	991.39	1067.46	271.15	1.0	4.	.25	.97	.88	.65	.59	.56	.66	.65	.62	.63	31.
25.	20	JF2	11.0	9.0	381.04	1039.36	1115.65	280.69	2.0	4.	.25	.97	.79	.62	.56	.54	.63	.63	.59	.60	31.
26.	20	JF2	9.0	11.0	413.58	1085.89	1119.30	319.52	-2.0	4.	.45	.78	.96	.61	.56	.52	.64	.63	.59	.61	31.
27.	20	JF2	9.5	10.5	399.88	1038.71	1070.80	297.91	-1.0	4.	.45	.86	.96	.64	.58	.54	.67	.65	.61	.64	31.
28.	20	JF2	10.0	10.0	382.82	965.06	1022.37	274.31	.0	4.	.45	.95	.96	.67	.61	.57	.70	.68	.64	.67	31.
29.	20	JF2	10.5	9.5	372.99	983.22	1059.35	269.39	1.0	4.	.45	.97	.88	.65	.59	.55	.68	.66	.62	.65	31.
30.	20	JF2	11.0	9.0	377.99	1031.02	1107.26	277.91	2.0	4.	.45	.97	.79	.62	.56	.53	.65	.63	.59	.62	31.

MODEL=11

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.916	0.071	0.750	0.980
UTM2	600	0.910	0.070	0.740	0.980
UTM3	600	0.618	0.058	0.450	0.760
UTM4	600	0.604	0.052	0.490	0.740
UTM5	600	0.606	0.050	0.480	0.740
UTM6	600	0.619	0.052	0.470	0.730
UTM7	600	0.615	0.059	0.480	0.730
UTM8	600	0.611	0.046	0.500	0.730
UTM9	600	0.603	0.051	0.460	0.740

MODEL=12

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.916	0.071	0.750	0.980
UTM2	600	0.911	0.070	0.740	0.980
UTM3	600	0.618	0.058	0.450	0.760
UTM4	600	0.604	0.052	0.490	0.740
UTM5	600	0.606	0.050	0.480	0.740
UTM6	600	0.619	0.052	0.470	0.730
UTM7	600	0.615	0.059	0.480	0.730
UTM8	600	0.611	0.046	0.500	0.730
UTM9	600	0.603	0.051	0.460	0.740

MODEL=13

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.915	0.071	0.750	0.980
UTM2	600	0.910	0.070	0.740	0.980
UTM3	600	0.618	0.058	0.450	0.760
UTM4	600	0.604	0.052	0.490	0.740
UTM5	600	0.606	0.050	0.480	0.740
UTM6	600	0.619	0.052	0.470	0.730
UTM7	600	0.615	0.059	0.480	0.730
UTM8	600	0.611	0.046	0.500	0.730
UTM9	600	0.603	0.051	0.460	0.740

Appendix 5. Grand-average machine utilization

MODEL=14

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.918	0.070	0.750	0.980
UTM2	600	0.913	0.072	0.730	0.980
UTM3	600	0.619	0.058	0.450	0.760
UTM4	600	0.606	0.054	0.490	0.750
UTM5	600	0.608	0.050	0.480	0.740
UTM6	600	0.621	0.053	0.470	0.730
UTM7	600	0.617	0.059	0.480	0.730
UTM8	600	0.612	0.046	0.500	0.730
UTM9	600	0.605	0.051	0.460	0.730

MODEL=21

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.913	0.072	0.750	0.980
UTM2	600	0.908	0.069	0.740	0.980
UTM3	600	0.616	0.057	0.450	0.760
UTM4	600	0.602	0.052	0.490	0.740
UTM5	600	0.605	0.050	0.480	0.740
UTM6	600	0.618	0.052	0.470	0.720
UTM7	600	0.613	0.059	0.470	0.730
UTM8	600	0.609	0.046	0.490	0.740
UTM9	600	0.602	0.051	0.460	0.730

MODEL=22

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.899	0.081	0.690	0.980
UTM2	600	0.893	0.067	0.740	0.980
UTM3	600	0.606	0.055	0.450	0.720
UTM4	600	0.593	0.054	0.470	0.740
UTM5	600	0.595	0.053	0.460	0.740
UTM6	600	0.608	0.054	0.460	0.720
UTM7	600	0.604	0.059	0.440	0.710
UTM8	600	0.600	0.050	0.480	0.730
UTM9	600	0.592	0.054	0.450	0.740

MODEL=23

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.901	0.078	0.720	0.980
UTM2	600	0.895	0.066	0.740	0.980
UTM3	600	0.607	0.055	0.450	0.720
UTM4	600	0.594	0.053	0.470	0.740
UTM5	600	0.596	0.052	0.470	0.740
UTM6	600	0.609	0.054	0.460	0.720
UTM7	600	0.605	0.059	0.440	0.710
UTM8	600	0.601	0.048	0.480	0.730
UTM9	600	0.593	0.053	0.450	0.730

MODEL=24

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.911	0.073	0.750	0.980
UTM2	600	0.905	0.067	0.730	0.980
UTM3	600	0.614	0.057	0.450	0.750
UTM4	600	0.601	0.053	0.490	0.750
UTM5	600	0.603	0.050	0.480	0.750
UTM6	600	0.616	0.052	0.470	0.720
UTM7	600	0.612	0.059	0.480	0.730
UTM8	600	0.607	0.045	0.490	0.740
UTM9	600	0.600	0.051	0.460	0.740

MODEL=31

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.912	0.074	0.750	0.980
UTM2	600	0.906	0.067	0.740	0.970
UTM3	600	0.615	0.058	0.450	0.760
UTM4	600	0.601	0.052	0.490	0.740
UTM5	600	0.603	0.050	0.480	0.740
UTM6	600	0.616	0.052	0.470	0.730
UTM7	600	0.612	0.059	0.470	0.730
UTM8	600	0.608	0.046	0.490	0.730
UTM9	600	0.600	0.051	0.460	0.740

MODEL=32

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.899	0.081	0.690	0.980
UTM2	600	0.892	0.065	0.740	0.970
UTM3	600	0.605	0.055	0.450	0.720
UTM4	600	0.592	0.054	0.470	0.740
UTM5	600	0.594	0.052	0.460	0.740
UTM6	600	0.607	0.054	0.460	0.730
UTM7	600	0.603	0.059	0.440	0.710
UTM8	600	0.599	0.049	0.480	0.730
UTM9	600	0.591	0.054	0.450	0.740

MODEL=33

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.904	0.078	0.720	0.980
UTM2	600	0.897	0.067	0.740	0.970
UTM3	600	0.609	0.056	0.450	0.720
UTM4	600	0.596	0.054	0.470	0.740
UTM5	600	0.598	0.051	0.470	0.740
UTM6	600	0.611	0.054	0.470	0.730
UTM7	600	0.606	0.059	0.450	0.710
UTM8	600	0.602	0.048	0.490	0.730
UTM9	600	0.595	0.053	0.450	0.740

MODEL=34

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.899	0.080	0.710	0.980
UTM2	600	0.892	0.059	0.730	0.970
UTM3	600	0.606	0.056	0.450	0.740
UTM4	600	0.593	0.053	0.470	0.740
UTM5	600	0.594	0.049	0.470	0.740
UTM6	600	0.607	0.050	0.460	0.710
UTM7	600	0.603	0.057	0.470	0.720
UTM8	600	0.599	0.045	0.480	0.730
UTM9	600	0.592	0.051	0.440	0.730

MODEL=41

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.910	0.077	0.730	0.980
UTM2	600	0.904	0.064	0.740	0.970
UTM3	600	0.614	0.058	0.450	0.760
UTM4	600	0.600	0.052	0.480	0.740
UTM5	600	0.602	0.050	0.480	0.740
UTM6	600	0.615	0.052	0.470	0.720
UTM7	600	0.611	0.059	0.470	0.720
UTM8	600	0.607	0.046	0.490	0.730
UTM9	600	0.599	0.051	0.450	0.740

MODEL=42

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.899	0.082	0.710	0.980
UTM2	600	0.893	0.064	0.740	0.970
UTM3	600	0.606	0.055	0.450	0.720
UTM4	600	0.593	0.054	0.470	0.740
UTM5	600	0.595	0.052	0.470	0.740
UTM6	600	0.608	0.054	0.470	0.720
UTM7	600	0.603	0.059	0.440	0.710
UTM8	600	0.600	0.049	0.490	0.730
UTM9	600	0.592	0.054	0.450	0.740

MODEL=43

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.906	0.079	0.720	0.980
UTM2	600	0.899	0.066	0.740	0.970
UTM3	600	0.610	0.056	0.450	0.730
UTM4	600	0.597	0.055	0.470	0.740
UTM5	600	0.599	0.051	0.480	0.740
UTM6	600	0.612	0.054	0.470	0.720
UTM7	600	0.608	0.060	0.460	0.720
UTM8	600	0.604	0.048	0.490	0.730
UTM9	600	0.596	0.053	0.450	0.740

MODEL=44

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.886	0.087	0.700	0.980
UTM2	600	0.879	0.054	0.730	0.970
UTM3	600	0.597	0.057	0.420	0.740
UTM4	600	0.584	0.055	0.460	0.730
UTM5	600	0.586	0.048	0.460	0.730
UTM6	600	0.599	0.052	0.440	0.710
UTM7	600	0.594	0.058	0.440	0.710
UTM8	600	0.590	0.045	0.470	0.720
UTM9	600	0.583	0.049	0.440	0.720

MODEL=51

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.907	0.068	0.750	0.980
UTM2	600	0.902	0.072	0.720	0.970
UTM3	600	0.612	0.057	0.440	0.750
UTM4	600	0.598	0.052	0.490	0.740
UTM5	600	0.600	0.050	0.480	0.740
UTM6	600	0.614	0.052	0.460	0.730
UTM7	600	0.609	0.058	0.470	0.730
UTM8	600	0.605	0.046	0.490	0.740
UTM9	600	0.598	0.051	0.450	0.730

MODEL=52

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.909	0.069	0.740	0.980
UTM2	600	0.905	0.073	0.710	0.970
UTM3	600	0.614	0.058	0.440	0.750
UTM4	600	0.600	0.053	0.490	0.740
UTM5	600	0.602	0.049	0.480	0.750
UTM6	600	0.616	0.054	0.450	0.730
UTM7	600	0.611	0.061	0.460	0.730
UTM8	600	0.607	0.045	0.490	0.740
UTM9	600	0.599	0.051	0.460	0.730

MODEL=53

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.909	0.069	0.740	0.980
UTM2	600	0.905	0.073	0.710	0.970
UTM3	600	0.614	0.058	0.440	0.750
UTM4	600	0.600	0.053	0.490	0.740
UTM5	600	0.602	0.049	0.480	0.750
UTM6	600	0.616	0.054	0.450	0.730
UTM7	600	0.611	0.061	0.460	0.730
UTM8	600	0.607	0.045	0.490	0.740
UTM9	600	0.599	0.051	0.460	0.730

MODEL=54

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.892	0.069	0.730	0.980
UTM2	600	0.887	0.072	0.710	0.970
UTM3	600	0.602	0.056	0.430	0.740
UTM4	600	0.589	0.053	0.470	0.740
UTM5	600	0.591	0.050	0.460	0.740
UTM6	600	0.603	0.051	0.450	0.720
UTM7	600	0.599	0.057	0.460	0.720
UTM8	600	0.595	0.046	0.480	0.730
UTM9	600	0.588	0.050	0.440	0.730

MODEL=61

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.915	0.074	0.750	0.980
UTM2	600	0.909	0.068	0.740	0.980
UTM3	600	0.617	0.058	0.450	0.760
UTM4	600	0.604	0.052	0.490	0.740
UTM5	600	0.606	0.050	0.480	0.740
UTM6	600	0.619	0.052	0.470	0.720
UTM7	600	0.614	0.059	0.480	0.730
UTM8	600	0.610	0.046	0.490	0.730
UTM9	600	0.603	0.051	0.460	0.740

MODEL=62

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.902	0.080	0.710	0.980
UTM2	600	0.896	0.067	0.740	0.980
UTM3	600	0.608	0.055	0.450	0.720
UTM4	600	0.595	0.055	0.460	0.750
UTM5	600	0.597	0.053	0.470	0.740
UTM6	600	0.610	0.053	0.470	0.720
UTM7	600	0.605	0.059	0.450	0.710
UTM8	600	0.602	0.050	0.480	0.730
UTM9	600	0.594	0.054	0.450	0.730

MODEL=63

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.904	0.080	0.720	0.980
UTM2	600	0.898	0.066	0.740	0.980
UTM3	600	0.609	0.055	0.450	0.720
UTM4	600	0.596	0.055	0.460	0.750
UTM5	600	0.598	0.051	0.470	0.740
UTM6	600	0.611	0.054	0.470	0.720
UTM7	600	0.607	0.059	0.450	0.720
UTM8	600	0.603	0.049	0.480	0.730
UTM9	600	0.595	0.053	0.450	0.730

MODEL=64

Variable	N	Mean	Std Dev	Minimum	Maximum
UTM1	600	0.910	0.075	0.740	0.980
UTM2	600	0.904	0.065	0.730	0.980
UTM3	600	0.614	0.057	0.450	0.750
UTM4	600	0.600	0.052	0.490	0.750
UTM5	600	0.602	0.050	0.470	0.740
UTM6	600	0.616	0.052	0.470	0.720
UTM7	600	0.611	0.059	0.480	0.720
UTM8	600	0.607	0.046	0.490	0.740
UTM9	600	0.600	0.052	0.450	0.730

		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1	UT-M1
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
TBCREA	DFAVPT																								
0	-2	.80	.80	.80	.80	.79	.77	.77	.79	.79	.77	.78	.76	.78	.77	.78	.74	.79	.79	.79	.77	.79	.78	.78	.78
	-1	.88	.88	.88	.88	.87	.84	.85	.87	.87	.84	.85	.84	.86	.84	.85	.81	.87	.88	.88	.84	.87	.85	.85	.86
	0	.96	.96	.96	.96	.95	.92	.92	.95	.95	.92	.93	.92	.95	.92	.93	.88	.95	.95	.95	.91	.96	.92	.93	.94
	1	.97	.97	.97	.97	.97	.96	.96	.97	.97	.96	.96	.97	.98	.96	.97	.96	.96	.96	.96	.93	.98	.96	.96	.98
	2	.98	.98	.98	.97	.98	.98	.98	.97	.98	.98	.98	.97	.98	.98	.98	.98	.96	.96	.96	.93	.98	.98	.98	.98
4	-2	.80	.80	.80	.80	.80	.79	.79	.79	.79	.78	.79	.78	.79	.78	.78	.78	.79	.79	.79	.79	.79	.79	.79	.79
	-1	.88	.88	.88	.88	.88	.86	.86	.88	.87	.86	.86	.86	.87	.86	.86	.85	.88	.88	.88	.87	.88	.86	.86	.87
	0	.96	.95	.95	.96	.95	.95	.94	.95	.95	.94	.95	.94	.95	.94	.95	.93	.95	.95	.95	.95	.96	.95	.95	.95
	1	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97	.96	.97	.97	.96	.97	.97	.97	.97
	2	.98	.98	.98	.97	.98	.98	.98	.98	.98	.98	.98	.97	.98	.98	.98	.98	.97	.97	.97	.96	.98	.98	.98	.98

Appendix 6. Average machine utilization (PCDEV = 0.25)

		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2	UT-M2
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
TBCREA	DFAVPT																								
0	-2	.97	.97	.97	.97	.96	.94	.94	.96	.96	.93	.94	.93	.95	.94	.95	.90	.96	.97	.97	.93	.96	.94	.95	.95
	-1	.97	.97	.97	.97	.96	.92	.93	.95	.96	.92	.93	.92	.95	.93	.93	.89	.96	.96	.96	.93	.96	.93	.93	.94
	0	.95	.95	.95	.96	.95	.91	.92	.94	.95	.91	.92	.91	.94	.92	.93	.88	.94	.94	.94	.91	.95	.92	.92	.94
	1	.88	.88	.88	.88	.87	.86	.87	.87	.87	.86	.87	.87	.88	.87	.87	.86	.86	.86	.86	.84	.88	.86	.87	.88
	2	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.78	.78	.78	.76	.79	.79	.79	.79
4	-2	.97	.97	.97	.97	.97	.96	.96	.96	.96	.95	.96	.95	.96	.95	.95	.94	.97	.97	.97	.96	.97	.96	.96	.96
	-1	.97	.97	.96	.97	.96	.95	.95	.96	.96	.94	.95	.95	.95	.94	.95	.94	.96	.96	.96	.96	.96	.95	.95	.96
	0	.95	.95	.95	.96	.95	.94	.94	.95	.95	.94	.94	.94	.94	.93	.94	.92	.95	.95	.95	.94	.95	.94	.94	.95
	1	.87	.88	.88	.88	.87	.87	.87	.88	.87	.87	.87	.87	.88	.88	.88	.87	.86	.87	.87	.86	.88	.87	.87	.88
	2	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.78	.79	.79	.78	.79	.79	.79	.79

		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3	UT-M3
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
TBCREA	DFAVPT																								
0	-2	.60	.60	.60	.60	.59	.58	.58	.59	.59	.58	.58	.57	.59	.58	.58	.55	.59	.60	.60	.58	.60	.58	.58	.59
	-1	.62	.62	.62	.63	.62	.60	.60	.61	.62	.60	.60	.59	.61	.60	.60	.57	.62	.62	.62	.60	.62	.60	.60	.61
	0	.65	.65	.64	.65	.64	.62	.62	.64	.64	.62	.63	.62	.64	.62	.63	.60	.64	.64	.64	.62	.65	.62	.63	.64
	1	.63	.63	.63	.62	.62	.62	.62	.62	.62	.62	.62	.62	.63	.62	.62	.62	.61	.62	.62	.60	.63	.62	.62	.63
	2	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.59	.59	.59	.57	.60	.60	.60	.60
4	-2	.60	.60	.60	.60	.60	.59	.59	.59	.59	.59	.59	.59	.59	.58	.59	.58	.60	.60	.60	.59	.60	.59	.59	.59
	-1	.62	.62	.62	.63	.62	.61	.61	.62	.62	.61	.61	.61	.62	.61	.61	.60	.62	.62	.62	.62	.62	.61	.61	.62
	0	.64	.64	.64	.65	.64	.64	.64	.64	.64	.64	.64	.64	.64	.63	.64	.63	.64	.64	.64	.64	.65	.64	.64	.64
	1	.63	.63	.63	.62	.62	.62	.62	.62	.62	.62	.62	.62	.63	.62	.62	.63	.62	.62	.62	.62	.63	.63	.63	.63
	2	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.59	.59	.59	.59	.60	.60	.60	.60

		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4	UT-M4
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
TBCREA	DFAVPT																								
0	-2	.58	.58	.58	.59	.58	.56	.57	.58	.58	.56	.57	.56	.57	.56	.57	.54	.58	.58	.58	.56	.58	.57	.57	.57
	-1	.61	.61	.61	.61	.61	.58	.59	.60	.61	.58	.59	.58	.60	.58	.59	.56	.61	.61	.61	.59	.61	.59	.59	.60
	0	.63	.63	.63	.64	.63	.60	.61	.62	.63	.61	.61	.60	.63	.61	.62	.58	.62	.63	.63	.60	.63	.61	.61	.62
	1	.61	.61	.61	.61	.61	.60	.60	.61	.61	.60	.60	.61	.61	.61	.61	.60	.60	.60	.60	.58	.61	.60	.61	.61
	2	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.59	.59	.59	.59	.58	.58	.58	.56	.59	.59	.59	.59
4	-2	.58	.58	.58	.59	.58	.58	.58	.58	.58	.57	.58	.57	.58	.57	.57	.57	.58	.58	.58	.58	.58	.58	.58	.58
	-1	.61	.61	.61	.61	.61	.60	.60	.61	.61	.60	.60	.60	.60	.60	.60	.59	.61	.61	.61	.61	.61	.60	.60	.61
	0	.63	.63	.63	.63	.63	.63	.62	.63	.63	.62	.63	.62	.63	.62	.63	.61	.63	.63	.63	.63	.63	.63	.63	.63
	1	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.60	.61	.61	.60	.61	.61	.61	.61
	2	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.59	.59	.59	.59	.58	.58	.58	.58	.59	.59	.59	.59

		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25	O.-25
		UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5	UT-M5
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
TBCREA	DFAVPT																								
0	-2	.59	.59	.59	.59	.58	.57	.57	.58	.58	.57	.57	.56	.58	.57	.57	.54	.58	.59	.59	.56	.58	.57	.57	.58
	-1	.61	.61	.61	.62	.61	.58	.59	.60	.61	.58	.59	.58	.60	.59	.59	.56	.61	.61	.61	.59	.61	.59	.59	.60
	0	.63	.63	.63	.64	.63	.61	.61	.63	.63	.61	.62	.61	.63	.61	.62	.59	.63	.63	.63	.61	.63	.61	.61	.62
	1	.61	.61	.61	.61	.61	.60	.61	.61	.61	.61	.61	.61	.62	.61	.61	.61	.60	.60	.60	.59	.62	.61	.61	.61
	2	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.58	.58	.58	.56	.59	.59	.59	.59
4	-2	.59	.59	.59	.59	.59	.58	.58	.58	.58	.58	.58	.58	.58	.57	.58	.57	.58	.58	.58	.58	.59	.58	.58	.58
	-1	.61	.61	.61	.62	.61	.60	.60	.61	.61	.60	.60	.60	.60	.60	.60	.59	.61	.61	.61	.61	.61	.60	.60	.61
	0	.63	.63	.63	.64	.63	.63	.62	.63	.63	.62	.63	.62	.63	.62	.63	.61	.63	.63	.63	.63	.63	.63	.63	.63
	1	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61
	2	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.58	.58	.58	.58	.59	.59	.59	.59

TBCREA	DFAVPT	MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6	UT-M6
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
0	-2	.60	.60	.60	.60	.60	.58	.58	.59	.59	.58	.58	.57	.59	.58	.59	.55	.59	.60	.60	.58	.60	.58	.59	.59
	-1	.63	.63	.63	.63	.62	.60	.60	.62	.62	.60	.61	.60	.61	.60	.61	.58	.62	.62	.62	.60	.62	.60	.60	.61
	0	.65	.65	.65	.65	.64	.62	.62	.64	.64	.62	.63	.62	.64	.62	.63	.60	.64	.64	.64	.62	.65	.63	.63	.64
	1	.63	.63	.63	.63	.63	.62	.62	.63	.63	.62	.62	.62	.63	.62	.62	.62	.62	.62	.62	.60	.63	.62	.62	.63
	2	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.59	.59	.59	.57	.60	.60	.60	.60
4	-2	.60	.60	.60	.60	.60	.59	.59	.60	.59	.59	.59	.59	.59	.59	.59	.58	.60	.60	.60	.59	.60	.59	.59	.60
	-1	.63	.63	.63	.63	.62	.61	.61	.62	.62	.61	.62	.61	.62	.61	.61	.61	.62	.62	.62	.62	.62	.61	.62	.62
	0	.65	.65	.65	.65	.64	.64	.64	.65	.64	.64	.64	.64	.64	.64	.64	.63	.64	.65	.65	.64	.65	.64	.64	.65
	1	.63	.63	.63	.63	.63	.63	.62	.63	.63	.62	.62	.63	.63	.63	.63	.63	.62	.62	.62	.62	.63	.63	.63	.63
	2	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.59	.60	.60	.59	.60	.60	.60	.60

		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7	UT-M7
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
TBCREA	DFAVPT																								
0	-2	.60	.60	.60	.60	.59	.58	.58	.59	.59	.57	.58	.57	.58	.57	.58	.55	.59	.59	.59	.57	.59	.58	.58	.59
	-1	.62	.62	.62	.62	.62	.59	.60	.61	.62	.59	.60	.59	.61	.60	.60	.57	.62	.62	.62	.60	.62	.60	.60	.61
	0	.64	.64	.64	.65	.64	.62	.62	.64	.64	.62	.63	.62	.64	.62	.63	.59	.64	.64	.64	.61	.64	.62	.62	.63
	1	.62	.62	.62	.62	.62	.61	.62	.62	.62	.61	.62	.62	.62	.62	.62	.61	.61	.61	.61	.60	.62	.61	.62	.62
	2	.60	.60	.60	.60	.59	.60	.59	.59	.60	.60	.60	.60	.60	.60	.60	.60	.59	.59	.59	.57	.60	.60	.60	.60
4	-2	.59	.59	.59	.60	.59	.59	.59	.59	.59	.58	.59	.58	.59	.58	.59	.58	.59	.59	.59	.59	.59	.59	.59	.59
	-1	.62	.62	.62	.62	.62	.61	.61	.62	.62	.61	.61	.61	.61	.61	.61	.60	.62	.62	.62	.62	.62	.61	.61	.62
	0	.64	.64	.64	.65	.64	.64	.63	.64	.64	.63	.64	.63	.64	.63	.64	.62	.64	.64	.64	.64	.64	.64	.64	.64
	1	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.61	.62	.62	.62	.62
	2	.60	.60	.60	.60	.59	.60	.59	.59	.60	.60	.59	.60	.60	.60	.60	.60	.59	.59	.59	.59	.60	.60	.60	.60

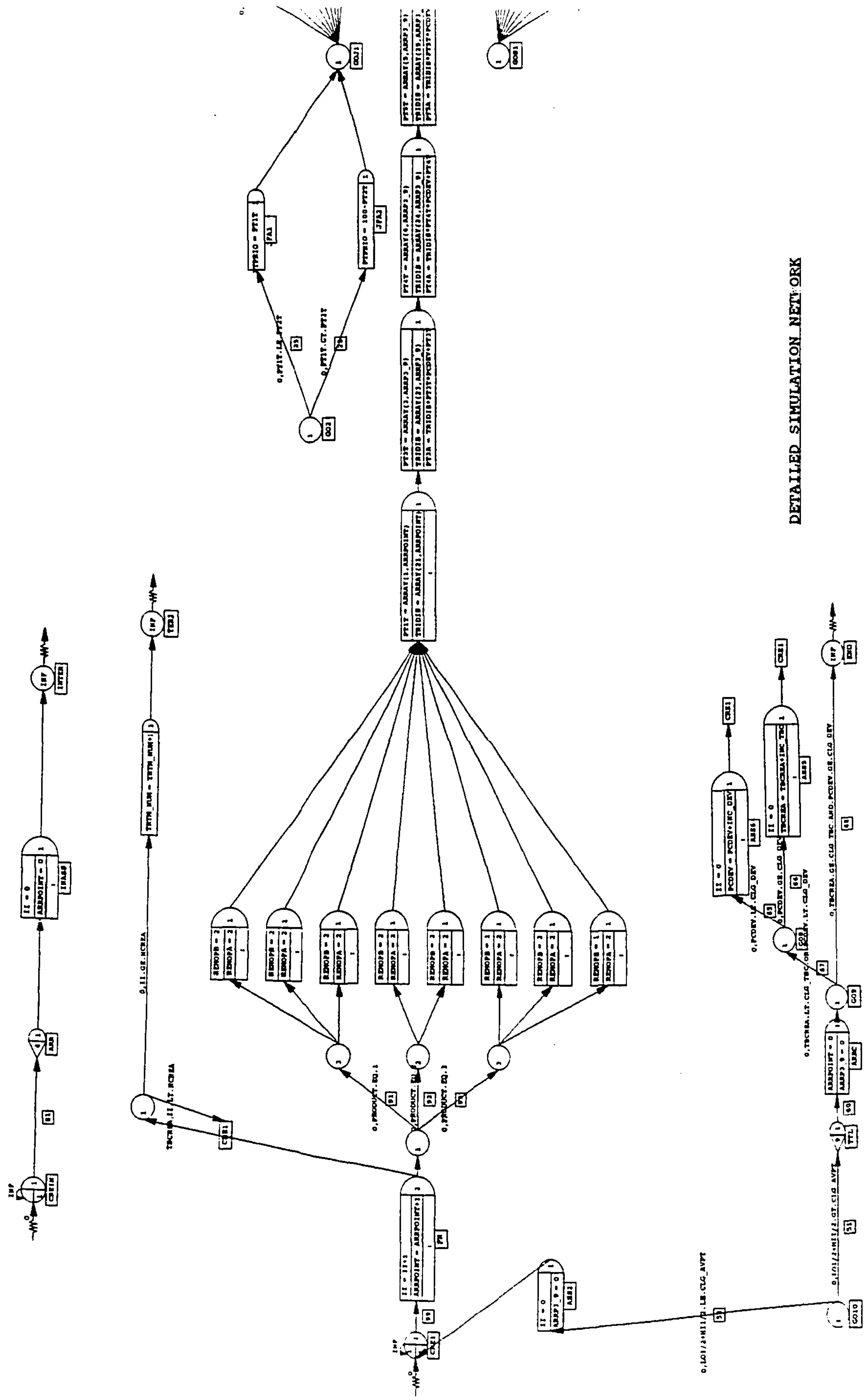
		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8	UT-M8
		ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
TBCREA	DFAVPT																								
0	-2	.59	.59	.59	.59	.59	.57	.57	.58	.58	.57	.58	.57	.58	.57	.58	.55	.59	.59	.59	.57	.59	.58	.58	.58
	-1	.62	.62	.62	.62	.61	.59	.59	.61	.61	.59	.60	.59	.60	.59	.60	.57	.61	.62	.62	.59	.61	.59	.60	.60
	0	.64	.64	.64	.64	.64	.61	.61	.63	.64	.61	.62	.61	.63	.61	.62	.59	.63	.63	.63	.61	.64	.62	.62	.63
	1	.62	.62	.62	.62	.62	.61	.61	.62	.62	.61	.61	.62	.62	.61	.62	.61	.61	.61	.61	.59	.62	.61	.61	.62
	2	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.58	.58	.58	.57	.59	.59	.59	.59
4	-2	.59	.59	.59	.59	.59	.58	.58	.59	.59	.58	.58	.58	.58	.58	.58	.58	.59	.59	.59	.59	.59	.58	.58	.59
	-1	.62	.62	.62	.62	.62	.61	.61	.62	.61	.60	.61	.61	.61	.60	.61	.60	.62	.61	.61	.61	.61	.60	.61	.61
	0	.64	.64	.64	.64	.63	.63	.63	.64	.64	.63	.63	.63	.63	.63	.63	.62	.63	.64	.64	.63	.64	.63	.63	.64
	1	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.61	.61	.61	.61	.62	.62	.62	.62
	2	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.59	.58	.59	.59	.59	.59

		MODEL																							
		11	12	13	14	21	22	23	24	31	32	33	34	41	42	43	44	51	52	53	54	61	62	63	64
		PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV	PC-DEV
		0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25	0.-25
		UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9	UT-M9
TBCREA	DFAVPT	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN	ME-AN
0	-2	.58	.58	.58	.59	.58	.56	.57	.58	.58	.56	.57	.56	.57	.56	.57	.54	.58	.58	.58	.56	.58	.57	.57	.57
	-1	.61	.61	.61	.61	.61	.58	.59	.60	.60	.58	.59	.58	.60	.58	.59	.56	.61	.61	.61	.58	.61	.59	.59	.60
	0	.63	.63	.63	.63	.63	.60	.61	.62	.63	.61	.61	.60	.63	.61	.61	.58	.62	.63	.63	.60	.63	.61	.61	.62
	1	.61	.61	.61	.61	.61	.60	.60	.61	.61	.60	.60	.61	.61	.61	.61	.60	.60	.60	.60	.58	.61	.60	.61	.61
	2	.58	.58	.58	.58	.58	.59	.58	.58	.58	.58	.58	.58	.59	.59	.59	.58	.58	.58	.58	.56	.59	.59	.59	.58
4	-2	.58	.58	.58	.59	.58	.58	.58	.58	.58	.57	.58	.57	.58	.57	.57	.57	.58	.58	.58	.58	.58	.57	.58	.58
	-1	.61	.61	.61	.61	.61	.60	.60	.61	.60	.59	.60	.60	.60	.59	.60	.59	.61	.61	.61	.60	.61	.60	.60	.61
	0	.63	.63	.63	.63	.63	.62	.62	.63	.63	.62	.63	.62	.63	.62	.63	.61	.63	.63	.63	.62	.63	.62	.63	.63
	1	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.61	.60	.61	.61	.60	.61	.61	.61	.61
	2	.58	.58	.58	.58	.58	.59	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58	.58

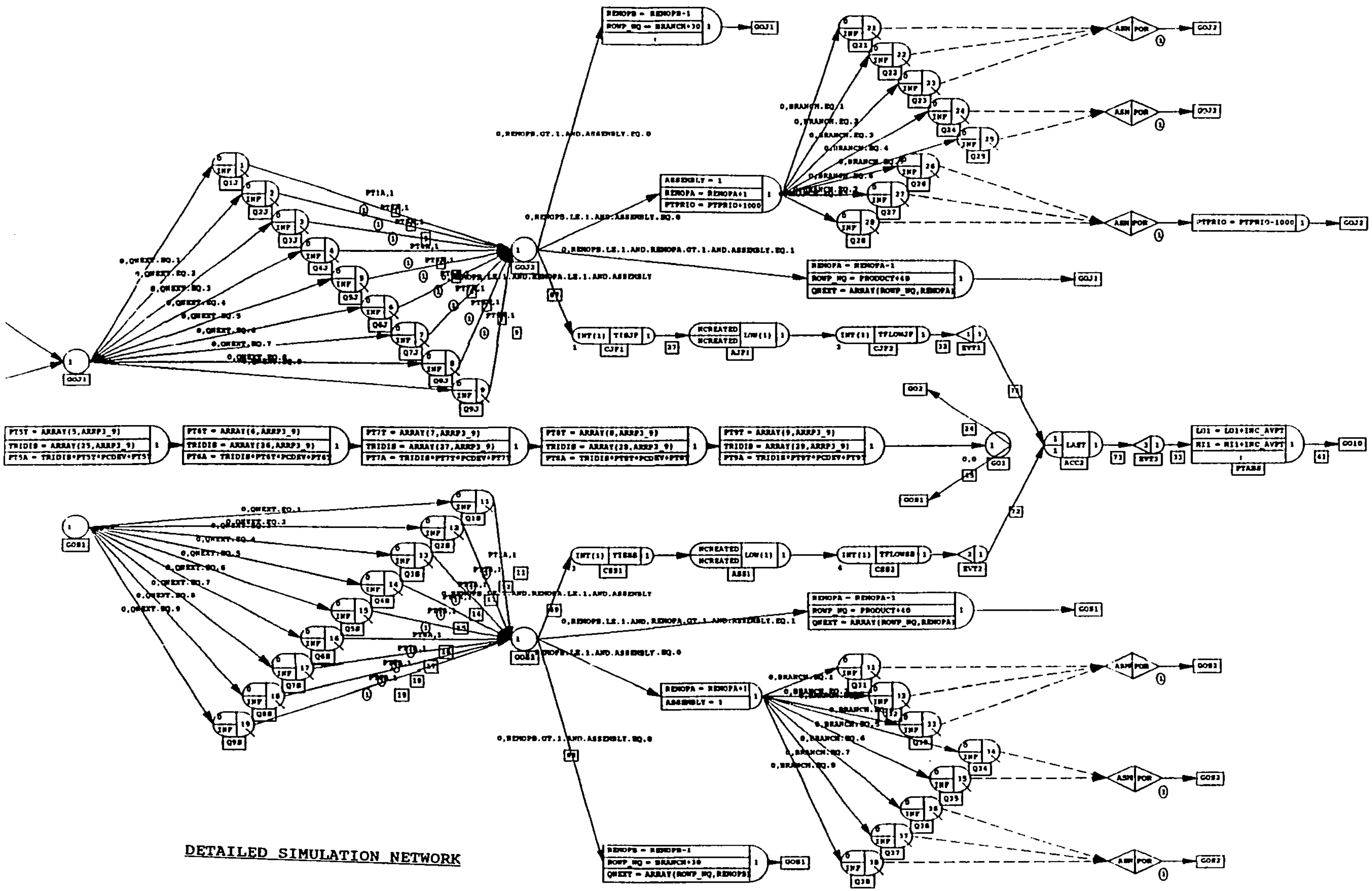
```
                    Interactive Statistical Programs
                           Basic Statistics
                           Test Hypothesis

Compute the sample statistics from a variable in your spreadsheet ?  Yes
Which column do you want to use ? 9
Enter the population mean from the null hypothesis : 0
Do you want :   A Two-tailed test
Do you want an alpha (TYPE I error) of :    .05

                              S-JSLOPE
Sample size:                        20
Sample mean:                  4.292488
Sample standard deviation:    14.38029

The sample evidence suggests that the null hypothesis
that the population mean is  .0000000     can be accepted.

The computed t-value is  +1.335           The corresponding p-value is  .1977

The critical t-values are  -2.093 and   +2.093
```

```
                    Interactive Statistical Programs
                           Basic Statistics
                           Test Hypothesis

Compute the sample statistics from a variable in your spreadsheet ?  Yes
Which column do you want to use ? S-JSLOPE
Enter the population mean from the null hypothesis : 0
Do you want :   A Two-tailed test
Do you want an alpha (TYPE I error) of :    .05

                              S-JSLOPE
Sample size:                        20
Sample mean:                  6.457565
Sample standard deviation:    14.54660

The sample evidence suggests that the null hypothesis
that the population mean is  .0000000     can be accepted.

The computed t-value is  +1.985           The corresponding p-value is  .0617

The critical t-values are  -2.093 and   +2.093
```

Appendix 7. Results of the slope interaction test



DETAILED SIMULATION NETWORK



DETAILED SIMULATION NETWORK