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Simulated annealing algorithm applied in the flexible manufacturing systems design

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Simulated annealing algorithm

applied in the flexible manufacturing systems design

by

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

v

LIST OF TABLES

CHAPTER I INTRODUCTION

Manufacturing firms today operate in an increasing
turbulent environment. Shorter product life cycles, an
increase in the number of new products introduced, fragmented
markets, rapid technological change, unexpected competitors,
and fluctuating demand create an extremely dynamic environment
in which firms face a great deal of uncertainty [McDougall and
Noori 1986].

Therefore, it's becoming increasingly difficult for firms
to identify and maintain long-term competitive advantage in
today's turbulent environment. The competition forces firms
to create products with higher quality, less expensively, and
more quickly than the competitors. It appears that future
successful firms will be those that can respond quickly to
changes in the global market requirements.

Consequently, the ability to respond quickly to changing
market requirements is becoming much more important. Flexible
manufacturing systems (FMS) provide an opportunity to adjust
to these market changes.

FMS is an evolving technology particularly suited for
mid-volume, mid-variety manufacturing. A defining feature of
FMS is the ability to run small batches of parts efficiently
with low set-up times which can reduce lead time by 50-75%
[Ranky 1983]. It was developed to fill a void between job

shop and transfer line production. Job shops are found to be inefficient and costly due to large set-up time requirements, high work in process (WIP) inventories and long lead times. On the other hand, hard automation technologies, such as transfer lines reduce inventories and are highly balanced. However, they have proved to be unsuitable for mid-volume, mid-variety manufacturing because of their inflexibility. In addition, a group of expediters are required for traditional batch manufacturing methods to keep jobs flowing through the shop and to reduce set-up time. Consequently, FMSs are well suited for batch production at medium volumes (200 - 20,000 units/year) and medium number of parts (between 10 and 200 part types).

An FMS is a fully integrated manufacturing system consisting of computer numerically controlled (CNC) machines connected by conveyors or automated guided vehicles (AGVs) controlled by a central computer [Nandkeolyar 1988]. The optimal design of an FMS is a very complex problem. This is because it is a highly integrated manufacturing system and inter-relationships between its various components are not well understood [Goldhar and Jelinek 1985]. Inappropriate use of an FMS represents a potential problem area.

Regardless of the technique used to justify an FMS, the question of designing an optimal FMS for a given set of product remains. Successful adoption of an FMS proceeds in

broad stages - design, implementation, and operation. The potential for reducing cost is the highest during the design phase. This research will outline the development of a technique using computer simulation and a search procedure called simulated annealing to optimally design an FMS, based upon a chosen performance measure.

Computer simulation is a widely used numerical modelling technique for the analysis of complex systems such as FMSs. However, simulation is an evaluative technique; that is, it provides an accurate estimate of performance for a given set of decisions. To search for an optimal set of decisions, a search procedure, (i.e., a procedure that generates alternate sets of decisions) is required. One such generative procedure is the simulated annealing algorithm [Hajek 1985; Mitra et al. 1986].

The simulated annealing algorithm is a randomized algorithm which searches for the globally optimum configurations of combinatorial optimization problems whose objective functional value may have many local optima. However, for the algorithm to work, it must be possible to evaluate the function deterministically. Any measure obtained from simulation experiments is a stochastic variable. Consequently, the simulated annealing algorithm must be modified to allow for the stochastic nature of the function being optimized.

In this research, a modified version of simulated annealing is developed. A simulation model representing an FMS is interfaced with the modified simulated annealing algorithm to search for an optimal design.

CHAPTER II LITERATURE REVIEW

2.1 Flexible Manufacturing Systems (FMS)

2.1.1 Introduction

A flexible manufacturing system is a fully integrated manufacturing system consisting of computer numerically controlled machines connected by conveyors or AGVs controlled by a central computer. The CNC machine with large tool magazines is flexible and it is feasible to produce many different parts in small batches. The details on the CNC machine tools are provided in Talavage and Hannom [1988].

The material handling systems (MHS), such as conveyors or AGVs, move parts/ pallets among the work stations. The interface between the machines and MHS is made possible by the turrets and loading/unloading stations. The MHS is controlled by the central computer and generally supports routing flexibility.

The central computer reduces the need for humans to monitor the system and provides continuous feedback on the state of the system. Its functions include managing the circulation of parts and tools, monitoring tool wear, routing of parts, fault detection of the system and coordination of subsystems.

These systems have been found to be most suitable for

mid-volume mid-variety manufacturing. It's desirable to have
a flexible and efficient manufacturing system. The power of
today's computer technology makes this possible through the
use of FMS.

Flexibility in the sense of a manufacturing system
implies the ability to cope with uncertainty. Browne et al.
[1984] define eight types of flexibility:

Machine: ease of change to process a given set of part
types.

Process: ability to process a given set of part types in
several ways.

Product: ability to change to process new part types
economically and quickly.

Routing: ability to process a given set of parts on
alternative machines.

Volume: ability to operate profitably at varying overall
production volumes.

Expansion: ability to easily add capability and capacity.

Operation: ability to interchange ordering of operation
on a part.

Production: the universe of part types that can be
processed.

They also discuss the benefits that may be obtained from this
flexibility. Similar definitions of the types of flexibility
are presented by McDougall and Noori [1986].

Flexibility is a very important factor in FMS. To
achieve flexibility, an FMS requires flexible machines and a
flexible material handling system. One of the questions that
arises during design of an FMS concerns the choice of the

degree of flexibility to be provided at each individual machine. Too much flexibility will result in high initial capital outlays, thus increasing investment and possibly cost. Conversely, too little flexibility may, for example, result in the FMS being restricted to producing only a limited number of products, using a limited number of processes at certain levels of operation speed with limited options for future expansion.

The flexibility afforded by an FMS increase its operating capabilities. The operating capabilities of an FMS have been summarized by Goldhar and Jelinek [1985]. They point out that the levels of performance are not easily achieved since the effect of and interaction among the FMS design parameters are not well understood.

Problems associated with FMSs can be classified as planning, scheduling, control and design [Stecke 1985]. FMS planning problems include the determination of which parts should be simultaneously machined, the optimal partition of machine tools into groups, allocation of pallets and fixtures to part types, and the assignment of operations and associated cutting tools among the limited capacity tool magazines of machine tools. In other words, FMS planning problems can be defined to be those decisions that have to be made before the FMS can begin to produce parts.

FMS scheduling problems, on the other hand, are those

concerned with running the system and scheduling the flow parts throughout the FMS. This includes the optimal input sequence of parts and an optimal sequence at each machine tool given the current part mix.

FMS control problems are those associated with continuous monitoring of the system, keeping track of production to be certain that production requirements and due dates are being met as scheduled, and that reliability problems are handled.

In order to better understand the operation of an FMS, numerous studies have been conducted. These studies cover the areas of production planning [Ahamadi and Ali 1986; Chakravarty and Shtub 1986], shop scheduling [Schriber and Stecke 1986; Gershwin 1986; Ammons et al. 1986; Seidmann and Tenebaum 1986], Lot sizing [Chang and Sullivan 1986], FMS scheduling [Reynolds and McMahon 1987], and FMS planning, scheduling and control [Kusiak 1986a].

In addition to these problems, part of the FMS design problem has also been researched. The design problem is the subject of this research and is discussed in detail below.

2.1.2 FMS Design Problem

As mentioned in the previous section, the benefits offered by FMS (i.e., short lead time, low WIP, shorter product life cycle, etc.) are difficult to achieve due to their complexity and interconnection of their components. The

design phase offers the greatest possibilities for reducing costs. Proper design of an FMS is, therefore, a critical step to successful implementation and achievement of FMS goals. [Ahmad and Farrah 1986] describe the specific goals of FMS in a great detail. These goals include shortening product life cycles, producing high quality products, providing efficient automated mass production, increasing productivity, being open to new products, providing a design environment to facilitate product (changes) engineering, responsive to increased product complexity, provide flexibility, effective material handling system, and effective monitoring.

Buzacott and Yao [1986] enumerate a number of issues related to FMS design. They categorize the FMS design process into two hierarchical levels: establishing the basic design and the detailed design. The basic design includes issues such as the number and capacity of machines, the size and location of inventory banks (buffers), the number of pallets and fixtures, and the type and capacity of material handling facilities. During the detailed design the emphasis is on the system operation, processing requirements and resources, such as required equipment.

Stecke [1986] partitions the FMS design problem into two hierarchical stages: initial specification and subsequent implementation decisions. Initial specification decisions cover determination of the range of part types to be produced,

manufacturing process, specification of the types of
flexibility, the type of FMS (cells or flow line),
specification of the type and capacity of the material
handling system (i.e., conveyors or AGVs), specification of
the type and size of buffers, specification of the computer
system, and selection of vendors. Implementation issues
involve: determination of the FMS layout, determination of
the number of pallets, design of fixtures, determination of
the number of fixtures, specification of operation strategies
for the FMS, and software development.

Other classification schemes of the FMS design problem
have been reported [Aspahl 1985; Kumar 1985; Ranky 1985].
Though not identical, each of these is similar to the scheme
presented by Stecke [1986].

The keyword in FMS is system. The optimal specification
of individual components considered separately will not,
generally, result in an optimal FMS [Kalkunte et al. 1986].
An FMS takes advantages of the flexibility of its components
in synergistic fashion [Aspahl 1985]. Consequently, the FMS
must be designed as a system.

Finally, the process of design is not a one time only
process. Jablonowsky [1985] found that an FMS is an evolving
system. He reports that changes in work pieces, tooling
technology, system control software, and human attitude
towards unattended manufacturing continuously occur and affect

the FMS systems.

In this research, the basic design problem is considered. Given a set of parts to be produced, a methodology to obtain the best basic design is developed. This involves the development of a measure of performance, a modelling technique, and an optimization method.

2.1.3 Measure of Performance

Due to the large investment involved in FMS, it is very important to determine not only if an FMS should be employed in a particular case, but also the best configuration of the FMS to achieve its full potential. The literature on FMS offers very little information pertaining to the evaluation of alternative FMS designs. One set of studies has proposed performance criteria which must be optimized with respect to certain characteristics.

Suri [1984] presents some typical measures of performance used to evaluate an FMS. The performance measures presented are utilization, production rate, work in process (WIP), part flow times, queue at each resource, flexibility, payback period, return on investment, and net present value. The most commonly used performance measures have been throughput or production rate [Solberg 1977; Suri and Hildebrant 1984; Buzacott and Shanthikumar 1980; Cheng 1985]. Other system performance measures like mean flow time [Suri and Hildebrant

1984; Buzacott and Shanthikumar 1980; ElMaraghy and Ho 1982; Buzacott and Gupta 1986], and facilities utilization [Suri and Hildebrant 1984; Buzacott and Shanthikumar 1980; Buzacott and Gupta 1986], have also been used.

Economic measures such as costs based upon technology progress and financial parameters (interest rate), internal (WIP) and external (product life cycles) parameters have been used. [Yao 1986; Newman 1986; Dallery and Frein 1986] use these economic measures to determine appropriate designs. However, these analyses do not address the problems associated with the inability of conventional accounting systems to capture benefits from flexibility and synergy [Nandkeolyar 1988].

Miltenburg and Krinsky [1987] propose a methodology for selecting a number of FMS designs. They propose the use of the annuity equivalent of cash flows as the correct financial criterion. The use of the discount rate based financial measures presents two problems. First, the discount rate is assumed to be a constant rate over the life of the project. Second, the problem of specification of opportunity cost has to be resolved.

Throughput or production rate is the most widely used system performance measure for an FMS. Researchers have attempted to maximize production rate or utilization while making changes in the FMS structure, its operation conditions,

or combination of the two [Azadivar and Lee 1986; Liu and Sanders 1986; Dallery and Frein 1986]. These measures are suitable for optimizing the performance of a particular FMS. In the design problems, these measures may present a difficulty in that an arbitrarily large FMS could be designed to maximized throughput rate. However, constraints on factors like investment and plant size are always carefully considered in the FMS design phase. Therefore, production rate can also be reliable to measure the performance of a particular FMS design. In this research production rate will be the performance measure utilized.

2.1.4 FMS Modelling Techniques

An FMS is extremely complex. Thus it is not likely that a single model can be used to describe its behavior completely. In general, the models used to evaluate FMS performance can be divided into 2 categories: analytical models and non-analytical models.

Analytical models such as queuing models, network analysis, mathematical programming models, mean value analysis, and petri nets provide considerable insights. But these approaches usually consider only a subset of the decision parameters, are generally limited by their inability to capture the complex nature of FMSs, and depend on a large number of simplifying assumptions [Nandkeolyar 1988]. The

results obtained can, however, be generalized

Non-analytical models such as simulation, perturbation analysis, and expert system/artificial intelligence can be more detailed, incorporate a number of stochastic processes, and produce accurate estimates. Results obtained from these models are usually valid only for the system modelled. Therefore, they suffer from not being easily generalized [Nandkeolyar 1988].

2.1.4.1 Analytical Models   Some excellent reviews of the analytical models used in the FMS design problem are provided by Buzacott and Yao [1986], Kalakunte et al. [1986], and Looveren et al. [1986]. Buzacott and Yao [1986] observe that an FMS is extremely complex so that analytical models always address a small subset of design issues.

Network analysis   Network analysis has been extensively used to analytically model FMSs. Suri and Hilderbrant [1984] developed the concept of mean value analysis (MVA) for FMSs. This procedure uses the estimate of mean value of the queues in a network to aid decision making.

Buzacott and shanthikumar [1980] used a Jackson queuing network to show that, in general, capacity depends on the expected number of visits to a particular machine and not on the routing of parts, and is maximized when parts are selected such that it leads to a job shop structure, and minimized in

the case of a flow shop structure. They also claim that central storage is better than local storage, and balancing of the work load may not be an optimal strategy under certain circumstances.

Solberg [1980] developed a computer program called CAN-Q using a closed queuing network model of an FMS developed by Posner and Berbholtz [1968] to study the effect of a number of decision variables on performance measures like utilization, queue lengths, and throughput rates. CAN-Q allows a user to specify FMS design parameters such as number and type of machines, number of parts, sequence of operations, processing and set-up times, and transportation times. The output includes station utilization, queue lengths at each station, throughput rates, mean flow times, part transit time, and queue times. The model, however, is limited by the assumptions inherent in the general closed network models. It does not allow the modelling of random arrivals, central storage, machine blocking, and interaction among transporters. Consequently, the model is limited to the rough-cut design of FMSs [Suri 1987].

Mathematical programming   A number of authors have proposed methods to design an FMS using mathematical programming even though their application has been limited due to the complexity of the problem. Hildebrandt and Suri [1980] used mathematical programming for scheduling and real time

control of the FMS. Kimemia and Gershwin [1979] used a non-linear programming approach to select the routing plans of parts to maximize production output.

Stecke and Kim [1986] used integer programming to optimally determine the part types to be machined together and the product mix for a short time horizon. The formulation attempts to minimize load imbalance subject to technological constraints.

Yao [1986] uses concepts of inventory planning to determine the optimal storage requirements for an FMS. Yao and Shanthikumat [1986] develop an algorithm to optimally allocate buffer spaces, machines, and production capacity among various cells in a multi-level manufacturing facility.

2.1.4.2 Non-analytical Models   Several non-analytical models have been used to model FMSs. The most commonly used technique has been computer simulation. Recently, perturbation analysis, and expert systems/artificial intelligence concepts have also been applied.

Perturbation analysis   Perturbation analysis is an efficient technique to study complex systems. Perturbation analysis enables very efficient optimization of parameters in simulation, thus reducing simulation time drastically. The basic idea is to estimate the gradient vector of system output with respect to a number of parameters by observing only one

sample or simulation run [Looveren et al. 1986]. It not only evaluates decisions but also suggests direction for improving these decisions. A detailed discussion on perturbation analysis can be found in Suri and Cao [1982], and Ho [1984].

Suri and Dille [1986] discuss the application of this technique to the FMS design problem. They use this technique to determine the relationship of performance measures of FMS with the change in parameter values. They found that the results of perturbation analysis matched closely with those obtained from experiments conducted using the desired parameter values. However, the results are generally valid for small changes in parameters. Furthermore, this technique does not capture interaction effects between parameters so that if significant interaction between parameters exists, and more than one parameter change is contemplated, perturbation analysis may not provide accurate results.

<u>Artificial intelligence</u>   The recent development of Artificial intelligence based expert simulation systems hold a lot of future promise. Shannon [1984] conceptualizes an expert simulation system for manufacturing. The integration of all these developments offer interesting prospects for future generic FMS simulators.

Several research papers have addressed the FMS scheduling problem using expert system/ artificial intelligence approaches [Thesen and Lei 1986; Lin and Chung 1986; Shen and

Chang 1986; Subramanyam and Askin 1986]

Mellichamp and Wahab [1987] among others have developed an expert system/ artificial intelligence technique to optimally design an FMS. A simulation model used to estimate performance is interfaced with the expert system. Based on certain rules and data passed from the model, the expert system modifies the simulation model. Fresh results are obtained and the process is repeated until an optimal design is reached or no solution can be found.

<u>Computer simulation</u>   Computer simulation has been a widely used technique for modelling complex systems such as manufacturing systems. Accurate estimates can be obtained for a number of performance measures in a complex system [Suri and Hildebrant 1984]. However, simulation takes considerable time to develop, requires a large amount of input data, and requires simulation expertise. This is because in order to obtain useful results from simulation, the model must be developed and validated carefully. Much greater detail can be employed in simulation models, whereas other forms of modelling require aggregation of information [Nandkeolyar 1988]. Furthermore, simulation allows the dynamic analysis of the system. This is very important because the status of an FMS changes over time [Ranky 1983]. In recent years this task has been eased by the development of simulation languages such as GPSS, GASP, SLAM, and SIMAN.

Simulation has been used successfully to determine the sequencing structure, conveyor speed, number of pallets in an FMS, scheduling rules, and as a tool to improve queuing network results. Simulation provides some benefits to its users. These include less initial investment, shorter planning time, lower probability of unanticipated expenditures, the potential of higher system efficiency and the ability to experiment on a system without any disturbance to the real system [Warnecke et al. 1986].

Jain and Foley [1986] propose design criteria and features for a generic FMS simulator. Useful features include transparency of model details, user friendly input interface, capability for real-time control, facility to interface a real time scheduler, flexibility for level of detail, statistical analysis capability, and graphical animation. In order to achieve these, a modular structure with a detailed description of all the modules is required for a generic FMS simulator.

In this research, the simulation model technique is used due to its ability to model most of the complexity of an FMS.

2.1.5 Optimization Techniques

Suri [1985] specifically divides FMS design models into two categories: evaluative (descriptive) model and generative (prescriptive) model. The evaluative models provide estimates of performance based on a set of decisions, allowing the

designer to consider many possible alternatives. Evaluative
tools include queuing models and simulation as explained in
the previous section.

Generative models, on the other hand, analyze complex
systems and find candidate decision which improve the current
solution. Generative tools are considered to be the various
search procedures (optimization techniques) which have been
used by researchers to identify an optimal design.

The most commonly used approach is a user interactive
computer program [Nandkeolyar 1988]. Both CAN-Q [Solberg
1980] and MVAQ [Suri and Hilderbrant 1984] utilize user
interfaces to search for optimal designs. The system
evaluates the effect of certain changes to design parameters,
returns the evaluation to the user and requests changes.

Chakravarty and Shtub [1986] adopt a dynamic programming
approach to search for an optimal integration policy for
different types of robots in flexible manufacturing systems.

Mellchamp and Wahab [1987] develop a rule based expert
system which searches for an optimal design based on multiple
criteria.

Azadivar and Lee [1986] use the concepts of integer
complex search to determine the optimal number of buffer
spaces in an FMS. Newman [1986] utilizes a full factorial
statistical design spanning the range of feasible options to
identify the optimum flexibility and number of fixtures in an

FMS.

Nandkeolyar and Christy [1989] interface a computer simulation model of an FMS with the modified version of Hooke-Jeeves algorithm to search for an optimum design without full factorial experimentation.

A new analytical procedure to search for optimal solutions to complex problems is the simulated annealing algorithm. This algorithm has been successfully implemented for various deterministic optimization problems. In the FMS design optimization problems, this is not so. The value of the response (performance measures) is a stochastic variable, dependent on the string of random events that may affect the system [Nandkeolyar 1988]. This complication will require some modifications to the algorithm to extend the application of the algorithm to stochastic systems such as an FMS.

2.2 Simulated Annealing Algorithm

2.2.1 Overview

Simulated annealing is a randomized algorithm to search for the globally optimum configurations in combinatorial optimization problems whose objective functional values may have many local optima. This optimization method has received a great deal of attention from researchers since it was presented by Kirkpatrick et al. [1983]. It was successfully implemented for various deterministic optimization problems and proofs of convergence for deterministic optimization cases are provided in Hajek [1985], and Mitra et al. [1986].

The name simulated annealing has been proffered because of a deep and useful connection between statistical mechanics and multivariate or combinatorial optimization (finding the optimum value of a given function depending on many parameters). The name comes from an analogous procedure in statistical mechanics in which experiments that determine the low-temperature state of a material (i.e., by growing a single crystal from a melt) are done by careful annealing: first melting the substance, then lowering the temperature slowly, and spending a long time at a temperature in the vicinity of the freezing point. In addition, a control technique is utilized in a manner similar to the Metropolis procedure, as described below, in order to allow the process to escape local

optimum points.

The simulated annealing procedure will allow the process to accept a configuration that results in a higher objective functional value for minimization problems or a lower value for maximization problems. However, the probability of accepting a worse configuration decreases with time as the temperature is lowered. At each iteration, the present configuration is compared with a randomly generated configuration. If the objective functional value of the new configuration is less than the present value for minimization problems, then the new configuration is accepted. Otherwise, the acceptance of the new configuration is based upon the Metropolis procedure in which a random number generated uniformly over the interval [0,1] is compared to the probability of accepting the configuration, $P(c_j)$, defined as:

$$P(C_j) = \exp^{\frac{-ABS(C_j - C_i)}{T_m}} \qquad (1)$$

where: C_j: Objective functional value of new configuration
C_i: Objective functional value of present configuration
T_m: the controlling parameter, temperature, at iteration m.
m: time, m = 1,2,...

If the random number is less than $P(C_j)$, than the new configuration is accepted. Otherwise, it will be discarded and the present configuration is used to start the next

iteration. In either case the time is incremented and the controlling parameter, temperature, is updated. The process is started with a large temperature and the value of the temperature is decreased at each iteration. Thus, the value of $P(C_j)$ is also lowered as the process continues. The speed of the algorithm and the quality of the final configuration depend upon the initial temperature, the amount of time spent at each temperature, and the speed at which the temperature is decreased.

2.2.2 Previous Work

This section describes some of the research previously done concerning optimization by simulated annealing.

Kirkpatrick, Gelatt, and Vecchi [1983] introduce optimization by simulated annealing. They describe in great detail the analogy between annealing in solids and multivariate combinatorial optimization which provides a framework for optimization of the properties of large and complex systems. They show how the Metropolis procedure from statistical mechanics provides a natural tool for bringing the techniques of statistical mechanics to bear on optimization. Implementation of the simulated annealing algorithm is also discussed. The examples of various optimization problems provided are all very complex and difficult to solve due to their sizes. Those problems include the physical design of a

computer and the travelling salesman problem. They conclude that good quality solutions to the above problem types are attainable with the simulated annealing algorithm. Encouraged by these results, they hypothesized the fruitfulness of a wide application of this heuristic technique to other combinatorial optimization problems.

Vecchi and Kirkpatrick [1983] applied simulated annealing to global wire routing for both idealized (synthetic) and actual designs of realistic size and complexity. The experimental results show that simulated annealing performs favorably when compared to other conventional heuristic techniques for solution of combinatorial optimization problems. Hence, they use them as a standard against which to compare several sequential or greedy strategies commonly employed in automated wiring program.

Wilhelm and Ward [1987] apply the simulated annealing method to solve the quadratic assignment problem (QAP). The performance is tested on a set of "standard" problems, as well as some newly generated larger problems (n=50 and n=100). The results of simulated annealing are compared to those from a revised Hillier procedure. They conclude that under certain circumstances, simulated annealing can yield higher quality solutions at comparable CPU times.

Mitra, Romes, and Sangiovanni-Vincentelly [1986] present a theoretical analysis of simulated annealing based on its

precise model, a time-inhomogeneous Markov Chain. An annealing schedule is given for which the Markov Chain is strongly ergodic and the algorithm converges to a global optimum. They analyze the finite-time behavior of simulated annealing and obtain a bound on the departure of the probability distribution of the state at finite time from the optimum. This bound gives an estimate of the rate of convergence and insights into the conditions on the annealing schedule which gives optimum performance.

Hajek [1988] establishes cooling schedules for optimal annealing. He describes that the simulated annealing is a randomized algorithm where the level of randomization is determined by a control parameter T called temperature which tends to zero according to a deterministic "cooling schedule". He gives a simple necessary and sufficient condition on the cooling schedule for the algorithm state to converge in the set of globally minimum value states.

Sasaki and Hajek [1986] use simulated annealing to find maximum cardinality matchings in polynomial average time.

Bulgak and Sanders 1988] present a modified version of the simulated annealing algorithm in an attempt to extend its application to the domain of Monte Carlo optimization. They integrate the extension of the simulated annealing algorithm used in combinatorial optimization with a discrete event simulation of a manufacturing system to find optimal buffer

sizes for asynchronous assembly systems, which involves automated inspection as well as automated assembly. They conclude that even though the original convergence proofs do not apply to applications of simulated annealing for the optimization of stochastic systems, the simulated annealing algorithm has the potential to provide "good" solutions of not only deterministic but also stochastic combinatorial optimization problems.

Gemmill and Sanders [1988] modify the original simulated annealing algorithm to incorporate the algorithm in stochastic environments. They use the new version of the simulated annealing method to determine the best combination of sheets to stock in inventory in order to minimize material wastage given that the bill of material is random (portfolio problem). The simulated annealing results are compared with two other approaches: stochastic quasigradient methods and optimization homotopy.

2.3 Summary

The FMS design problem is an important problem that must be solved optimally because of the large investments required, and the risks in the environment. The FMS design problem may consist of determining the number and type of FMS required, and the capacity and the type of buffers for a given set of parts to be produced.

In order to solve this problem, a carefully considered measure of performance, a modelling technique for the FMS, and an optimization procedure must be selected and developed.

Several techniques have been used to model FMSs. Computer simulation is a powerful technique that can model most of the complexities of an FMS with fewer simplifying assumptions. This is essential to the FMS design problem because of the interaction among the components of an FMS.

The simulated annealing algorithm is proposed to be used to search for the optimal design because it has a potential to search for the global optimum. Since FMS is a stochastic system, some modification of the algorithm is required to adapt the algorithm into the stochastic environment.

In this research, an appropriate measure of performance, is proposed. This set of choices of performance measure, modelling technique, and optimization technique produce an iterative process to determine an optimal FMS design.

CHAPTER III   MODIFIED SIMULATED ANNEALING ALGORITHM

As mentioned in the previous chapter, simulated annealing is a randomized algorithm which has been developed for deterministic multivariate combinatorial optimization problems and it proved to be a useful and reasonably general purpose tool for deterministic combinatorial problems. As with many other general purpose tools, its efficiency is not always as great as one might hope. But, it does provide a general purpose approach for a wide class of difficult problems. Unfortunately, most of the real-world optimization problems are stochastic and the original convergence proofs do not apply to the applications of the simulated annealing algorithm for the optimization of stochastic systems. Therefore, some modifications are necessary in the simulated annealing algorithm to adapt it to the stochastic environment.

The modified version of the simulated annealing algorithm is provided in Figure 1 and the following notations will be used:

j : iteration number.
J_{max}: Maximum number of iteration.
T_j : Temperature value at iteration j.
X_j : Value of decision variable at iteration j.
X^0 : Current best value of the decision variable.
M_{xjR}: Statistical estimated mean of the objective function $F(x)$, estimated by discrete event simulation at X_j and based on r replications.
V_{xjR}: Statistical estimate of variance of the objective function, $F(x)$, estimated by discrete event simulation at X_j and based on r replications.

$CI_{x_{jr}}$: Confidence interval of the objective function, $F(x)$.
c   : Constant which is greater or equal to the height of the
         highest local maximum which is not a global maximum/
         minimum state.
N   : Maximum number of replications.
$N(X^0)$: The set of all possible neighboring configurations of X^0

The basic ideas in the modified version of simulated
annealing are to make the comparisons based on whether or not
the values of the objective functions indicate statistically
significant differences at each iteration and to determine the
stopping criteria.

The differences between the objective functional values
are decided to be statistically significant or not based on
the confidence interval (CI) set for these values. Each
confidence interval is set based on a minimum of 3
replications of the discrete event simulation. If the current
value of the objective function is in the confidence interval
set for this value, one more simulation replication is
conducted, the confidence interval is updated, and another
comparison is made. This process is repeated until the
present and previous value of the objective function are found
to have a statistically significant difference (the present
optimum value of Objective function falls outside the CI) or a
maximum number of replications is achieved. If they do not
have a significant difference, the iteration is ignored, the

Determine X_J
Assign $X^\theta = X_J$, &
Set J=0

Compute $M_{X^\theta_{JR}}$

Simulation
with X^θ, J=0,
and R=N

E

Generate another
X_J and $X_J \in N(X^\theta)$

Simulation
with X_J at J
and R=3

Compute $M_{X_{JR}}$
and $CI_{X_{JR}}$

Interval
$$\left[M_{X_{JR}} - (t\alpha/2, R-1)\sqrt{U_{X_{JR}}} / \sqrt{R} \, , \right.$$
$$\left. M_{X_{JR}} + (t\alpha/2, R-1)\sqrt{U_{X_{JR}}} / \sqrt{R} \, \right]$$

Max.
$M_{X_{JR}} > M_{X^\theta_{JR}}$
$M_{X_{JR}} < M_{X^\theta_{JR}}$
Min.

Yes

Accept X_J
$M_{X^\theta_{JR}} = M_{X_{JR}}$

No

Random #, U from
Interval [0,1]

J = J+1

A

Simulation
with X_J at J
and R

Is $M_{X^\theta_{JR}}$
in the interval
above ?

No

$Y = |M_{X_{JR}} - M_{X^\theta_{JR}}|$

$T_J = \dfrac{C}{Log(1+J)}$

Yes

R = R+1

$U < e^{-Y/T_J}$

Yes

$J > J_{MAX}$

No

E

Yes

Yes

R < N

No

E

No

Reject X_J

A

B

Figure 1. Simulated Annealing Algorithm for Stochastic Systems
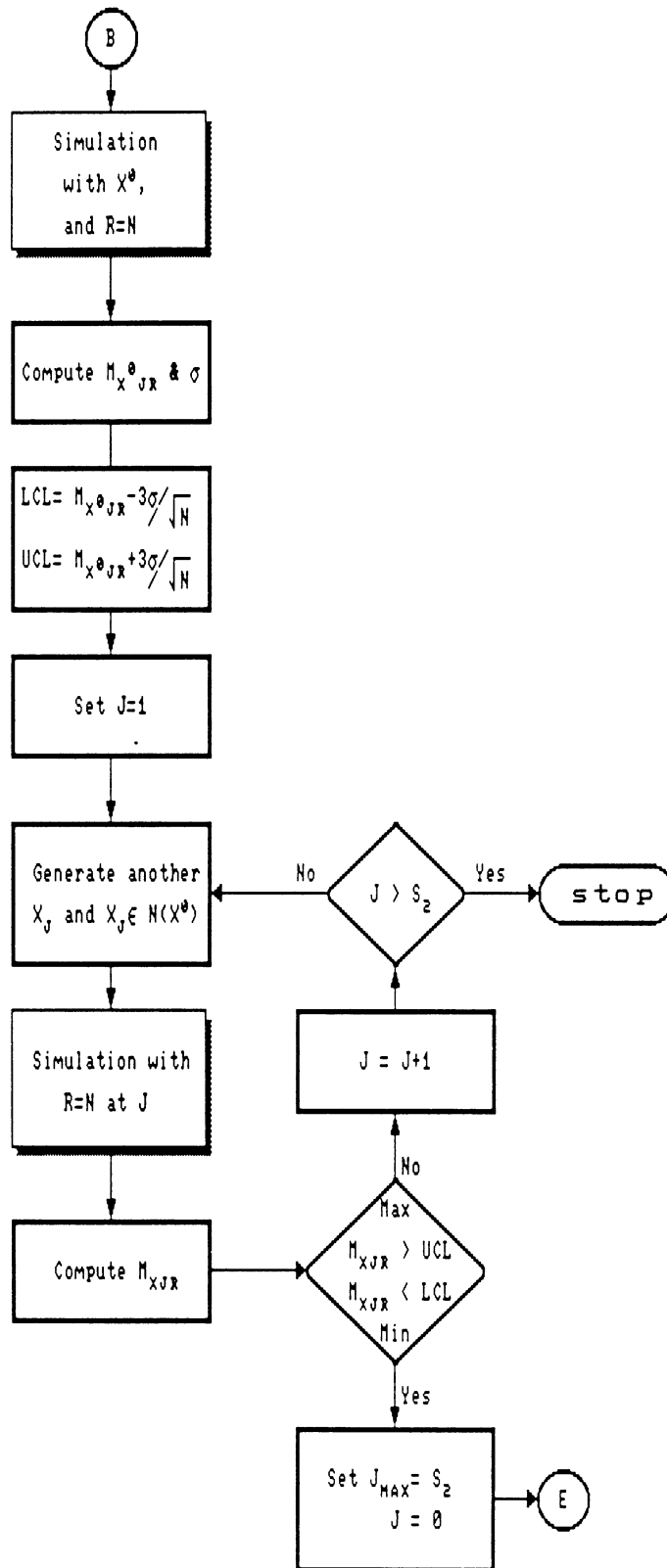
Figure 1. (Continued)

temperature is not updated, and a new iteration is started based on the previous configuration with the current temperature.

If the difference is statistically significant then the objective functional value of the proposed configuration is compared to the current best objective functional value. You will accept the proposed configuration if its objective functional value is greater than the current best objective functional value (for maximization problem) or is smaller (for minimization problem). If not, this configuration will be accepted with a certain probability which is a function of the absolute difference between the proposed and current best objective functional values, and the current temperature (see Equation 1). This whole process is repeated until a maximum number of iterations (J_{max}) is achieved. Then, the algorithm will be terminated if the stopping criteria are met.

Stopping criteria   As stated above, convergence for statistical adaptation of simulated annealing has not yet been proven and even if the proof can be found the convergence rate is likely to be quite slow. Therefore, the stopping criteria used, although it cannot guarantee global optimality, must at least check for local optimality. The stopping criteria should avoid stopping the algorithm when the present configuration lies on the "side of a hill" rather than near the top or the bottom (local optimum if not global optimum).

The technique used to check the position of the present
configuration is analogous to a variable control X-chart. We
will check if a better solution exists within a limited range
around the present configuration.

Initially, a simulation with N replications and current
optimum configuration is executed in order to determine the
upper and Lower control limit (UCL and LCL) of the objective
functional value, which are defined as follows:

$$UCL = M_{X^0_{jR}} + 3\frac{\sigma}{\sqrt{n}} \qquad (2)$$

$$LCL = M_{X^0_{jR}} - 3\frac{\sigma}{\sqrt{n}} \qquad (3)$$

If S_2 more iterations are performed and no configuration
provides a solution with the objective functional value above
the UCL for a maximization problem or below the LCL for a
minimization problem then the stopping criteria has been
satisfied. Otherwise, as soon as a configuration provides a
solution with an objective functional value above the UCL or
below the LCL, S_2 more iterations are performed. This is
continued until the stopping criteria is satisfied.

CHAPTER IV SIMULATION MODEL OF AN FMS

4.1 Overview

Computer simulation analysis is an indispensable tool in designing complex systems. It is a widely used numerical modelling technique for the analysis of complex systems. Simulation has been most commonly applied to model manufacturing systems to estimate their performance under different policies. Usually discrete event simulation is used for modelling flexible manufacturing systems [Looveren et al. 1986].

These models mimic the detailed operation of a system through a computer program which effectively steps through each event that would occur in the system. As such, simulation permits controlled experiments on a complex system with little or no disturbance to the actual system. Simulation analysis can be performed at different levels of sophistication and therefore with varying degrees of accuracy and credibility. The price for simulation is the programming time to create the model, time to collect data sets, and computer time for each run.

In FMSs, simulation can be used to test the layout of the system (screening) [Looveren et al. 1986], and to study the effect of different control strategies, scheduling priority

rules, breakdown scenarios, and maintenance schemes (releasing and dispatching). A more detailed list of problems that can be analyzed with simulation is given by Hutchinson and Wynne [1973].

This research proposes to interface a simulation model with a generative model (simulated annealing algorithm) in an effort to search for an optimal FMS design.

4.2 Components of FMS

A flexible manufacturing system consists of the following components [Buzacott 1984]:

Work stations   Operations such as machining, inspection, assembly and test are performed at a work station.

Material handling system   Jobs are moved from one work station to another or between a work station and storage (buffer) locations by a material handling system. The most commonly used material handling systems are conveyors and AGVs.

Storage (buffer)   Work in process (WIP) waiting for the next operation is stored in this storage or buffer. Storage for WIP can be at individual work stations on either input side (input buffer) or output side (output buffer), and in the central store (central buffer).

<u>Pallets</u>   These are necessary to hold jobs in a precise

orientation while operations are performed at different

work stations. Thus the pallets (and job) are moved from

one work station to the next.

<u>Dispatcher</u>   Some systems employ a dispatcher to assign jobs

to work stations. He may be assisted by a computer or

even replaced by a computer.

<u>Tools and tool delivery system</u>   In machining systems it is

necessary to make provisions for replacing worn or broken

tools and ensuring that appropriate tools are available

in the tool magazine at the work station.

<u>Communication, computing and control system</u>   This system

will monitor the performance of each work station,

controlling the material handling system, ensuring that

the appropriate operations are performed on each job at

each work station and generally ensuring the effective

operation of the system.

4.3 Approach to Model Development

An FMS can consist of anywhere between 3 and 30 work

stations, all linked by material handling and tool delivery

systems. It will be monitored and controlled by a network of

linked computers, microprocessors, and data acquisition

devices [Buzacott 1984]. The FMS will be required to process

a variety of different jobs. Some existing FMSs process as many as 200 different types of parts, while others as few as 2 or 3. Each type of job will have its own specific processing requirements.

The operation of the FMS may have many potential disturbances. These may include tool wear or breakage, machine failures, defective parts, inaccurate results at inspection and test stations, the number and variety of jobs can change with time as can the priorities for completion of different jobs, and repair and maintenance facilities may not always be effective in fixing machine failures or in finding and eliminating computer hardware and software faults.

In short, FMS is an extremely complex system. It would be an almost impossible task to capture all features of its operation in one model. Therefore, a more effective strategy is to focus on some key features of the system. That is, begin with models that are essentially simple and only add in those features which are necessary in order to make the model more realistic.

The essential features of a simulation model for an FMS are described by Jain and Foley [1986]. Their recommendations are appropriate for a simulation model used for planning and operation of FMSs. A generic simulation model, which includes some of the essential features described by Jain and Foley [1986], for the FMS design problem is discussed below.

4.3.1 A Generic Simulation Model of FMS Design

To be useful, a generic simulator for FMS design must satisfy some of the broad criteria outlined by Jain and Foley [1986]. These criteria include transparency of model details, user friendly input, flexibility in level of detail, and statistical analysis capability.

In addition to these aspects of interface with designer and modules of the FMS design model, the simulation model should include certain features that are important to the FMS design problems. These features must include [Nandkeolyar 1988]:

    a. machining and assembly operation,

    b. material handling system, and

    c. parts and part types.

<u>Machining and assembly operation</u>   An FMS may need to complete a number of operations on a number of part types. This may require the installation of several different types of machines. With respect to machining and assembly operations, the simulation model should make it possible to [Nandkeolyar 1988]

    a. identify different types of machines,

    b. specify the number of units of each type of machine,

    c. reflect processing time flexibility,

    d. reflect routing flexibility,

    e. limit number of input and output buffer spaces,

f. reflect periods of machine failure and maintenance, and

g. reflect quality control operations.

<u>Material handling system (MHS)</u>   Parts need to be transported between stations upon arrival to the system, between operations, and prior to departure from the system. The two types of material handling systems that commonly appear in the literature are conveyors and automated guided vehicles (AGVs). The model should allow the changes in the capacity of the MHS by changing either the size (i.e., fewer or more number of buckets in the conveyor, or fewer or more number of AGVs) or the speed of the system.

<u>Parts and part types</u>   It is very unlikely that one part will be manufactured by the FMS. Consequently, the simulation model should have the capability of identifying and processing different part types. In some cases, it may be possible to group different parts into part types using group technology techniques. It should be possible to specify the characteristic of each part and identify parts belonging to these types.

4.4 Hypothetical FMS Model

The hypothetical FMS model is considered. This model is derived from the models presented by Haddock [1987]. In this hypothetical FMS model three different part types are produced in this hypothetical system. Here, parts that undergo the same sequence of operations are assumed to belong to the same part type. Each part type consists of several different parts. Though each part belonging to a part type follows the same route, they are differentiated by the individual processing time for each operation.

The model generates part arrivals according to an arrival process. The parts flow through the shops from their arrival at the central buffer to the machine groups operating area (work stations) and finally to the exit station. When parts arrive, they are assigned the part type and specified operation time, then wait in the loading station to be loaded into the AGVs. Once parts are loaded into the AGVs, they will be transported to the work stations where they wait to be processed. After all the required operations in each of the work stations are finished, the part is then transported to the unloading station. The AGV will then be freed to pick up the waiting parts.

In this paper, the production rate is used solely as the performance measure. Wang [1986] shows that other performance

measures, such as queue length, average waiting time, and machine utilization rate are moving in the same consistent directions. If production rate is increased, the waiting time will be decreased, average queue length will be decreased and machine utilization rate will be increased.

CHAPTER V EXPERIMENTATION AND RESULTS

5.1 Introduction

The FMS design problem involves the specification of the level of inputs required to produce a set of parts in a way that production rate is maximized. These inputs may consist of the determination of the number and type of machines required, the capacity and type of the FMS, and the capacity and type of buffers for a given set of parts to be produced.

Here a computer simulation is used to model an FMS. Since simulation is an evaluative technique [Suri 1984], this model is interfaced with an optimization method to search for the optimal design. The modified simulated annealing discussed in Chapter 3 is used as the search procedure.

The following factors are expected to have an effect on the ability and the speed of the modified simulated annealing algorithm to converge to the global optimal design.

a. Maximum number of iterations, J_{max} & S_2, in the algorithm

b. Maximum number of replications, N, in the simulation model

c. The size of the neighborhood, $N(X^0)$, in the algorithm

d. The value of c constant.

These factors are the potential subjects for investigation.

To study these, a model of a hypothetical FMS is

developed. Though the features of this model are not based on any existing FMS, they are considered representative.

5.2 Problem Definition

Consider a hypothetical FMS that receives orders for parts according to some arrival process. All customer orders may not be accepted. The parts are released in batches representing the economic lot size of some other system outside the FMS. These parts could belong to a single part type. Here, a part type is defined as parts that undergo the same sequence of operations. Each part type may consist of several different parts. They differ from the other parts in that they require different amounts of time for processing. These processing times are deterministic. This is made possible by the exclusion of uncertainty through the high level of automation in an FMS.

The FMS is assumed to contain machines that altogether can perform all the operations for all the part types under consideration. Machines are grouped according to similarity and arranged in a functional layout. In addition, each machine is capable of performing one or more operations, which is termed the flexibility of the system. If a machine is required to process parts from different part types

consecutively, or if it is required to conduct different operations consecutively, a set-up is incurred. During this time the machine is idle. This set-up results from the limited capacity of the tool carousel at each machine. The amount of set-up time incurred depends on the level of flexibility. This hypothetical FMS model is assumed to be at its optimal flexibility when each machine is assigned to perform only one type of operation.

Each group of machines has a limited number of input buffer spaces from which parts are drawn for processing. Upon completion of processing, parts are placed in a limited capacity output buffer.

Automated guided vehicles (AGVs) transport parts from the loading station to the input buffers of the appropriate work station, and from the output buffers to the input buffers of the next work station or the unloading station. The capacity of the MHS is determined by the number of AGVs employed and the speed at which they operate. Several AGVs may be employed to provide sufficient MHS capacity. Here, it is assumed that four AGVs at a speed of 10 distance units per time unit will provide sufficient MHS capacity.

5.3 Problem Parameters

Some of the parameters that define the FMS and the parts that may be processed are discussed in the following sections.

5.3.1 Parts

Parts that arrive to the system all require at least three operations to be completed. Three part types are defined. Table 1 shows the sequence of operations for each part type, and the corresponding average processing time.

The part type is determined using a discrete probability. Table 2 provides the proportion of arrivals of each type.

Table 1. Part Types, Operation Sequence and Processing
         Time

Part Type	Operating Station #				Mean Processing Time			
	1	2	3	4	1	2	3	4
1	1	2	3	4	10	5	3	10
2	1	2	4	3	12	7	6	15
3	1	2	3		10	9	5	0

Table 2. Proportion of arrivals of each Type
          (Batch size of 5 units)

Part Type	Proportion of arrivals
1	.56
2	.33
3	.11

Part arrival is assumed to follow a Poison distribution with a mean of one every 30 time units and a batch size of 5. All parts in a batch belong to the same part type.

Within each part type, there are several individual parts. These parts follow the same sequence of operations as other members of the part family, but require a different amount of time at each operation. Here, the specific time is achieved by multiplying the mean processing time of the part type for an operation by a factor drawn from discrete distributions. The discrete probability distributions used for these three part types are provided in Table 3. These probability distributions are derived from Nandkeolyar [1989].

Table 3. Probability Distributions of Processing Time Multipliers.

Part Type	Mach.:	1	2	3	4
1	Factor	.80	1.00	1.30	
	Probability	.300	.50	.20	
2	Factor	.80	.93	1.20	
	Probability	.10	.60	.30	
3	Factor	.15	1.00	1.20	.30
	Probability	.20	.25	.25	.30

The maximum number of parts allowed in the system is the summation of input and output buffer sizes and number of machines in all stations.

5.3.2 Machines

The machines used in an FMS are usually CNC machines which are capable of performing more than one type of operation, giving the system more flexibility. Here, the hypothetical FMS model is assumed to be at its optimal flexibility when each machine may perform only one type of operation. Hence, the FMS has four types of machines, each capable of performing one operation. Table 1 shows the routing of the three part types among the four machine types, and the corresponding processing time for this level of flexibility. If a machine is required to process parts from different part types consecutively, a set-up time is incurred. Table 4 shows the set-up times per part.

Table 4. Set-up Times per Part Type

Part Type	Machine Type			
	1	2	3	4
1	4	3	3	1
2	3	3	5	2
3	5	2	4	0

The distances between machine stations are given in Table 5. The maximum number of machines allowed in each work station is 10 units.

Table 5.   Distances Between Stations

		To				
		1	2	3	4	Unload
	Load	5	7	9	7	5
F	1		5	7	9	7
R	2			5	7	9
O	3				5	9
M	4					5

Note that machine failure is assumed to be negligible and routing flexibility is not reflected here. We will attempt to determine the optimum number of machines in each work station.

5.3.3 Buffers

Two types of buffers (input and output buffer) are defined for the FMS. The input and output buffers are located near machines. Input buffers provide space for parts that must be processed on the corresponding machine. Output buffers store parts that have been processed at the corresponding machine and are waiting for transportation to the next station. Usually a limited number of buffer spaces are available. The maximum buffer size is 10.

The FMS design process attempts to determine the optimum number of buffer spaces at each location.

5.3.4 Material handling system

The material handling system is assumed to consist of AGVs. Four units of AGVs are employed and they travel at a

constant speed of 10 distance units per time unit. This is assumed to provide sufficient material handling systems capacity.

5.3.5 Production Rate

Production rate is the objective function that must be optimized. It is defined as the number of completed jobs that leave the system per unit of time.

5.4 Optimization Technique

The optimization technique used here is the simulated annealing algorithm. The simulated annealing algorithm is modified to allow for the stochastic nature of the function (production rate) being optimized. Details of the modified version of the algorithm is provided in Chapter 3. A FORTRAN program is written to perform the algorithm. This algorithm is then interfaced with computer simulation (SIMAN) of the hypothetical FMS model to search for the optimal design. Here, the usefulness of a computer simulation model interfaced with the modified simulated Annealing algorithm to search for an optimum FMS design will be investigated and demonstrated.

In order to accomplish the investigation, the following tasks will be executed:

a. Using some predetermined values of J_{max}, S_2, N, and $N(X^0)$, an initial good FMS design is determined and the computer run time is also obtained.

b. Change the maximum number of iterations, J_{max}, obtain a new good FMS design, and mark down the run time. Compare the run time and the new design to initial results.

c. Repeat step b for the size of neighborhood, $N(X^0)$.

d. Repeat step b for the constant c (constant which is greater or equal to the height of the highest local optimum which is not a global optimum).

e. Repeat the same procedure (b) for maximum number of replications, N.

f. Repeat step b for maximum number of iterations, S_2.

g. Search for an optimal FMS design based on the previous runs.

Finally, we will discuss the effects that the above factors have on the ability and the speed of the modified simulated annealing algorithm to converge to the global optimal design. The applications of the algorithm in the FMS design will also be discussed. How well the algorithm can be used as a design tool in the FMS design will be addressed.

5.5   SIMAN Model and Experimental Framework

The general framework of flexible manufacturing systems is defined into three major components: arrival pattern, machine centers (work stations), and transportation device [Haddock 1987]. Table 6, as presented by Haddock [1987],

shows the characteristics associated with these three
components.

Table 6. Characteristics Associated with the FMS Components

Component	Characteristics
Arrival Pattern	• Arrival distribution and its parameters • Number of part types - Proportion of arrival of each type • Batch size

Machine Centers	• Number of machines centers
	    - Number of machines at each center
	
	• Input/Output buffer capacity
	    - Shared/Unshared input/output buffers
	
	• Part sequence (routing)
	• Set-up times per part per machine
	• Processing times per part per machine

Transportation Device	• Conveyor or transporter (AGV, etc.) • Capacity • Speed • Transportation distance between stations

The SIMAN block model and experimental framework are
presented in Appendix A. This model, originally presented by
Haddock [1987], is modified to include the different
processing time for each part in a part type, different
routings for part types, and to allow the model to interface

with FORTRAN program which is shown in Appendix B.

After the modification and programming process are accomplished, the SIMAN block model is verified to ensure that the model is performing as desired. This is done by tracing the simulation process using the TRACE element in the experimental file for 480 minutes.

A run time of 2400 time units for each simulation replication (equivalent to one week) is assumed to be reasonable to ensure a steady state. Ensuring that the simulation run has reached the steady state is not critical in this research since our major interests are the modification of simulated annealing algorithm and the investigation of the factors effecting the ability and the speed of the algorithm to search for the global optimum.

5.6 Results

Once both the FORTRAN and the SIMAN program are done, the initial run using predetermined values of maximum number of iterations (J_{max} =250), neighborhood size ($N(X^0)$=2), constant c (c=15), S_2 (=10), maximum number of replications (N=10), and a 95% confidence interval is then performed to search for an initial good FMS design. This design is as shown in Table 7.

Table 7. Initial Optimum Configuration

No.	Work Station # of Mach.	Input Buffers	Output Buffers
1	3	6	1
2	7	6	8
3	4	5	2
4	4	5	3

The average production rate of this configuration is 9.85 units per hour. This initial run took about 6.72 hours on 386 computer with a speed of 16 Mhz.

The next thing to do is to perform more runs with different parameters as described in Section 5.4. Based on the results of these runs we will analyze the effect of each parameter on the ability and the speed of the modified simulated annealing algorithm to search for the global optimum.

5.6.1. Effect of Maximum Number of Iterations, J_{max}

We increased the maximum number of iterations from 250 to 500 and kept the other parameters the same as in the initial run. As expected, it takes about twice as long to run with the maximum of 500 iterations. The optimum configuration as well as the production rate stay the same as the initial results. This procedure is then repeated using different values for the other parameters. The results seem to be consistent, except when we change the value of constant c from

15 to 20 and 25. In that case, we get a different optimum configuration and a higher average production rate than that with 250 iterations. The time is still about twice as long. Therefore, we should use J_{max}=500 instead of 250 iterations. As the maximum number of iterations increases, we will be more confident with the results. However, the run time will also increase. Due to the long run time (i.e. the run time with 500 iterations takes between 12 to 24 hours depending upon the combinations of the parameters in the algorithm) we assume that using 500 iterations is good enough for the purpose of this research. (See Appendix C for detail)

5.6.2. Effect of Neighborhood Size, $N(X^0)$

To examine the effect of neighborhood size, we run the program with different neighborhood sizes (2, 3, 4, 5, and 6) and keep the other parameters the same as the initial run except J_{max} (500). These runs are repeated with a different set of random numbers.

Table 8. Effect of Neighborhood Size

$N(X^0)$ =	2	3	4	5	6
Average Run Time (hrs)	13	26	14	20.4	13.6
Average Opt. Prod. Rate	9.5	9.3	10	9.2	9.5

Table 8 shows that it takes a lot longer (about 1.5 to 2

times as long) when the neighborhood size is changed from an even number to odd. The even neighborhood sizes take an average of 13 to 14 hours of running time and the odd sizes about 20 to 26 hours. This behavior is probably caused by the way the new configurations are generated within the neighborhood. A new configuration is generated randomly in such a way that each configuration in the neighborhood has the same probability of being selected. For example, if the last configuration is 4 and neighborhood size is 2, the neighborhood will be between 3 and 5. A new configuration of 3, 4 or 5 has the same probability to be generated. However, when the size is odd, eg. 3, the neighborhood will be between 2.5 and 5.5. Since truncation is used, the actual neighborhood size becomes between 2 and 5. This violates the symmetry concept and makes the program tend to generate a new configuration that is located on the left side of the optimum configuration. In this case, if the global optimum of the objective function is located at the right hand side of the present configuration (as in our case because we start the algorithm with one unit for all work stations and buffers), it will certainly take a longer time to reach the optimum point. We think that because of that most of the new configurations generated under this condition are not statistically significant (the new production rate is inside the confidence interval as explained in Chapter 3) , which then causes the

algorithm to stay in the loop (where the checking of statistically significance takes place) a lot longer before another iteration is performed. Thus, a longer run time results.

The average production rate from the even neighborhood sizes are also higher than the odd cases as shown in the above table. For these reasons, we suggest that an even neighborhood size should be used. We then analyze the performance of each of the even neighborhood sizes (2, 4, and 6). Their average run times are about the same (13 - 14 hours). However, the average production rate of the neighborhood size 4 (10.0 parts per hour) seems to be better than those of sizes of 2 and 6 (about 9.5 parts per hour). (See Appendix D for detail)

5.6.3 Effect of the Constant c

The speed of the algorithm and the quality of the final configuration depend upon the initial temperature, the amount of time spent at each temperature, and the speed at which temperature is decreased [Gemmill 1988]. The function that we use for updating the temperature has the parametric form of $T_j = c/\log(1+j)$, as proposed by Hajek [1988]. Hajek defines c as a constant which is greater than or equal to the height of the highest local optimum which is not a global optimum configuration. If c is greater or equal to the height

mentioned above, the necessary and sufficient condition on the cooling schedule for the algorithm to converge in probability to the set of globally optimum configurations is satisfied.

As the value of constant c increases, the initial temperature increases and the probability of accepting worse configurations also increases (see Equation 1), thus effecting the speed of the algorithm to converge to the global optimum. Since the average optimum production rate obtained from the previous run with c=15 is about 10 parts per hour, the value of c must be at least 10. To see the effect of the c value, we run the program with different c values (10, 15, 20, and 25), 500 iterations, neighborhood sizes of 2 and 4, and keep other parameters the same as the initial run (N=10, and S_2=10). These runs are then repeated with different sets of random numbers. So a total of 16 runs are performed.

The results show that when $N(X^0)$=2, the average run times for c=10, 15, 20, and 25 are 14, 13, 17, and 18 hours respectively. And when $N(X^0)$=4, the average run times for c=10, 15, 20, and 25 are 13, 14, 21, and 19 hours. As expected, the run time increases as the c value increases from between 10-15 to 20-25. So if the initial temperature is higher (higher c value), it will take a longer time for the algorithm to converge to the global optimum. There should be an optimum c value for each system being analyzed.

Table 9. Effect of C Value

$N(X^0)=2$				
c =	10	15	20	25
Average Run Time (hrs)	14	13	17	18
Average Opt. Prod. Rate	10.1	9.5	9.4	9.4
$N(X^0)=4$				
Average Run Time (hrs)	13	14	21	19
Average Opt. Prod. Rate	9.8	**10.0**	9.7	9.9

Table 9 shows that neighborhood size of 4 is better than that of 2 since its average optimum production rate tends to be higher for different values of c and the better combination is c=15 and $N(X^0)=4$. (See Appendix E for detail)

5.6.4. Effect of Maximum Number of Extra Iterations, S_2

The role of S_2 in the modified simulated annealing algorithm is to avoid stopping the algorithm when the present optimum configuration lies on the "side of a hill" rather than near the top or the bottom (local optimum if not global optimum).

To examine the effect of this parameter, 6 runs are performed with different value of S_2 (10, 15, and 20) with N=10, $N(X^0)=2$, and c=15. The run time tends to get a little longer (about 30 to 45 minutes longer as shown in Table 10) as

the value of S_2 increases. The average optimum production rate stays the same. Therefore, we conclude that it is sufficient to set the value of S_2 to 10. (See Appendix F)

Table 10. Effect of S_2

$N(X^0)=2$, c=15, N=10			
S_2 =	10	15	20
Average Run Time (hrs)	12.8	13.2	13.9
Average Opt. Prod. Rate	9.5	9.5	9.5

5.6.5. Effect of Maximum Number of Replications, N

We expect that as we increase the maximum number of replications allowed in the algorithm the run time will also increase. To examine this effect, we run our program with different values of N (10, 15, and 20) while keeping the other parameters the same. These runs are repeated with $N(X^0)=4$ and then the procedure is repeated again with a different set of random numbers. The results are summarized in Table 11 as shown below.

Table 11 shows that as the value of N increases the average run time tends to increase as we expected. From the above table we conclude that a good combination is $N(X^0)=4$, c=15, $S_2=10$, and N=10 since the average optimum production rate tends to be higher and the average run time is shorter. (See Appendix G for detail)

Table 11. Effect of N

$N(X^0)=2$, c=15, $S_2=10$			
N =	10	15	20
Average Run Time (hrs)	13	18.2	20
Average Opt. Prod. Rate	9.5	9.4	9.7
$N(X^0)=4$, c=15, $S_2=10$			
Average Run Time (hrs)	14	15	20
Average Opt. Prod. Rate	10.0	9.4	9.8

5.6.6. Search for Optimal FMS Design

Based on the above analysis, we determine that a good combination of the parameters in the modified simulated annealing algorithm is one with $N(X^0)=4$, c=15, $S_2=10$, $J_{max}=500$, and N=10. Note that the value of c might change for different FMS systems under study.

Running the program with the above parameters, we determine that a good optimum configuration for the FMS system under study is the FMS design as shown in Table 12.

The production rate is 10.2 units per hour and the 95% confidence interval is 9.36 - 11.0 units per hour. The average production rate (out of 10 simulation replications) of the maximum capacity of the FMS (the FMS design with 10 units of machines in each station and 10 units of each buffers) is 9.7 units per hour. The difference is not statistically

significant since 9.7 is in the confidence interval. The reason is that you oversupply the capacity of the FMS when you incorporate the maximum capacity to the FMS system.

Table 12. Final good configuration

No.	Work Station # of Mach.	Input Buffers	Output Buffers
1	6	4	3
2	3	7	6
3	4	3	9
4	9	7	10

5.7. Summary

A simulation model of an FMS and a FORTRAN program were developed and interfaced to study the effect of the parameters of the modified simulated annealing algorithm (J_{max}, $N(X^0)$, constant c, N, and S_2) on the ability and the speed of the algorithm to converge to the global optimum. The performance measure used to evaluate the FMS is production rate or throughput.

Based on the results, we suggest that an even neighborhood size be used to ensure the symmetry concept is not violated, thus increasing the ability and the speed of the algorithm to converge to the global optimum. However, when the value of constant c increases, the speed decreases because

the probability of accepting worse configurations increases as the value of c becomes higher (see Equation 1). There should be an optimum value of constant c for each system being analyzed and this value should be equal to or greater than the optimum value of the system's objective function. We suggest that the c value is not too large compared to the optimum value of the system's objective function in order to avoid long run time.

The maximum number of extra iteration, S_2, does not affect the ability and the speed of the algorithm as much as the previous parameters. As its value increases the speed of the algorithm decreases but not significantly. The higher the value of S_2, the more confident you are about whether or not your optimum configuration is a local optimum ,if not global optimum. The maximum number of iterations, N, also causes the speed of the algorithm to decrease as its value increases. Finally, a good combination of these parameters is J_{max}=500, $N(X^0)$=4, N=10, S_2=10, and c equals to or a little bit greater than the value of the system's objective function.

CHAPTER VI   CONCLUSION

The design of a flexible manufacturing system (FMS) is an important problem because the potential for benefits during this phase are much greater than those during the implementation or operational phases.   The FMS design involves the specification of the type and capacity of its various components such as machines, buffer sizes, and the material handling system.

There have been a lot of optimization methods or search procedures provided in the literature (see Section 2.1.5) for optimizing an FMS.   A new analytical search procedure for optimal solution to complex problems is simulated annealing. In this research, we develop a modified version of the simulated annealing algorithm to extend the application of the algorithm to stochastic systems such as an FMS.   Then, we investigate how the parameters of the simulated annealing algorithm affect the ability and the speed of the algorithm to converge to the global optimum.

In conclusion, we think that even though proof of convergence for this modified simulated annealing has not yet been provided, the simulated annealing algorithm has the potential to provide a good solution of not only deterministic but also stochastic combinatorial problems.   And it can be a good optimization method in the design of an FMS.

6.1. Contributions

This research presents modifications to the simulated annealing algorithm. With these modifications it is possible to apply the simulated annealing algorithm to stochastic systems. A large number of real-world problems fall into this category and could be solved using the procedure developed here. Recall that the search procedure is not directly connected with the modelling techniques. The model could take any form so long as it can be interfaced with the search procedure.

We investigate the effects of simulated annealing parameters on the ability and the speed of the algorithm to converge to the global optimum. Based on the investigations we provide suggested values for the simulated annealing algorithm parameters.

We also demonstrate the usefulness of the simulated annealing algorithm in the FMS design. It has been shown that computer simulation can be used in conjunction with an optimization routine to design an FMS.

6.2. Directions for Further Research

The procedures developed and the results obtained in this research open avenues for further research.

One of the directions in which this research could be extended is to study the effect of the number of part types processed by an FMS and the flexibility of the FMS on system performance and design using a more realistic simulation model.

Another area of extension is to use this procedure in other applications where a system must be optimally designed, the performance measure is a stochastic value, and it is a complex unknown function of the design parameter.

We can also compare the performance of this modified version of simulated annealing algorithm with some other stochastic optimization procedures such as stochastic quasigradient methods.

Another area of extension is to use real life data and observe the performance of the procedures in finding good solutions. It may be interesting to compare the solutions obtained by this procedure with the actual FMS when implemented. Causes for the differences could be identified. This would help in the development of better models and procedures.

This procedure could be used to study the effect of a

large number of factors that may affect the design of an FMS. These could be factors like breakdown, maintenance policies, alternate material handling systems, and incorporation of cost in the objective functions.

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APPENDIX A.   SIMAN MODEL OF FMS

The following is the definitions of the attributes and variables used in the SIMAN MODEL of FMS:

Attribute and variable definition.

	Definition
Attributes	
A(1)	Arrival time
A(2)	Part type
A(4)	Next machine visit
A(5)	Number of machine visits remaining
A(6)	Parameter number corresponding to the discrete distribution associated with the individual part's processing time
A(7)	Processing time for a part in a part family
Variables	
X(1)	Batch size
X(2)	Current number of units in the system
X(4)	Batch type
X(10)...X(13)	Capacity change of stations 2...5
X(14)...X(17)	Capacity change of input buffer 2...5
X(18)...X(21)	Capacity change of output buffer 2...5
X(26)	Maximum number of entities in the system

SIMAN MODEL of FMS

```
Begin;
        CREATE;
        EVENT:1;
        ALTER:MACHINE(1),X(10);
        ALTER:MACHINE(2),X(11);
        ALTER:MACHINE(3),X(12);
        ALTER:MACHINE(4),X(13);
        ALTER:BUFIN(1),X(14);
        ALTER:BUFIN(2),X(15);
        ALTER:BUFIN(3),X(16);
        ALTER:BUFIN(4),X(17);
        ALTER:BUFOUT(1),X(18);
        ALTER:BUFOUT(2),X(19);
        ALTER:BUFOUT(3),X(20);
        ALTER:BUFOUT(4),X(21);
        ALTER:DUMMY(1),X(22);
        ALTER:DUMMY(2),X(23);
        ALTER:DUMMY(3),X(24);
        ALTER:DUMMY(4),X(25);
        ASSIGN:X(26)=X(22)+X(23)+X(24)+X(25);
;

        CREATE,X(1):EXP(2,1):MARK(1);     Arrival of units
        QUEUE,1;                          Wait in file 1
        GROUP:X(1),FIRST;                 Create a temporary set

;                                         from X(1) arriving

;                                         units
        ASSIGN:X(4)=DP(1,1);              Assign part type
        SPLIT;
        ASSIGN:A(2)=X(4);
        ASSIGN:A(5)=TF(12,A(2));          # of operations
        ROUTE:0,1;                        Route the unit to
;                                         station 1 with 0 delay
;                                         time
        STATION,1;                        Loading station
        QUEUE,2;
        SCAN:X(2).LT. X(26);              Arriving entities are
;                                         held in file 2 until

;                                         # in sys. is < 10
        ASSIGN:X(2)=X(2)+1;               Number in the system
        ASSIGN:J=A(2);
        ASSIGN:J=A(2)+8;
        ASSIGN:A(4)=TF(J,A(5))+1;         Assign first operation
        ASSIGN:A(5)=A(5)-1;
        BRANCH,1:
          IF,A(4).EQ. 2,WT2:
          IF,A(4).EQ. 3,WT3:
```

```
                 IF,A(4).EQ. 4,WT4:
                 ELSE,WT5;                              to first operation
WT2      QUEUE,12 ;
         SEIZE:DUMMY(1):NEXT(FST);
WT3      QUEUE,13 ;
         SEIZE:DUMMY(2):NEXT(FST);
WT4      QUEUE,14 ;
         SEIZE:DUMMY(3):NEXT(FST);
WT5      QUEUE,15 ;
         SEIZE:DUMMY(4):NEXT(FST);
FST      QUEUE,3;
         REQUEST:ROBOT(SDS,3);
         TRANSPORT:ROBOT(A(3)),A(4);          to station A(4)
;
         STATION, 2-5;
         FREE:ROBOT(A(3));
         QUEUE,M + 18,1;
         SEIZE:BUFIN(M-1);
         QUEUE,M+2;
         SEIZE:MACHINE(M-1);
         RELEASE:BUFIN(M-1);
         ASSIGN:A(6)=A(2)+2;
         ASSIGN:A(7)=(TF(M-1,A(2))*DP(A(6),1));
;                                             processing time for an
;                                             individual part in a
;                                             part family
         DELAY:TF(M+3,A(2))+A(7);             setup and proc. time
         QUEUE,M+22;
         SEIZE:BUFOUT(M-1);
         RELEASE:DUMMY(M-1);
         RELEASE:MACHINE(M-1);
         BRANCH,1:
            IF,A(5).EQ.0,UNLOD:
            ELSE,NSTA;
UNLOD    ASSIGN:A(4)=6 :NEXT(FWD);
NSTA     ASSIGN:J=A(2)+ 8;
         ASSIGN:A(4)=TF(J,A(5))+1;
         ASSIGN:A(5)=A(5)-1;
         BRANCH,1:
            IF,A(4).EQ. 2,WTT2:
            IF,A(4).EQ. 3,WTT3:
            IF,A(4).EQ. 4,WTT4:
            ELSE,WTT5;                        to first operation
WTT2     QUEUE,16 ;
         SEIZE:DUMMY(1):NEXT(FWD);
WTT3     QUEUE,17 ;
         SEIZE:DUMMY(2):NEXT(FWD);
WTT4     QUEUE,18 ;
         SEIZE:DUMMY(3):NEXT(FWD);
WTT5     QUEUE,19 ;
```

```
            SEIZE:DUMMY(4):NEXT(FWD);
FWD         QUEUE,M+6,1;
            REQUEST:ROBOT(SDS,3);
            RELEASE:BUFOUT(M-1);
            TRANSPORT:ROBOT(A(3)),A(4);
            STATION, 6;                       unloading station
            FREE:ROBOT(A(3));
            ASSIGN:X(2)=X(2)-1;
            TALLY:1, INT(1);                  time in the system
            BRANCH,1:
               IF,A(2).EQ. 1 ,TY1:
               IF,A(2).EQ. 2 ,TY2:
               ELSE,TY3;
TY1         TALLY: 2, 1:DISPOSE;              # part type 1 produced
TY2         TALLY: 3, 1:DISPOSE;              # part type 2 produced
TY3         TALLY: 4, 1:DISPOSE;              # part type 3 produced
;
            CREATE,1;
AGAIN       DELAY:2400;
            EVENT:2:NEXT(AGAIN);
END;
```

Experimental File
```
Begin;
;PROJECT,FMS,Laurensius,1/24/91;
DISCRETE,1000,7,27,6;
TABLES:
        1 ,1,1, 10, 12, 10:
        2 ,1,1, 5, 7, 9:
        3 ,1,1, 3, 6, 5:
        4 ,1,1, 10, 15, 0:
        5 ,1,1, 4, 3, 5:
        6 ,1,1, 3, 3, 2:
        7 ,1,1, 3, 5, 4:
        8 ,1,1, 1, 2, 0:
        9 ,1,1, 4, 3, 2, 1:
        10 ,1,1, 3, 4, 2, 1:
        11 ,1,1, 3, 2, 1:
        12 ,1,1, 4, 4, 3;
RESOURCES:1-4, MACHINE, 0, 0, 0, 0:
         5-8, DUMMY, 0, 0, 0, 0:
         9-12, BUFIN, 0, 0, 0, 0:
         13-16, BUFOUT, 0, 0, 0, 0;
TRANSPORTER:1,ROBOT,4,1,10;
DISTANCES:1,1-6, 5,7,9,7,5/5,7,9,7/5,7,9/5,9/5;
```

```
PARAMETERS:1,  .56,  1,  .89,  2,  1,  3:
           2, 30:
           3,  .3,  .8,  .8,  1,  1,  1.3:
           4,  .1,  .8,  .7,  .93,  1,  1.2:
           5,  .2,  .15,  .45,  1,  .7,  1.2,
DSTAT:1 ,NQ(1),  ACCUM.QUEUE:
      2 ,NQ(2),  LOADING QUEUE:
      3 ,NR(1),  UTIL. MACHINE 1:
      4 ,NR(2),  UTIL. MACHINE 2:
      5 ,NR(3),  UTIL. MACHINE 3:
      6 ,NR(4),  UTIL. MACHINE 4:
      7 ,NR(9),  BUFIN 1. UTIL.:
      8 ,NR(10),  BUFIN 2. UTIL.:
      9 ,NR(11),  BUFIN 3. UTIL.:
      10 ,NR(12),  BUFIN 4. UTIL.:
      11 ,NR(13),  BUFOUT 1. UTIL.:
      12 ,NR(14),  BUFOUT 2. UTIL.:
      13 ,NR(15),  BUFOUT 3. UTIL.:
      14 ,NR(16),  BUFOUT 4. UTIL.:
      15 ,NT(1),  ROBOT UTIL.:
      16 ,X(2),  NO. IN SYSTEM;
REPLICATE,10000,0,2400;
TALLIES:1,TIME IN SYSTEM:
        2, PART TYPE 1:
        3, PART TYPE 2:
        4, PART TYPE 3;
SEEDS:1,5333,NO;
INITIALIZE,X(1)=5;
END;
```

APPENDIX B. FORTRAN SUBPROGRAMS

```
      SUBROUTINE EVENT(JOB,I)
      COMMON/SIM/D(50),DL(50),S(50),SL(50),X(50),DTNOW,TNOW,TFIN,J,NRUN

      GOTO (1,2),I
1     CALL UPDATE(JOB)
      RETURN
2     CALL TRY(JOB)
      RETURN
      END
```

```
      SUBROUTINE UPDATE(JOB)
      COMMON/SIM/D(50),DL(50),S(50),SL(50),X(50),DTNOW,TNOW,TFIN,J,NRUN
      COMMON/CS1/K,SUM,OPT,M,R,N,MEAN,STADEV,UCL,LCL,SIGN,U,Y,TJ,P,CHECK
      COMMON/CS2/JMAX,DIFF,Z(50),NSIZE,NC,N2,NFIN,CONFIG(12)
      REAL PROD(100),SUM,OPT,MEAN,STADEV,UCL,LCL,U,Y,TJ,CHECK,DIFF
      INTEGER K,M,R,N,SIGN,P,JMAX,Q(12),LAST(12),IO,IN,NFIN,IP

C  X(10)...X(13) are the number of machines of station 2...5
C  X(14)...X(17) are the input buffer sizes of station 2...5
C  X(18)...X(21) are the output buffer sizes of station 2...5
C  X(22)...X(25) are the capacities of the four dummy resources
C
      N=20
      NSIZE=2
      NC=15
      N2=10
      PRINT *,'NFIN :',NFIN
      IF(NFIN .EQ. 0) JMAX=500
      PRINT *,'JMAX :',JMAX
      PRINT *,'NC   :',NC
      IF(SIGN .EQ. 2) THEN
          DO 11 IP=1,12
              X(IP+9) = CONFIG(IP)
11        CONTINUE
          X(22)=X(10)+X(14)+X(18)
          X(23)=X(11)+X(15)+X(19)
          X(24)=X(12)+X(16)+X(20)
          X(25)=X(13)+X(17)+X(21)
          GOTO 101
      ENDIF
      IF(K .LE. N-1) THEN

C  Assign initial configuration

          X(10)=1
          X(11)=1
          X(12)=1
          X(13)=1
          X(14)=1
          X(15)=1
```

```fortran
            X(16)=1
            X(17)=1
            X(18)=1
            X(19)=1
            X(20)=1
            X(21)=1
            X(22)=X(10)+X(14)+X(18)
            X(23)=X(11)+X(15)+X(19)
            X(24)=X(12)+X(16)+X(20)
            X(25)=X(13)+X(17)+X(21)
         ELSE
            PRINT *,'SIGN:',SIGN
C
C  Generate new configurations
C
         IF(SIGN .EQ. 1) THEN
            DO 15 IO=1,12
               RANDOM = ABS(RAND(8888))
C               PRINT *,'RANDOM:',RANDOM,NSIZE
               Q(IO)=AINT((LAST(IO)-NSIZE/2) + |
               QC= AINT(LAST(IO)+NSIZE/2+1)
               IF(Q(IO) .GE. QC) Q(IO)=QC-1
               IF(Q(IO) .GE. 10) Q(IO)=10
               IF(Q(IO) .LE. 1) Q(IO)=1
15          CONTINUE
            SIGN=0
         ENDIF
         PRINT *,'SIGN:',SIGN
         X(10)=Q(1)
         X(11)=Q(2)
         X(12)=Q(3)
         X(13)=Q(4)
         X(14)=Q(5)
         X(15)=Q(6)
         X(16)=Q(7)
         X(17)=Q(8)
         X(18)=Q(9)
         X(19)=Q(10)
         X(20)=Q(11)
         X(21)=Q(12)
         X(22)=X(10)+X(14)+X(18)
         X(23)=X(11)+X(15)+X(19)
         X(24)=X(12)+X(16)+X(20)
         X(25)=X(13)+X(17)+X(21)
         ENDIF
101      DO 10 IN=1,12
            LAST(IN)=X(IN+9)
10       CONTINUE
         RETURN
         END
```

```
      SUBROUTINE TRY(JOB)
      COMMON/SIM/D(50),DL(50),S(50),SL(50),X(50),DTNOW,TNOW,TFIN,J,NRUN
      COMMON/CS1/K,SUM,OPT,M,R,N,MEAN,STADEV,UCL,LCL,SIGN,U,Y,TJ,P,CHECK
      COMMON/CS2/JMAX,DIFF,Z(50),NSIZE,NC,N2,NFIN,CONFIG(12)
      REAL PROD(50),SUM,OPT,MEAN,STADEV,UCL,LCL,U,Y,TJ,CHECK,DIFF
      INTEGER K,M,R,N,SIGN,P,JMAX,PRIOR,PRIORM
      REAL SUMB,SUMPB,DIFFB,MEANB,MEANPB,UCLB,LCLB,BSTADEV
      INTEGER C,N2,B,PB,PC,FINAL,CJ,NC,NFIN

C
C  Generate the initial optimum production rate (units/day)
C

      OPEN (UNIT=70, FILE='FMSOUT',STATUS='NEW')
      OPEN (UNIT=75, FILE='FMSBAK',STATUS='NEW')
      K=K+1
      IF(K .LE. N-1) THEN
          PROD(K)=TNUM(1)/40
          SUM=SUM+PROD(K)
          PRINT *,'PRODUCTION RATE:',PROD(K)
          PRINT *,'SUM:',SUM
          GOTO 100
      ELSEIF(K .EQ. N) THEN
              SUM=SUM+(TNUM(1)/40)
              OPT=SUM/K

              WRITE(70,*)'N (Maximum # of Replications)  :',N
              WRITE(70,*)'NSIZE (Size of Neighborhood)   :',NSIZE
              WRITE(70,*)'JMAX (Max. # of Iterations)    :',JMAX
              WRITE(70,*)'N2 (# of Extra Iterations, S2) :',N2
              WRITE(70,*)'NC (C value in Tj Equation)    :',NC
              WRITE(70,*)
              WRITE(70,*)'Iter. #    # mach.  Bufin        Bufout'
              WRITE(70,*)
              WRITE(70,5)  P,X(10),X(11),X(12),X(13),X(14),X(15)
              WRITE(70,6)  X(16),X(17),X(18),X(19),X(20),X(21),OPT
5             FORMAT(2X,I3,6(1X,F3.0))
6             FORMAT(2X,3X,6(1X,F3.0),1X,1X,F8.4)
              PRINT *,'NUMBER OF RUN',K
              PRINT *,'OPTIMUM PRODUCTION RATE:',OPT
              SUM=0
              SIGN=1
              GOTO 100
      ELSE
        GOTO 10
      ENDIF
```

```
C
C  Calculating a 95% confidence interval of the nev
C

10      IF(FINAL .EQ. 0) THEN
            M=M+1
            PRINT *,'M:',M
            IF(M .EQ. 1) R=3
            IF(M .LE. R-1) THEN
                PROD(M)=TNUM(1)/40
                SUM=SUM+PROD(M)
                PRINT *,'PRODUCTION RATE:',PROD(M)
                PRINT *,'SUM:',SUM
                GOTO 100
            ELSEIF(M .EQ. R) THEN
                    PROD(M)=TNUM(1)/40
                    SUM=SUM+(TNUM(1)/40)
                    MEAN=SUM/M
                    PRINT *,'NUMBER OF RUN',M
                    PRINT *,'MEAN:',MEAN
                    DO 20 L=1,M
                        DIFF=DIFF+(PROD(L) - MEAN)**2
20                  CONTINUE
                    STADEV=(DIFF/(M-1))**0.5
                    DIFF=0
                    PRINT *,'STADEV:',STADEV
                    UCL= MEAN + Z(R-1)*STADEV/SQRT(R)
                    LCL= MEAN - Z(R-1)*STADEV/SQRT(R)
                    PRINT *,'LCL..UCL',LCL,UCL
            ENDIF
```

```
C  Check if the new production rate is statistically significant
         IF(OPT .LE. UCL .AND. OPT .GE. LCL) THEN
            R=R+1
            IF(R .LE. N) THEN
               GOTO 100
            ELSE
               SIGN=1
               M=0
               SUM=0
               GOTO 100
            ENDIF
         ELSEIF(MEAN .LT. OPT) THEN
               U=ABS(RAND(5773))
               Y=ABS(MEAN-OPT)
               TJ=NC/LOG10(2+P)
               PRINT *,'U,Y,NC,TJ:',U,Y,NC,TJ
               CHECK=EXP(-Y/TJ)
               PRINT *,'CHECK :',CHECK
               IF(U .LT. CHECK) THEN
                  GOTO 30
               ELSE
                  WRITE(75,5) P,X(10),X(11),X(12),X(13),X(14),X(15)
                  WRITE(75,6)  X(16),X(17),X(18),X(19),X(20),X(21),MEAN
                  GOTO 40
               ENDIF
         ELSE
            GOTO 30
         ENDIF
30       OPT=MEAN
         DO 35 IM=1,12
            CONFIG(IM) = X(IM+9)
35       CONTINUE
         WRITE(70,7) P,X(10),X(11),X(12),X(13),X(14),X(15)
         WRITE(70,8) X(16),X(17),X(18),X(19),X(20),X(21),OPT
7        FORMAT(2X,I3,6(1X,F3.0))
8        FORMAT(2X,3X,6(1X,F3.0),1X,1X,F8.4)
40       P=P+1
         PRINT *,'P:',P
         TJ=C/LOG10(2+P)
         IF(P .GT. JMAX) THEN
            FINAL=1
            SIGN=2
            GOTO 100
         ELSE
            SIGN=1
            M=0
            SUM=0
            GOTO 100
         ENDIF
      ENDIF
```

```
C  Obtain the optimum production rate from the optimum configuration
C  generated.  Calculate the upper and lower control limit

80      IF(P .GT. JMAX) THEN
            B=B+1
            IF(B .LE. N-1) THEN
                PROD(B)=TNUM(1)/40
                SUMB=SUMB+PROD(B)
                PRINT *,'PRODUCTION RATE:',PROD(B)
                PRINT *,'SUMB:',SUMB
                WRITE(70,*)'Ten runs of opt. config. with prod. rate'
                WRITE(70,7) B,X(10),X(11),X(12),X(13),X(14),X(15)
                WRITE(70,8) X(16),X(17),X(18),X(19),X(20),X(21),PROD(B)
                SIGN=2
                GOTO 100
            ELSEIF(B .EQ. N) THEN
                    PROD(B)=TNUM(1)/40
                    SUMB=SUMB+PROD(B)
                    MEANB=SUMB/B

                    WRITE(70,7) B,X(10),X(11),X(12),X(13),X(14),X(15)
                   WRITE(70,8)  X(16),X(17),X(18),X(19),X(20),X(21),PROD(B)
                    PRINT *,'NUMBER OF RUN:',B
                    PRINT *,'SUMB:',SUMB
                    PRINT *,'MEANB:',MEANB

                    DO 50 CJ=1,B
                        DIFFB=DIFFB+(PROD(CJ)  - MEANB)**2
50                  CONTINUE
                    BSTADEV=(DIFFB/(B-1))**0.5
                    DIFFB=0
                    PRINT *,'BSTADEV:',BSTADEV
                    UCLB= MEANB + 3*BSTADEV/SQRT(N)
                    LCLB= MEANB - 3*BSTADEV/SQRT(N)
                    WRITE(70,*)'UCLB :',UCLB
                    WRITE(70,*)'MEANB:',MEANB
                    WRITE(70,*)'LCLB :',LCLB
                    PRINT *,'LCLB....UCLB',LCLB,UCLB
                    SIGN=1
                    GOTO 100
            ELSE
                GOTO 60
            ENDIF
```

```fortran
C  Testing the optimum production rate corresponding to the optimum
C  configuration by comparing it with the production rate generated
C  from simulation run with a new randomly generated configuration.
60        PB=PB+1
          PRINT *,'PB:',PB
          IF(PB .LE. N-1) THEN
              PROD(PB)=TNUM(1)/40
              SUMPB=SUMPB+PROD(PB)
              PRINT *,'PRODUCTION RATE:',PROD(PB)
              PRINT *,'SUMPB:',SUMPB
              GOTO 100
          ELSEIF(PB .EQ. N) THEN
              SUMPB=SUMPB+TNUM(1)/40
              MEANPB=SUMPB/PB
              PRINT *,'MEANPB:',MEANPB
              IF(MEANPB .LT. UCLB) THEN
                  PC=PC+1
                  IF(PC .GT. N2) THEN
                      STOP
                  ELSE
                      SIGN=1
                      PB=0
                      SUMPB=0
                      GOTO 100
                  ENDIF
              ELSE
                  OPT=MEANPB
                  WRITE(70,*)'MEANPB > UCLB. SET OPT=MEANPB'
                  DO 36 IM=1,12
                      CONFIG(IM) = X(IM+9)
36                CONTINUE
                  WRITE(70,5) P,X(10),X(11),X(12),X(13),X(14),X(15)
                  WRITE(70,6) X(16),X(17),X(18),X(19),X(20),X(21),OPT
                  P=JMAX+2
                  JMAX=JMAX+N2
                  PB=0
                  PC=0
                  M=0
                  B=0
                  SUMB=0
                  SUM=0
                  SUMPB=0
                  FINAL=0
                  SIGN=1
                  NFIN=1
                  GOTO 100
              ENDIF
          ENDIF
      ENDIF
100   RETURN
      END
```

```
      SUBROUTINE PRIME
      COMMON/SIM/D(50),DL(50),S(50),SL(50),X(50),DTNOW,TNOW,TFIN,J,NRUN
      COMMON/CS1/K,SUM,OPT,M,R,N,MEAN,STADEV,UCL,LCL,SIGN,U,Y,TJ,P,CHECK
      COMMON/CS2/JMAX,DIFF,Z(50),NSIZE,NC,N2,NFIN,CONFIG(12)
      REAL PROD(100),SUM,OPT,MEAN,STADEV,UCL,LCL,U,Y,TJ,CHECK,DIFF
      INTEGER K,M,R,N,SIGN,P,JMAX,NC,NSIZE
C
C  Assign the t(alpha, n-1) values for a 95% confidence interval
C
      N=10
      NSIZE=2
      NC=15
      N2=10

      Z(1)=12.706
      Z(2)=4.303
      Z(3)=3.182
      Z(4)=2.776
      Z(5)=2.571
      Z(6)=2.447
      Z(7)=2.365
      Z(8)=2.306
      Z(9)=2.262
      Z(10)=2.228
      Z(11)=2.201
      Z(12)=2.179
      Z(13)=2.160
      Z(14)=2.145
      Z(15)=2.131
      Z(16)=2.120
      Z(17)=2.110
      Z(18)=2.101
      Z(19)=2.093
      Z(20)=2.086

      RETURN
      END
```

```
      SUBROUTINE WRAPUP
      COMMON/SIM/D(50),DL(50),S(50),SL(50),X(50),DTNOW,TNOW,TFIN,J,NRUN
      COMMON/CS1/K,SUM,OPT,M,R,N,MEAN,STADEV,UCL,LCL,SIGN,U,Y,TJ,P,CHECK
      COMMON/CS2/JMAX,DIFF,Z(50),NSIZE,C,N2,NFIN,CONFIG(12)
      REAL PROD(100),SUM,OPT,MEAN,STADEV,UCL,LCL,U,Y,TJ,CHECK,DIFF
      INTEGER K,M,R,N,SIGN,P,JMAX,NFIN
C
      PRINT *,'X10...X13',X(10),X(11),X(12),X(13)
      PRINT *,'X14...X17',X(14),X(15),X(16),X(17)
      PRINT *,'X18...X21',X(18),X(19),X(20),X(21)
      PRINT *,'OPTIMUM PRODUCTION RATE:',OPT
      RETURN
```

```
      END
C  This function generates a random real number in the interval from
C  0 to 1.

      FUNCTION RAND(K)
      INTEGER K,M,CONST1
      REAL RAND, CONST2
      PARAMETER (CONST=2147483647, CONST2=.4656613E-9)
      SAVE
      DATA M/0/

      IF(M .EQ. 0) M=K
      M=M*65539
      IF(M .LT. 0) M=(M+1) + CONST1
      RAND=M*CONST2
      END
```

APPENDIX C.   PROGRAM OUTPUTS - Jmax

EXPERIMENT #1.1 : Max. # of Iteration, JMAX

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	2	2	4	4
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	15	15	15	15
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	250	500	250	500
Optimization achieved at iteration #	43	43	112	112
Prod. Rate UCL MEAN LCL	10.49783 9.84750 9.19717	10.98489 9.83250 8.68011	11.17197 10.03000 8.88803	10.99974 10.18250 9.36526
RUN TIME	6.72 hrs	11.83 hrs	8.10 hrs	13.50 hr
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	3, 7, 4, 4 6, 6, 5, 5 1, 8, 2, 1	3, 7, 4, 4 6, 6, 5, 5 1, 8, 2, 1	6, 3, 4, 9 4, 7, 3, 7 3, 6, 9,10	6, 3, 4, 9 4, 7, 3, 7 3, 6, 9,10

EXPERIMENT #1.1 : Max. # of Iteration, JMAX

Parameter	5	6	7	8
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	3	3	5	5
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	15	15	15	15
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	250	500	250	500
Optimization achieved at iteration #	50	50	226	226
Prod. Rate UCL MEAN LCL	10.34876 9.41500 8.48124	10.01095 9.33750 8.66405	10.48702 9.55000 8.61298	10.12690 9.33750 8.54810
RUN TIME	13.00 hrs	22.03 hrs	11.65 hrs	19.86 hrs
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	9, 8, 9, 9 10,7, 9,10 10,10,10,10	9, 8, 9, 9 10,7, 9,10 10,10,10,10	6,7, 9,8 6,10,10,5 4,8, 8,7	6,7, 9,8 6,10,10,5 4,8, 8,7

EXPERIMENT #1.1 : Max. # of Iteration, JMAX

Parameter	9	10	11	12
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	2	2	2	2
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	**20**	**20**	**25**	**25**
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	**250**	**500**	**250**	**500**
Optimization achieved at iteration #	94	304	94	304
Prod. Rate UCL MEAN LCL	10.28178 9.35250 8.42322	10.79310 9.58000 8.36690	10.28178 9.35250 8.42322	10.79310 9.58000 8.36694
RUN TIME	10.78 hrs	19.88 hrs	10.70 hrs	19.75 hrs
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	7, 2, 8, 7 4, 3, 8, 8 2, 9, 6, 4	4, 4, 5, 8 3, 9, 6, 2 4, 4, 5, 3	7, 2, 8, 7 4, 3, 8, 8 2, 9, 6, 4	4, 4, 5, 8 3, 9, 6, 2 4, 4, 5, 3

JMAX1.1

```
N (Maximum # of Replications)  :         10
NSIZE (Size of Neighborhood)   :          2
JMAX (Max. # of Iterations)    :        250
N2 (# of Extra Iterations, S2) :         10
NC (C value in Tj Equation)    :         15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833

Ten runs of opt. config. with prod. rate

1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.7250
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.9500
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.8000
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.7000
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.5750
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.7500
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.0750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.4500
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.0000

```
UCLB :      10.497830
MEANB:       9.847500
LCLB :       9.197168
```

```
Run Time : 6 hours and 43 minutes
           386 Computer in IE 441 Lab
```

JMAX1.2

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         2
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines Rate				Bufin Size				Bufout Size				Production
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833

Ten runs of opt. config. with prod. rate

Iter. #	# machines Rate				Bufin Size				Bufout Size				Production
1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

```
UCLB :      10.984890
MEANB:       9.832500
LCLB :       8.680108
```

Run Time : 11 hours and 50 minutes
            386 computer in IE 277 Lab.

JMAX1.3

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         4
JMAX (Max. # of Iterations)     :       250
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
13	4.	8.	6.	3.	5.	8.	2.	9.	1.	4.	7.	4.	9.5042
15	5.	6.	3.	2.	5.	8.	1.	6.	1.	1.	6.	4.	8.7125
16	4.	8.	4.	4.	4.	9.	1.	8.	3.	1.	8.	4.	9.6375
18	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.6500
24	3.	10.	9.	2.	2.	9.	3.	2.	1.	5.	6.	6.	9.3083
90	3.	8.	4.	5.	7.	10.	8.	10.	8.	2.	10.	7.	9.6750
101	6.	10.	6.	8.	9.	6.	2.	6.	10.	8.	8.	5.	10.2833
102	8.	10.	7.	7.	10.	4.	1.	6.	10.	8.	10.	4.	9.5929
112	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5972

Ten runs of opt. config. with prod. rate

1	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5000
2	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.7000
3	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.3750
4	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.9750
5	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.2000
6	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.1500
7	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	8.2250
8	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.0000
9	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	7.5000
10	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.6750

```
UCLB :     11.171970
MEANB:     10.030000
LCLB :      8.888028
```

Run Time : 8 hours and 5 minutes
          386 Computer in IE 277 Lab

JMAX1.4

N (Maximum # of Replications) :	10
NSIZE (Size of Neighborhood) :	4
JMAX (Max. # of Iterations) :	500
N2 (# of Extra Iterations, S2) :	10
NC (C value in Tj Equation) :	15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
13	4.	8.	6.	3.	5.	8.	2.	9.	1.	4.	7.	4.	9.5042
15	5.	6.	3.	2.	5.	8.	1.	6.	1.	1.	6.	4.	8.7125
16	4.	8.	4.	4.	4.	9.	1.	8.	3.	1.	8.	4.	9.6375
18	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.6500
24	3.	10.	9.	2.	2.	9.	3.	2.	1.	5.	6.	6.	9.3083
90	3.	8.	4.	5.	7.	10.	8.	10.	8.	2.	10.	7.	9.6750
101	6.	10.	6.	8.	9.	6.	2.	6.	10.	8.	8.	5.	10.2833
102	8.	10.	7.	7.	10.	4.	1.	6.	10.	8.	10.	4.	9.5929
112	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5972
Ten runs of opt. config. with prod. rate													
1	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3250
2	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.0000
3	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3500
4	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.6750
5	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.9000
6	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.4500
7	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5250
8	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.2000
9	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3000
10	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.1000

UCLB :	10.999740
MEANB:	10.182500
LCLB :	9.365261

Run Time : 13 hours and 31 minutes
386 computer in IE 277 Lab.

JMAX1.5

N (Maximum # of Replications) : 10
NSIZE (Size of Neighborhood) : 3
JMAX (Max. # of Iterations) : 250
N2 (# of Extra Iterations, S2) : 10
NC (C value in Tj Equation) : 15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	2.	3.	1.	1.	1.	2.	1.	3.	3.	2.	2.	.7833
1	1.	3.	2.	1.	1.	2.	1.	1.	4.	3.	1.	2.	4.0583
2	2.	2.	2.	2.	2.	3.	2.	2.	3.	4.	2.	1.	7.7167
3	3.	3.	3.	3.	1.	4.	3.	1.	2.	3.	3.	1.	9.3688
7	6.	1.	2.	3.	2.	7.	5.	4.	7.	8.	5.	5.	6.4000
8	6.	3.	1.	5.	3.	8.	5.	6.	8.	6.	4.	5.	6.9208
9	7.	2.	2.	4.	4.	7.	4.	5.	7.	5.	4.	6.	8.6650
10	6.	2.	3.	5.	4.	7.	5.	6.	8.	5.	4.	5.	9.3469
11	8.	6.	6.	5.	7.	9.	6.	4.	8.	8.	7.	8.	8.6393
12	9.	7.	6.	6.	7.	9.	7.	5.	7.	7.	8.	7.	9.3000
14	10.	6.	5.	8.	7.	10.	7.	7.	10.	10.	10.	9.	10.1344
19	7.	9.	3.	9.	10.	10.	10.	8.	5.	10.	8.	9.	8.5667
20	6.	10.	4.	10.	10.	10.	10.	9.	6.	9.	8.	10.	9.6313
21	7.	9.	4.	9.	10.	10.	10.	10.	4.	10.	8.	10.	9.0250
22	6.	10.	4.	8.	10.	10.	10.	9.	3.	10.	8.	10.	11.1062
43	6.	8.	6.	10.	8.	10.	9.	10.	9.	8.	10.	10.	10.0000
49	10.	5.	9.	10.	10.	10.	9.	10.	9.	10.	9.	7.	9.6000
50	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	10.5958

Ten runs of opt. config. with prod. rate

Run	# machines				Bufin Size				Bufout Size				Production Rate
1	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.1750
2	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	7.4750
3	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	10.3500
4	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.0500
5	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	10.4500
6	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	10.2750
7	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.4250
8	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	8.8750
9	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	8.6000
10	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	10.4750

UCLB : 10.348760
MEANB: 9.415000
LCLB : 8.481244

Run Time : 13 hours
    386 Computer in IE 277 Lab

JMAX1.6

```
N (Maximum # of Replications)  :         10
NSIZE (Size of Neighborhood)   :          3
JMAX (Max. # of Iterations)    :        500
N2 (# of Extra Iterations, S2) :         10
NC (C value in Tj Equation)    :         15
```

| Iter.
| # machines
Rate | | | | | | | | Bufin Size | | | Bufout Size | | | | Production |

Iter. #	# machines Rate							Bufin Size				Bufout Size				Production
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.				4.0850
0	2.	2.	3.	1.	1.	1.	2.	1.	3.	3.	2.	2.				.7833
1	1.	3.	2.	1.	1.	2.	1.	1.	4.	3.	1.	2.				4.0583
2	2.	2.	2.	2.	2.	3.	2.	2.	3.	4.	2.	1.				7.7167
3	3.	3.	3.	3.	1.	4.	3.	1.	2.	3.	3.	1.				9.3688
7	6.	1.	2.	3.	2.	7.	5.	4.	7.	8.	5.	5.				6.4000
8	6.	3.	1.	5.	3.	8.	5.	6.	8.	6.	4.	5.				6.9208
9	7.	2.	2.	4.	4.	7.	4.	5.	7.	5.	4.	6.				8.6650
10	6.	2.	3.	5.	4.	7.	5.	6.	8.	5.	4.	5.				9.3469
11	8.	6.	6.	5.	7.	9.	6.	4.	8.	8.	7.	8.				8.6393
12	9.	7.	6.	6.	7.	9.	7.	5.	7.	7.	8.	7.				9.3000
14	10.	6.	5.	8.	7.	10.	7.	7.	10.	10.	10.	9.				10.1344
19	7.	9.	3.	9.	10.	10.	10.	8.	5.	10.	8.	9.				8.5667
20	6.	10.	4.	10.	10.	10.	10.	9.	6.	9.	8.	10.				9.6313
21	7.	9.	4.	9.	10.	10.	10.	10.	4.	10.	8.	10.				9.0250
22	6.	10.	4.	8.	10.	10.	10.	9.	3.	10.	8.	10.				11.1062
43	6.	8.	6.	10.	8.	10.	9.	10.	9.	8.	10.	10.				10.0000
49	10.	5.	9.	10.	10.	10.	9.	10.	9.	10.	9.	7.				9.6000
50	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				10.5958

Ten runs of opt. config. with prod. rate

1	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				9.7000
2	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				9.5250
3	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				8.0250
4	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				9.9500
5	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				9.0500
6	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				9.9000
7	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				8.9500
8	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				9.0500
9	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				10.4750
10	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.				8.7500

```
UCLB :      10.010950
MEANB:       9.337500
LCLB :       8.664052
```

Run Time : 22 hours and 2 minutes
          386 computer in IE 277 Lab.

JMAX1.7

```
N (Maximum # of Replications)   :         10
NSIZE (Size of Neighborhood)    :          5
JMAX (Max. # of Iterations)     :        250
N2 (# of Extra Iterations, S2)  :         10
NC (C value in Tj Equation)     :         15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	3.	2.	4.	2.	1.	1.	3.	1.	5.	5.	3.	2.	2.9000
1	1.	4.	3.	1.	1.	3.	1.	1.	7.	5.	2.	1.	4.0167
2	2.	2.	3.	2.	2.	5.	3.	3.	6.	7.	4.	1.	8.0083
3	3.	4.	5.	4.	1.	7.	5.	1.	4.	5.	5.	1.	10.7333
5	2.	5.	5.	6.	4.	8.	7.	5.	6.	9.	6.	3.	7.7833
11	3.	4.	8.	3.	9.	10.	8.	8.	5.	10.	2.	10.	9.8938
47	7.	3.	6.	9.	10.	8.	10.	10.	8.	6.	9.	1.	8.9083
51	8.	3.	9.	10.	10.	9.	10.	10.	10.	7.	9.	7.	9.9625
83	5.	10.	10.	5.	8.	10.	10.	7.	10.	7.	8.	9.	10.5333
226	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.8833

Ten runs of opt. config. with prod. rate

Run	# machines				Bufin Size				Bufout Size				Production Rate
1	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.4000
2	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.3750
3	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.1000
4	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.3000
5	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.7500
6	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.9750
7	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.2250
8	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.7500
9	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.7500
10	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.8750

```
UCLB :     10.487020
MEANB:      9.550000
LCLB :      8.612984
```

Run Time : 11 hours and 39 minutes
           386 Computer in IE 277 Lab

           9 hours and 25 minutes
           on the new computer in IE 277 Lab

JMAX1.8

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         5
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	3.	2.	4.	2.	1.	1.	3.	1.	5.	5.	3.	2.	2.9000
1	1.	4.	3.	1.	1.	3.	1.	1.	7.	5.	2.	1.	4.0167
2	2.	2.	3.	2.	2.	5.	3.	3.	6.	7.	4.	1.	8.0083
3	3.	4.	5.	4.	1.	7.	5.	1.	4.	5.	5.	1.	10.7333
5	2.	5.	5.	6.	4.	8.	7.	5.	6.	9.	6.	3.	7.7833
11	3.	4.	8.	3.	9.	10.	8.	8.	5.	10.	2.	10.	9.8938
47	7.	3.	6.	9.	10.	8.	10.	10.	8.	6.	9.	1.	8.9083
51	8.	3.	9.	10.	10.	9.	10.	10.	10.	7.	9.	7.	9.9625
83	5.	10.	10.	5.	8.	10.	10.	7.	10.	7.	8.	9.	10.5333
226	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.8833
Ten runs of opt. config. with prod. rate													
1	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.1000
2	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.2000
3	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.9250
4	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.4000
5	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.1250
6	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.9250
7	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.2500
8	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.3750
9	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.3750
10	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.7000

```
UCLB :      10.126900
MEANB:       9.337501
LCLB :       8.548099
```

```
Run Time  : 15 hours and 40 minutes
            on the new 386 computer in IE 277 Lab.
```

JMAX1.9

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         2
JMAX (Max. # of Iterations)     :       250
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        20
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
47	4.	9.	3.	5.	6.	8.	4.	7.	2.	9.	1.	1.	9.6375
48	4.	10.	4.	5.	5.	9.	4.	7.	1.	10.	1.	2.	10.9063
54	3.	7.	6.	6.	6.	7.	1.	7.	1.	6.	4.	1.	9.5458
55	5.	7.	6.	4.	3.	6.	3.	9.	4.	6.	3.	2.	10.1156
57	8.	5.	5.	3.	2.	8.	6.	10.	5.	6.	2.	6.	9.3083
59	8.	5.	4.	3.	1.	8.	7.	10.	3.	4.	2.	4.	10.2400
94	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	8.7500
2	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.3500
3	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	10.3000
4	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.1250
5	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750
6	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.6000
7	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	10.9750
8	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	8.1000
9	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	7.7250
10	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.7250

```
UCLB :      10.281780
MEANB:       9.352500
LCLB :       8.423223
```

```
Run Time  : 10 hours and 47 minutes
            386 computer in IE 277 Lab.
```

JMAX1.10

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         2
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        20
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
47	4.	9.	3.	5.	6.	8.	4.	7.	2.	9.	1.	1.	9.6375
48	4.	10.	4.	5.	5.	9.	4.	7.	1.	10.	1.	2.	10.9063
54	3.	7.	6.	6.	6.	7.	1.	7.	1.	6.	4.	1.	9.5458
55	5.	7.	6.	4.	3.	6.	3.	9.	4.	6.	3.	2.	10.1156
57	8.	5.	5.	3.	2.	8.	6.	10.	5.	6.	2.	6.	9.3083
59	8.	5.	4.	3.	1.	8.	7.	10.	3.	4.	2.	4.	10.2400
94	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750
304	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.3875

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.6500
2	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.1250
3	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
4	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	7.9250
5	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	11.8500
6	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0250
7	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.8500
8	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
9	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0000
10	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.3750

```
UCLB :       10.793100
MEANB:        9.580000
LCLB :        8.366904

Run Time : 19 hours and 53 minutes
           386 computer in IE 441 Lab.
```

JMAX1.11

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         2
JMAX (Max. # of Iterations)     :       250
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        25
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
47	4.	9.	3.	5.	6.	8.	4.	7.	2.	9.	1.	1.	9.6375
48	4.	10.	4.	5.	5.	9.	4.	7.	1.	10.	1.	2.	10.9063
54	3.	7.	6.	6.	6.	7.	1.	7.	1.	6.	4.	1.	9.5458
55	5.	7.	6.	4.	3.	6.	3.	9.	4.	6.	3.	2.	10.1156
57	8.	5.	5.	3.	2.	8.	6.	10.	5.	6.	2.	6.	9.3083
59	8.	5.	4.	3.	1.	8.	7.	10.	3.	4.	2.	4.	10.2400
94	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750

Ten runs of opt. config. with prod. rate

1	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	8.7500
2	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.3500
3	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	10.3000
4	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.1250
5	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750
6	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.6000
7	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	10.9750
8	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	8.1000
9	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	7.7250
10	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.7250

```
UCLB :      10.281780
MEANB:       9.352500
LCLB :       8.423223
```

```
Run Time  : 10 hours and 42 minutes
            386 computer in IE 277 Lab.
```

JMAX1.12

N (Maximum # of Replications)   :   10
NSIZE (Size of Neighborhood)   :   2
JMAX (Max. # of Iterations)   :   500
N2 (# of Extra Iterations, S2) :   10
NC (C value in Tj Equation)   :   25

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
47	4.	9.	3.	5.	6.	8.	4.	7.	2.	9.	1.	1.	9.6375
48	4.	10.	4.	5.	5.	9.	4.	7.	1.	10.	1.	2.	10.9063
54	3.	7.	6.	6.	6.	7.	1.	7.	1.	6.	4.	1.	9.5458
55	5.	7.	6.	4.	3.	6.	3.	9.	4.	6.	3.	2.	10.1156
57	8.	5.	5.	3.	2.	8.	6.	10.	5.	6.	2.	6.	9.3083
59	8.	5.	4.	3.	1.	8.	7.	10.	3.	4.	2.	4.	10.2400
94	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750
304	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.3875

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.6500
2	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.1250
3	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
4	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	7.9250
5	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	11.8500
6	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0250
7	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.8500
8	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
9	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0000
10	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.3750

UCLB :   10.793100
MEANB: 9.580000
LCLB :   8.366904
Run Time : 19 hours and 45 minutes
        386 computer in IE 277 Lab.

APPENDIX D.   PROGRAM OUTPUTS – $N(X^0)$

EXPERIMENT #2.1 : Neigborhood Size

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	2	3	4	5
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	15	15	15	15
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	500	500	500	500
Optimization achieved at iteration #	43	50	112	226
Prod. Rate UCL MEAN LCL	10.98489 9.83250 8.68011	10.01095 9.33750 8.66405	10.99974 10.18250 9.36526	10.12690 9.33750 8.54810
RUN TIME	11.83 hrs	22.03 hrs	13.5 hrs	19.86 hrs
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	3, 7, 4, 4 6, 6, 5, 5 1, 8, 2, 1	9, 8, 9, 9 10,7, 9,10 10,10,10,10	6, 3, 4, 9 4, 7, 3, 7 3, 6, 9,10	6, 7, 9, 8 6,10,10, 5 4, 8, 8, 7

EXPERIMENT #2.2 : Neighborhood Size (Diff. SEEDS)

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	2	3	4	5
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	15	15	15	15
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	500	500	500	500
Optimization achieved at iteration #	202	61	40	70
Prod. Rate UCL MEAN LCL	10.33691 9.18499 8.03309	10.26037 9.22250 8.18463	11.01988 9.83750 8.65512	10.23972 8.96250 7.68528
RUN TIME	13.92 hrs	29.91 hrs	14.75 hrs	20.93 hrs

CONFIGURATION
 	
# of Machines 	
  in Station
  1, 2, 3, 4
 	
The size of
Input Buffer
1, 2, 3, 4
 	
The size of
Output Buffer
1, 2, 3, 4
	6, 8, 7, 9
	
	7, 9, 8, 5
	
	3, 9, 5, 5
		6, 8,10, 9
		
		9, 9,10,10
		
		9, 9,10, 9
			7, 7, 7, 9
			
			8, 6, 4, 7
			
			1, 3, 9, 5
				5, 8,10, 4
				
				4, 5, 9, 8
				
				2,10,10,10

EXPERIMENT #2.3 : Neighborhood Size, N

Parameter	1	2 (Diff. SEEDS)
N (Max. # of Replications)	10	10
NSIZE (Neighborhood Size)	6	6
S2 (Extra # of Iterations)	10	10
C (C value in Temperature)	15	15
R (Initial # of Replications)	3	3
JMAX (Max. # of Iterations)	500	500
Optimization achieved at iteration #	54	30

Prod.   Rate
    UCL
    MEAN
    LCL
	10.53343
	9.45750
	8.38157
		10.92059
		9.64000
		8.35942

RUN TIME	13.67 hrs.	13.50 hrs.

CONFIGURATION
 	
# of Machines 	
  in Station
  1, 2, 3, 4
 	
The size of
Input Buffer
1, 2, 3, 4
 	
The size of
Output Buffer
1, 2, 3, 4
	
	9, 2, 10, 7
	
	6, 8, 6, 3
	
	8, 4, 7, 5
		
		3, 7, 10, 3
		
		6, 4, 3, 5
		
		3, 2, 7, 1

NSIZE1.1

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         2
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

```
UCLB :      10.984890
MEANB:       9.832500
LCLB :       8.680108

Run Time   : 11 hours and 50 minutes
             386 computer in IE 277 Lab.
```

NSIZE1.2

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         3
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	2.	3.	1.	1.	1.	2.	1.	3.	3.	2.	2.	.7833
1	1.	3.	2.	1.	1.	2.	1.	1.	4.	3.	1.	2.	4.0583
2	2.	2.	2.	2.	2.	3.	2.	2.	3.	4.	2.	1.	7.7167
3	3.	3.	3.	3.	1.	4.	3.	1.	2.	3.	3.	1.	9.3688
7	6.	1.	2.	3.	2.	7.	5.	4.	7.	8.	5.	5.	6.4000
8	6.	3.	1.	5.	3.	8.	5.	6.	8.	6.	4.	5.	6.9208
9	7.	2.	2.	4.	4.	7.	4.	5.	7.	5.	4.	6.	8.6650
10	6.	2.	3.	5.	4.	7.	5.	6.	8.	5.	4.	5.	9.3469
11	8.	6.	6.	5.	7.	9.	6.	4.	8.	8.	7.	8.	8.6393
12	9.	7.	6.	6.	7.	9.	7.	5.	7.	7.	8.	7.	9.3000
14	10.	6.	5.	8.	7.	10.	7.	7.	10.	10.	10.	9.	10.1344
19	7.	9.	3.	9.	10.	10.	10.	8.	5.	10.	8.	9.	8.5667
20	6.	10.	4.	10.	10.	10.	10.	9.	6.	9.	8.	10.	9.6313
21	7.	9.	4.	9.	10.	10.	10.	10.	4.	10.	8.	10.	9.0250
22	6.	10.	4.	8.	10.	10.	10.	9.	3.	10.	8.	10.	11.1062
43	6.	8.	6.	10.	8.	10.	9.	10.	9.	8.	10.	10.	10.0000
49	10.	5.	9.	10.	10.	10.	9.	10.	9.	10.	9.	7.	9.6000
50	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	10.5958

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.7000
2	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.5250
3	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	8.0250
4	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.9500
5	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.0500
6	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.9000
7	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	8.9500
8	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	9.0500
9	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	10.4750
10	9.	8.	9.	9.	10.	7.	9.	10.	10.	10.	10.	10.	8.7500

```
UCLB :      10.010950
MEANB:       9.337500
LCLB :       8.664052
```

Run Time : 22 hours and 2 minutes
            386 computer in IE 277 Lab.

NSIZE1.3

```
N (Maximum # of Replications)  :          10
NSIZE (Size of Neighborhood)   :           4
JMAX (Max. # of Iterations)    :         500
N2 (# of Extra Iterations, S2) :          10
NC (C value in Tj Equation)    :          15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
13	4.	8.	6.	3.	5.	8.	2.	9.	1.	4.	7.	4.	9.5042
15	5.	6.	3.	2.	5.	8.	1.	6.	1.	1.	6.	4.	8.7125
16	4.	8.	4.	4.	4.	9.	1.	8.	3.	1.	8.	4.	9.6375
18	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.6500
24	3.	10.	9.	2.	2.	9.	3.	2.	1.	5.	6.	6.	9.3083
90	3.	8.	4.	5.	7.	10.	8.	10.	8.	2.	10.	7.	9.6750
101	6.	10.	6.	8.	9.	6.	2.	6.	10.	8.	8.	5.	10.2833
102	8.	10.	7.	7.	10.	4.	1.	6.	10.	8.	10.	4.	9.5929
112	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5972

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3250
2	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.0000
3	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3500
4	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.6750
5	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.9000
6	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.4500
7	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5250
8	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.2000
9	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3000
10	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.1000

```
UCLB :      10.999740
MEANB:      10.182500
LCLB :       9.365261
```

```
Run Time  : 13 hours and 31 minutes
            386 computer in IE 277 Lab.
```

NSIZE1.4

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         5
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	3.	2.	4.	2.	1.	1.	3.	1.	5.	5.	3.	2.	2.9000
1	1.	4.	3.	1.	1.	3.	1.	1.	7.	5.	2.	1.	4.0167
2	2.	2.	3.	2.	2.	5.	3.	3.	6.	7.	4.	1.	8.0083
3	3.	4.	5.	4.	1.	7.	5.	1.	4.	5.	5.	1.	10.7333
5	2.	5.	5.	6.	4.	8.	7.	5.	6.	9.	6.	3.	7.7833
11	3.	4.	8.	3.	9.	10.	8.	8.	5.	10.	2.	10.	9.8938
47	7.	3.	6.	9.	10.	8.	10.	10.	8.	6.	9.	1.	8.9083
51	8.	3.	9.	10.	10.	9.	10.	10.	10.	7.	9.	7.	9.9625
83	5.	10.	10.	5.	8.	10.	10.	7.	10.	7.	8.	9.	10.5333
226	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.8833

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.1000
2	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.2000
3	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.9250
4	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.4000
5	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	9.1250
6	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.9250
7	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.2500
8	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.3750
9	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	8.3750
10	6.	7.	9.	8.	6.	10.	10.	5.	4.	8.	8.	7.	10.7000

```
UCLB  :      10.126900
MEANB:        9.337501
LCLB  :       8.548099
```

Run Time : 15 hours and 40 minutes
            on the new 386 computer in IE 277 Lab.

NSIZE2.1

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         2
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.	7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.	5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.	8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.	7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.	9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.	10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.8167

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.4750

```
UCLB :        10.336910
MEANB:         9.184999
LCLB :         8.033088
```

Run Time : 11 hours and 15 minutes
          on the new 386 computer in IE 277 Lab.

NSIZE2.2

N (Maximum # of Replications)   :   10
NSIZE (Size of Neighborhood)   :   3
N2 (# of Extra Iterations, S2) :   10
NC (C value in Tj Equation)   :   15
JMAX (Max. # of Iterations)   :   500

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	5.	2.	2.	2.	2.	1.	3.	4.	3.	1.	1.	7.9833
1	1.	5.	4.	1.	3.	3.	2.	3.	4.	5.	2.	1.	4.0500
3	2.	6.	7.	2.	5.	3.	6.	2.	7.	9.	2.	4.	7.5500
4	3.	7.	8.	3.	4.	4.	7.	2.	8.	10.	3.	3.	9.2375
6	3.	7.	8.	3.	5.	7.	8.	2.	10.	9.	3.	1.	8.7531
7	5.	9.	8.	5.	6.	3.	9.	5.	10.	9.	5.	2.	9.8700
8	3.	10.	8.	6.	6.	6.	10.	8.	10.	8.	8.	2.	9.0042
10	2.	9.	7.	7.	8.	7.	10.	9.	10.	10.	9.	3.	7.8625
12	3.	10.	8.	7.	8.	6.	10.	8.	9.	10.	10.	3.	8.8333
13	4.	10.	10.	5.	9.	10.	10.	9.	9.	9.	8.	5.	9.8031
16	4.	10.	9.	7.	10.	9.	9.	10.	9.	9.	9.	8.	8.5812
17	5.	10.	8.	6.	10.	10.	10.	10.	8.	9.	10.	9.	9.4250
24	10.	10.	10.	4.	10.	6.	10.	8.	5.	10.	10.	10.	10.1708
26	10.	8.	9.	2.	10.	8.	9.	8.	7.	10.	10.	10.	9.3500
29	9.	9.	10.	6.	9.	10.	8.	10.	10.	9.	9.	8.	9.7925
61	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	10.3917
Ten runs of opt. config. with prod. rate													
1	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	8.2500
2	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	10.2500
3	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	8.8500
4	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	8.0250
5	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	11.4500
6	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	9.9500
7	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	9.0000
8	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	9.5750
9	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	8.0500
10	6.	8.	10.	9.	9.	9.	10.	10.	9.	9.	10.	9.	8.8250

UCLB :   10.260370
MEANB: 9.222500
LCLB :   8.184627

Run Time : 29 hours and 55 minutes
           386 computer in IE 441 Lab.

NSIZE2.3

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         4
JMAX (Max. # of Iterations)     :        500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	3.	7.	3.	3.	2.	2.	1.	2.	5.	3.	1.	1.	9.4583
1	3.	5.	5.	2.	1.	2.	1.	1.	5.	4.	1.	2.	3.9063
2	5.	6.	3.	3.	2.	3.	3.	1.	5.	5.	1.	1.	2.1972
4	7.	5.	3.	4.	3.	3.	1.	3.	4.	4.	1.	1.	4.5778
6	8.	6.	4.	4.	5.	3.	2.	9.	1.	9.	5.	3.	8.4667
7	9.	8.	4.	6.	7.	2.	4.	9.	1.	6.	6.	1.	9.5643
14	10.	9.	4.	10.	7.	7.	10.	5.	1.	5.	1.	3.	10.1750
21	4.	8.	2.	9.	6.	10.	8.	2.	7.	1.	4.	3.	9.5813
40	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8583

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9500
2	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	7.9250
3	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	11.5250
4	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8500
5	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5750
6	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.8750
7	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.1000
8	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5250
9	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.0750
10	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9750

```
UCLB :       11.019880
MEANB:        9.837501
LCLB :        8.655117
```

Run Time : 14 hours and 44 minutes
            386 computer in IE 277 Lab.

NSIZE2.4

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         5
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
JMAX (Max. # of Iterations)     :       500
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	1.	7.	1.	1.	1.	2.	1.	6.	4.	3.	3.	1.	4.0950
1	3.	8.	3.	3.	2.	4.	1.	4.	6.	5.	1.	1.	9.4500
4	3.	10.	7.	2.	4.	6.	3.	5.	6.	7.	3.	3.	7.8650
6	7.	9.	7.	3.	6.	8.	4.	9.	5.	10.	7.	1.	9.4750
9	9.	10.	10.	3.	9.	7.	7.	9.	4.	10.	7.	5.	10.0400
10	7.	10.	10.	2.	10.	9.	8.	7.	6.	8.	9.	4.	8.0250
11	9.	10.	9.	4.	10.	8.	8.	5.	6.	9.	10.	6.	9.0278
13	7.	8.	10.	3.	10.	9.	9.	8.	3.	10.	9.	6.	9.7167
14	7.	10.	9.	6.	10.	8.	10.	5.	1.	10.	9.	7.	9.4083
15	10.	10.	9.	10.	8.	8.	10.	7.	2.	10.	2.	8.	10.8167
18	8.	6.	8.	10.	8.	9.	9.	8.	4.	9.	1.	10.	9.9917
22	7.	10.	7.	8.	6.	10.	10.	8.	6.	8.	3.	10.	9.1786
23	6.	8.	8.	2.	4.	7.	8.	10.	10.	4.	1.	10.	8.3813
24	8.	10.	10.	4.	6.	9.	10.	10.	10.	6.	2.	9.	9.7250
27	10.	9.	10.	2.	10.	7.	6.	10.	8.	6.	1.	10.	8.8188
29	8.	8.	10.	3.	10.	7.	8.	10.	10.	5.	4.	10.	10.2000
45	10.	10.	8.	10.	9.	10.	6.	7.	7.	10.	5.	10.	9.5750
60	6.	9.	9.	9.	6.	10.	5.	9.	9.	10.	8.	9.	9.9167
70	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	10.8917
Ten runs of opt. config. with prod. rate													
1	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	7.2250
2	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	8.3250
3	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	10.1500
4	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	8.3500
5	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	10.0250
6	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	7.1250
7	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	10.1750
8	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	8.5750
9	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	11.1500
10	5.	8.	10.	4.	4.	5.	9.	8.	2.	10.	10.	10.	8.5250

```
UCLB :       10.239720
MEANB:        8.962500
LCLB :        7.685284
```

Run Time : 20 hours and 56 minutes
         386 computer in IE 277 lab (C/D).

NSIZE3.1

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         6
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	6.	6.	3.	1.	1.5500
1	1.	2.	1.	1.	1.	4.	1.	1.	9.	5.	1.	1.	3.5500
2	2.	1.	1.	2.	1.	6.	3.	3.	7.	8.	4.	1.	6.3417
3	3.	4.	4.	3.	1.	9.	6.	1.	5.	6.	4.	1.	10.2250
25	6.	2.	5.	4.	9.	8.	10.	9.	3.	5.	4.	1.	8.9050
47	3.	5.	7.	10.	8.	9.	4.	4.	1.	9.	1.	2.	10.1750
52	5.	3.	10.	7.	1.	7.	2.	4.	2.	7.	6.	3.	9.6150
54	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	10.7625

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	9.7750
2	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	9.3250
3	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	9.8250
4	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	11.1750
5	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	8.9250
6	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	10.1500
7	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	9.1750
8	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	8.5750
9	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	7.1000
10	9.	2.	10.	7.	6.	8.	6.	3.	8.	4.	7.	5.	10.5500

```
UCLB :       10.533430
MEANB:        9.457500
LCLB :        8.381568
```

Run Time : 11 hours and 1 minute.
         New 386 computer in IE 277 Lab (C/L).

NSIZE3.2 (Diff. SEEDS)

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         6
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	4.	8.	3.	4.	2.	2.	1.	2.	6.	3.	1.	1.	9.4250
1	1.	8.	8.	1.	2.	4.	2.	4.	4.	4.	3.	1.	4.0583
2	1.	10.	10.	1.	2.	3.	5.	2.	3.	5.	5.	1.	4.1000
4	4.	5.	8.	4.	6.	2.	8.	1.	4.	10.	1.	8.	9.2750
5	8.	4.	8.	9.	2.	8.	9.	1.	8.	10.	1.	1.	10.7300
6	10.	1.	10.	7.	1.	10.	10.	1.	10.	10.	1.	1.	6.3750
7	6.	2.	7.	8.	1.	10.	6.	1.	10.	10.	4.	3.	8.7583
8	4.	2.	8.	5.	3.	8.	4.	4.	9.	10.	7.	5.	9.3361
10	1.	3.	8.	6.	7.	9.	4.	9.	10.	10.	6.	1.	4.0750
11	3.	4.	10.	3.	10.	7.	5.	8.	7.	10.	4.	1.	8.9167
12	5.	3.	8.	3.	10.	9.	6.	9.	4.	10.	5.	1.	9.9917
29	4.	9.	10.	4.	10.	1.	2.	6.	2.	6.	6.	2.	9.0750
30	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	10.6167

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	7.3250
2	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	11.8250
3	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	8.7500
4	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	8.1000
5	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	9.9500
6	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	11.2750
7	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	10.2000
8	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	9.7000
9	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	9.5500
10	3.	7.	10.	3.	6.	4.	3.	5.	3.	2.	7.	1.	9.7250

```
UCLB :       10.920590
MEANB:        9.640000
LCLB :        8.359415
```

Run time : 13 hours and 28 minutes.
          386 computer in IE 277 Lab (C/D).

EXPERIMENT #3.2 : C_VALUE

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	2	2	2	2
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	10	15	20	25
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	500	500	500	500
Optimization achieved at iteration #	504	202	202	202
Prod. Rate UCL MEAN LCL	11.37924 10.30000 9.22076	10.33691 9.18500 8.03309	10.33691 9.18500 8.03309	10.33691 9.18500 8.03309
RUN TIME	16.17 hrs	13.92 hrs	13.88 hrs	15.3 hrs
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	3, 3, 8, 5 9, 6, 3, 3 1, 1,10, 4	6, 8, 7, 9 7, 9, 8, 5 3, 9, 5, 5	6, 8, 7, 9 7, 9, 8, 5 3, 9, 5, 5	6, 8, 7, 9 7, 9, 8, 5 3, 9, 5, 5

EXPERIMENT #3.3 : C_VALUE

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	4	4	4	4
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	10	15	20	25
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	500	500	500	500
Optimization achieved at iteration #	18	112	193	112
Prod. Rate UCL MEAN LCL	10.98930 9.76500 8.54071	10.99974 10.18250 9.36526	11.24162 10.07500 8.90838	11.20819 9.97250 8.73681
RUN TIME	11.75 hrs	13.5 hrs	13.65 hrs	18.60 hrs
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	4,10, 5, 3 1, 8, 1, 6 2, 1, 7, 4	6, 3, 4, 9 4, 7, 3, 7 3, 6, 9, 10	8, 5,10, 7 6, 6, 5, 9 2, 7,10,10	4, 5, 8, 5 1, 3, 2, 8 7, 8,10,10

EXPERIMENT #3.4 : C_VALUE (Diff. SEEDS)

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	10
NSIZE (Neighborhood Size)	4	4	4	4
S2 (Extra # of Iterations)	10	10	10	10
C (C value in Temperature)	10	15	20	25
R (Initial # of Replications)	3	3	3	3
JMAX (Max. # of Iterations)	500	500	500	500
Optimization achieved at iteration #	40	40	70 503	241 501
Prod. Rate UCL MEAN LCL	11.01988 9.83750 8.65512	11.01988 9.83750 8.65512	10.60487 9.31500 8.02513	10.95350 9.80250 8.65150
RUN TIME	14.75 hrs	14.75 hrs	26.30 hrs	19.34 hrs
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	7, 7, 7, 9 8, 6, 4, 7 1, 3, 9, 5	7, 7, 7, 9 8, 6, 4, 7 1, 3, 9, 5	5, 3, 4, 9 5, 9, 9, 5 3, 5, 9, 1	4, 8, 5, 7 7, 1, 7, 6 4, 1, 7, 5

C_VALUE1.1

```
N (Maximum # of Replications)  :      10
NSIZE (Size of Neighborhood)   :       2
JMAX (Max. # of Iterations)    :     500
N2 (# of Extra Iterations, S2) :      10
NC (C value in Tj Equation)    :      10
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833

Ten runs of opt. config. with prod. rate

1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

```
UCLB :     10.984890
MEANB:      9.832500
LCLB :      8.680108

Run Time  : 11 hours and 55 minutes
            386 computer in IE 441 Lab.
```

C_VALUE1.2

```
N (Maximum # of Replications)   :         10
NSIZE (Size of Neighborhood)    :          2
JMAX (Max. # of Iterations)     :        500
N2 (# of Extra Iterations, S2)  :         10
NC (C value in Tj Equation)     :         15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833

Ten runs of opt. config. with prod. rate

1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

```
UCLB :      10.984890
MEANB:       9.832500
LCLB :       8.680108

Run Time  : 11 hours and 50 minutes
            386 computer in IE 277 Lab.
```

C_VALUE1.3

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         2
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        20
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
47	4.	9.	3.	5.	6.	8.	4.	7.	2.	9.	1.	1.	9.6375
48	4.	10.	4.	5.	5.	9.	4.	7.	1.	10.	1.	2.	10.9063
54	3.	7.	6.	6.	6.	7.	1.	7.	1.	6.	4.	1.	9.5458
55	5.	7.	6.	4.	3.	6.	3.	9.	4.	6.	3.	2.	10.1156
57	8.	5.	5.	3.	2.	8.	6.	10.	5.	6.	2.	6.	9.3083
59	8.	5.	4.	3.	1.	8.	7.	10.	3.	4.	2.	4.	10.2400
94	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750
304	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.3875

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.6500
2	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.1250
3	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
4	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	7.9250
5	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	11.8500
6	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0250
7	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.8500
8	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
9	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0000
10	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.3750

```
UCLB :      10.793100
MEANB:       9.580000
LCLB :       8.366904
```

Run Time : 19 hours and 53 minutes
            386 computer in IE 441 Lab.

C_VALUE1.4

N (Maximum # of Replications)	:	10
NSIZE (Size of Neighborhood)	:	2
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	25

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
47	4.	9.	3.	5.	6.	8.	4.	7.	2.	9.	1.	1.	9.6375
48	4.	10.	4.	5.	5.	9.	4.	7.	1.	10.	1.	2.	10.9063
54	3.	7.	6.	6.	6.	7.	1.	7.	1.	6.	4.	1.	9.5458
55	5.	7.	6.	4.	3.	6.	3.	9.	4.	6.	3.	2.	10.1156
57	8.	5.	5.	3.	2.	8.	6.	10.	5.	6.	2.	6.	9.3083
59	8.	5.	4.	3.	1.	8.	7.	10.	3.	4.	2.	4.	10.2400
94	7.	2.	8.	7.	4.	3.	8.	8.	2.	9.	6.	4.	9.8750
304	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.3875

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.6500
2	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.1250
3	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
4	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	7.9250
5	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	11.8500
6	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0250
7	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.8500
8	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	10.0000
9	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	8.0000
10	4.	4.	5.	8.	3.	9.	6.	2.	4.	4.	5.	3.	9.3750

```
UCLB :     10.793100
MEANB:      9.580000
LCLB :      8.366904
```

Run Time : 19 hours and 45 minutes
          386 computer in IE 277 Lab.

C_VALUE2.1

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         2
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        10
JMAX (Max. # of Iterations)     :       500
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
9	4.	5.	4.	3.	1.	4.	2.	1.	3.	3.	5.	2.	9.7100
13	4.	6.	9.	3.	7.	4.	1.	2.	2.	2.	8.	6.	9.1825
14	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	10.4700

Ten runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	8.0500
2	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	8.3500
3	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	8.8250
4	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	10.6250
5	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	7.9750
6	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	8.8250
7	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	9.6750
8	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	9.1000
9	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	9.4250
10	4.	5.	9.	3.	8.	3.	1.	1.	3.	2.	9.	6.	9.5000

```
UCLB :       9.807107
MEANB:       9.035000
LCLB :       8.262893
MEANPB > UCLB.  SET OPT=MEANPB
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
501	5.	5.	9.	3.	8.	5.	2.	2.	2.	1.	9.	5.	9.8325
504	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	10.3643

Ten runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	11.7000
2	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	12.0000
3	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	10.0500
4	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	9.8000
5	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	10.1250
6	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	8.7250
7	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	11.7750
8	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	10.1000
9	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	9.3500
10	3.	3.	8.	5.	9.	6.	3.	3.	1.	1.	10.	4.	9.3750

```
UCLB :      11.379240
MEANB:      10.300000
LCLB :       9.220763
Run Time : 16 hours and 10 minutes
           386 computer in IE 277 Lab.
```

C_VALUE2.2

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         2
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.	7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.	5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.	8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.	7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.	9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.	10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.8167

Ten runs of opt. config. with prod. rate

1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.4750

```
UCLB :       10.336910
MEANB:        9.184999
LCLB :        8.033088

Run Time : 11 hours and 15 minutes
           on the new 386 computer in IE 277 Lab.
```

CVALUE2.3

N (Maximum # of Replications) :	10
NSIZE (Size of Neighborhood) :	2
N2 (# of Extra Iterations, S2) :	10
NC (C value in Tj Equation) :	20
JMAX (Max. # of Iterations) :	500

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.	7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.	5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.	8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.	7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.	9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.	10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.8167
Ten runs of opt. config. with prod. rate													
1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.4750

UCLB :	10.336910
MEANB:	9.184999
LCLB :	8.033088

Run Time : 13 hours and 53 minutes
386 computer in IE 277 Lab.

CVALUE2.4

```
N (Maximum # of Replications)  :        10
NSIZE (Size of Neighborhood)   :         2
N2 (# of Extra Iterations, S2) :        10
NC (C value in Tj Equation)    :        25
JMAX (Max. # of Iterations)    :       500
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.	7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.	5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.	8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.	7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.	9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.	10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.8167
Ten runs of opt. config. with prod. rate													
1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.4750

```
UCLB :      10.336910
MEANB:       9.184999
LCLB :       8.033088

Run Time :  12 hours and 35 minutes
            386 computer in IE 277 Lab.
```

C_VALUE3.1

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         4
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        10
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
13	4.	8.	6.	3.	5.	8.	2.	9.	1.	4.	7.	4.	9.5042
15	5.	6.	3.	2.	5.	8.	1.	6.	1.	1.	6.	4.	8.7125
16	4.	8.	4.	4.	4.	9.	1.	8.	3.	1.	8.	4.	9.6375
18	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.6500
Ten runs of opt. config. with prod. rate													
1	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	11.0500
2	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	9.3750
3	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	7.9250
4	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.8250
5	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.6000
6	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	9.7250
7	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	7.1250
8	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.4250
9	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.3000
10	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.3000

```
UCLB :       10.989300
MEANB:        9.765000
LCLB :        8.540705
```

Run Time : 11 hours and 45 minutes
          386 computer in IE 277 Lab (B/D).

C_VALUE3.2

N (Maximum # of Replications)	:	10
NSIZE (Size of Neighborhood)	:	4
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
13	4.	8.	6.	3.	5.	8.	2.	9.	1.	4.	7.	4.	9.5042
15	5.	6.	3.	2.	5.	8.	1.	6.	1.	1.	6.	4.	8.7125
16	4.	8.	4.	4.	4.	9.	1.	8.	3.	1.	8.	4.	9.6375
18	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.6500
24	3.	10.	9.	2.	2.	9.	3.	2.	1.	5.	6.	6.	9.3083
90	3.	8.	4.	5.	7.	10.	8.	10.	8.	2.	10.	7.	9.6750
101	6.	10.	6.	8.	9.	6.	2.	6.	10.	8.	8.	5.	10.2833
102	8.	10.	7.	7.	10.	4.	1.	6.	10.	8.	10.	4.	9.5929
112	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5972

Ten runs of opt. config. with prod. rate

1	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3250
2	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.0000
3	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3500
4	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.6750
5	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.9000
6	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.4500
7	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5250
8	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.2000
9	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3000
10	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.1000

UCLB :	10.999740
MEANB:	10.182500
LCLB :	9.365261

Run Time : 13 hours and 31 minutes
          386 computer in IE 277 Lab.

C_VALUE3.3

N (Maximum # of Replications)   :   10
NSIZE (Size of Neighborhood)   :   4
JMAX (Max. # of Iterations)   :   500
N2 (# of Extra Iterations, S2) :   10
NC (C value in Tj Equation)   :   20

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
10	3.	7.	2.	2.	3.	10.	4.	6.	1.	1.	6.	4.	9.2750
26	3.	10.	8.	6.	1.	9.	6.	1.	2.	1.	1.	6.	10.0286
32	6.	5.	2.	7.	2.	9.	2.	7.	8.	10.	1.	7.	8.8611
36	5.	6.	2.	10.	3.	10.	5.	8.	8.	9.	1.	10.	9.7500
38	4.	7.	1.	8.	1.	5.	8.	9.	5.	9.	1.	10.	7.2083
40	2.	10.	2.	7.	4.	4.	10.	6.	6.	8.	3.	6.	8.0833
42	6.	8.	2.	9.	5.	4.	8.	5.	8.	10.	3.	8.	10.9417
70	8.	8.	6.	10.	7.	1.	4.	10.	4.	5.	5.	6.	9.0750
71	10.	10.	2.	8.	6.	1.	4.	10.	7.	3.	6.	7.	9.8400
76	7.	10.	3.	5.	4.	3.	4.	9.	7.	6.	7.	10.	9.1531
77	7.	8.	6.	8.	7.	9.	9.	3.	6.	3.	10.	8.	9.8083
193	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	10.9667

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	8.8750
2	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	10.0750
3	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	9.4000
4	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	10.7000
5	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	7.5000
6	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	11.7000
7	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	11.2500
8	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	10.0000
9	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	10.8000
10	8.	5.	10.	7.	6.	6.	5.	9.	2.	7.	6.	8.	10.4500

UCLB :   11.241620
MEANB: 10.075000
LCLB :   8.908381

Run Time : 15 hours and 39 minutes
            386 computer in IE 277 LAb (C/D).

C_VALUE3.4

N (Maximum # of Replications)	:	10
NSIZE (Size of Neighborhood)	:	4
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	25

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
7	1.	3.	2.	4.	3.	8.	4.	5.	3.	1.	7.	1.	4.1583
8	1.	5.	1.	3.	4.	10.	3.	4.	3.	2.	7.	1.	4.0583
9	2.	9.	2.	3.	4.	8.	5.	5.	1.	1.	5.	3.	8.0833
10	3.	10.	2.	4.	3.	10.	3.	5.	1.	1.	7.	3.	9.2300
11	4.	10.	1.	6.	3.	10.	5.	7.	3.	1.	7.	5.	7.2083
12	4.	8.	2.	5.	3.	10.	2.	4.	4.	1.	5.	4.	10.2563
15	2.	8.	1.	6.	4.	8.	5.	7.	4.	1.	3.	2.	7.2333
17	5.	8.	3.	5.	3.	10.	4.	8.	7.	4.	3.	1.	9.8812
86	10.	10.	7.	9.	6.	7.	8.	3.	9.	7.	7.	3.	9.3208
87	10.	8.	10.	8.	10.	5.	10.	5.	6.	8.	5.	3.	9.7312
112	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	10.3393

Ten runs of opt. config. with prod. rate

1	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	8.5250
2	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	11.9750
3	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	10.0250
4	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	9.2750
5	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	8.8250
6	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	11.4250
7	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	8.0250
8	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	10.3000
9	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	11.1000
10	4.	5.	8.	5.	1.	3.	2.	8.	7.	8.	10.	10.	10.2500

UCLB :   11.208190
MEANB: 9.972500
LCLB :   8.736809

Rum Time : 18 hours and 35 minutes
            386 computer in IE 277 Lab (D/L).

C_VALUE4.1

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         4
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        10
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	3.	7.	3.	3.	2.	2.	1.	2.	5.	3.	1.	1.	9.4583
1	3.	5.	5.	2.	1.	2.	1.	1.	5.	4.	1.	2.	3.9063
2	5.	6.	3.	3.	2.	3.	3.	1.	5.	5.	1.	1.	2.1972
4	7.	5.	3.	4.	3.	3.	1.	3.	4.	4.	1.	1.	4.5778
6	8.	6.	4.	4.	5.	3.	2.	9.	1.	9.	5.	3.	8.4667
7	9.	8.	4.	6.	7.	2.	4.	9.	1.	6.	6.	1.	9.5643
14	10.	9.	4.	10.	7.	7.	10.	5.	1.	5.	1.	3.	10.1750
21	4.	8.	2.	9.	6.	10.	8.	2.	7.	1.	4.	3.	9.5813
40	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8583

Ten runs of opt. config. with prod. rate

1	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9500
2	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	7.9250
3	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	11.5250
4	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8500
5	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5750
6	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.8750
7	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.1000
8	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5250
9	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.0750
10	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9750

```
UCLB :      11.019880
MEANB:       9.837501
LCLB :       8.655117
```

```
Run Time : 14 hours and 44 minutes
           386 computer in IE 277 Lab (A/L).
```

C_VALUE4.2

```
N (Maximum # of Replications)  :        10
NSIZE (Size of Neighborhood)   :         4
JMAX (Max. # of Iterations)    :       500
N2 (# of Extra Iterations, S2) :        10
NC (C value in Tj Equation)    :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	3.	7.	3.	3.	2.	2.	1.	2.	5.	3.	1.	1.	9.4583
1	3.	5.	5.	2.	1.	2.	1.	1.	5.	4.	1.	2.	3.9063
2	5.	6.	3.	3.	2.	3.	3.	1.	5.	5.	1.	1.	2.1972
4	7.	5.	3.	4.	3.	3.	1.	3.	4.	4.	1.	1.	4.5778
6	8.	6.	4.	4.	5.	3.	2.	9.	1.	9.	5.	3.	8.4667
7	9.	8.	4.	6.	7.	2.	4.	9.	1.	6.	6.	1.	9.5643
14	10.	9.	4.	10.	7.	7.	10.	5.	1.	5.	1.	3.	10.1750
21	4.	8.	2.	9.	6.	10.	8.	2.	7.	1.	4.	3.	9.5813
40	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8583

Ten runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9500
2	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	7.9250
3	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	11.5250
4	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8500
5	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5750
6	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.8750
7	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.1000
8	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5250
9	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.0750
10	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9750

```
UCLB :      11.019880
MEANB:       9.837501
LCLB :       8.655117
```

Run Time : 14 hours and 44 minutes
            386 computer in IE 277 Lab.

C_VALUE4.3

```
N (Maximum # of Replications)  :          10
NSIZE (Size of Neighborhood)   :           4
JMAX (Max. # of Iterations)    :         500
N2 (# of Extra Iterations, S2) :          10
NC (C value in Tj Equation)    :          20
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	3.	7.	3.	3.	2.	2.	1.	2.	5.	3.	1.	1.	9.4583
1	3.	5.	5.	2.	1.	2.	1.	1.	5.	4.	1.	2.	3.9063
2	5.	6.	3.	3.	2.	3.	3.	1.	5.	5.	1.	1.	2.1972
4	7.	5.	3.	4.	3.	3.	1.	3.	4.	4.	1.	1.	4.5778
6	8.	6.	4.	4.	5.	3.	2.	9.	1.	9.	5.	3.	8.4667
7	9.	8.	4.	6.	7.	2.	4.	9.	1.	6.	6.	1.	9.5643
14	10.	9.	4.	10.	7.	7.	10.	5.	1.	5.	1.	3.	10.1750
21	4.	8.	2.	9.	6.	10.	8.	2.	7.	1.	4.	3.	9.5813
40	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8583
77	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	10.1333

Ten runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	10.2000
2	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	9.7750
3	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	9.0750
4	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	9.3750
5	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	8.5500
6	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	10.6250
7	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	7.6250
8	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	10.3250
9	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	8.7000
10	5.	9.	4.	10.	4.	10.	6.	4.	1.	6.	7.	2.	9.0000

```
UCLB :  10.203070      MEANB:  9.325000          LCLB : 8.446934
MEANPB > UCLB. SET OPT=MEANPB
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
501	6.	4.	8.	8.	6.	9.	10.	2.	2.	9.	10.	1.	10.2375
503	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	11.7250

Ten runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	10.3250
2	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	7.3250
3	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	9.2750
4	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	9.7250
5	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	7.7250
6	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	9.4250
7	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	7.4250
8	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	10.4000
9	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	10.7000
10	5.	3.	4.	9.	5.	9.	9.	5.	3.	5.	9.	1.	10.8250

```
UCLB :     10.604870
MEANB:      9.314999    Run Time : 21.15 hrs
LCLB :      8.025125        New 386 Computer in IE 277 Lab.
```

C_VALUE4.4

```
N (Maximum # of Replications)    :        10
NSIZE (Size of Neighborhood)     :         4
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        25
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	3.	7.	3.	3.	2.	2.	1.	2.	5.	3.	1.	1.	9.4583
1	3.	5.	5.	2.	1.	2.	1.	1.	5.	4.	1.	2.	3.9063
2	5.	6.	3.	3.	2.	3.	3.	1.	5.	5.	1.	1.	2.1972
4	7.	5.	3.	4.	3.	3.	1.	3.	4.	4.	1.	1.	4.5778
6	8.	6.	4.	4.	5.	3.	2.	9.	1.	9.	5.	3.	8.4667
7	9.	8.	4.	6.	7.	2.	4.	9.	1.	6.	6.	1.	9.5643
14	10.	9.	4.	10.	7.	7.	10.	5.	1.	5.	1.	3.	10.1750
16	6.	3.	9.	7.	7.	9.	7.	1.	5.	1.	3.	4.	9.3406
17	4.	5.	10.	7.	4.	7.	9.	1.	5.	4.	4.	1.	10.6375
18	3.	6.	8.	9.	6.	6.	9.	1.	5.	2.	2.	1.	9.6000
69	7.	8.	8.	8.	3.	6.	7.	7.	5.	10.	10.	1.	10.2844
92	5.	3.	4.	9.	1.	4.	9.	7.	4.	8.	1.	4.	9.3708
118	3.	5.	2.	5.	3.	7.	8.	3.	1.	2.	7.	9.	9.9139
241	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	10.6688

Ten runs of opt. config. with prod. rate

1	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	8.0750
2	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	9.4500
3	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	8.1000
4	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	9.2750
5	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	9.0000
6	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	8.3000
7	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	9.6500
8	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	11.1500
9	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	9.3750
10	3.	8.	5.	7.	7.	4.	5.	6.	5.	1.	6.	5.	9.4500

```
UCLB :        10.047880
MEANB:         9.182500
LCLB :         8.317121
```

```
MEANPB > UCLB. SET OPT=MEANPB
```

501	4.	8.	5.	7.	7.	1.	7.	6.	4.	1.	7.	5.	10.2000

Ten runs of opt. config. with prod. rate

1	4.	8.	5.	7.	7.	1.	7.	6.	4.	1.	7.	5.	8.6750
2	4.	8.	5.	7.	7.	1.	7.	6.	4.	1.	7.	5.	8.8500
3	4.	8.	5.	7.	7.	1.	7.	6.	4.	1.	7.	5.	10.5500
4	4.	8.	5.	7.	7.	1.	7.	6.	4.	1.	7.	5.	10.0750
5	4.	8.	5.	7.	7.	1.	7.	6.	4.	1.	7.	5.	10.9250

```
 6  4.  8.  5.  7.  7.  1.  7.  6.  4.  1.  7.  5.   11.4500
 7  4.  8.  5.  7.  7.  1.  7.  6.  4.  1.  7.  5.    7.6000
 8  4.  8.  5.  7.  7.  1.  7.  6.  4.  1.  7.  5.   10.9500
 9  4.  8.  5.  7.  7.  1.  7.  6.  4.  1.  7.  5.    9.2750
10  4.  8.  5.  7.  7.  1.  7.  6.  4.  1.  7.  5.    9.6750
UCLB :      10.953500
MEANB:       9.802500
LCLB :       8.651498

Run Time : 15 hours and 35 minutes
           386 computer in Shezad's office.
```

APPENDIX F.   PROGRAM OUTPUTS - S_2

EXPERIMENT #4.1 : Max. # of Extra Iterations, S2

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	
NSIZE (Neighborhood Size)	2	2	2	
S2 (Extra # of Iterations)	10	15	20	
C (C value in Temperature)	15	15	15	
R (Initial # of Replications)	3	3	3	
JMAX (Max. # of Iterations)	500	500	500	
Optimization achieved at iteration #	43	43	43	
Prod. Rate UCL MEAN LCL	10.98489 9.83250 8.68011	10.98489 9.83250 8.68011	10.98489 9.83250 8.68011	
RUN TIME	11.83 hrs	12.15 hrs	12.60 hrs	
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	3, 7, 4, 4 6, 6, 5, 5 1, 8, 2, 1	3, 7, 4, 4 6, 6, 5, 5 1, 8, 2, 1	3, 7, 4, 4 6, 6, 5, 5 1, 8, 2, 1	

EXPERIMENT #4.2 : Max. # of Extra Iterations, S2 (Diff. SEEDS)

Parameter	1	2	3	4
N (Max. # of Replications)	10	10	10	
NSIZE (Neighborhood Size)	2	2	2	
S2 (Extra # of Iterations)	10	15	20	
C (C value in Temperature)	15	15	15	
R (Initial # of Replications)	3	3	3	
JMAX (Max. # of Iterations)	500	500	500	
Optimization achieved at iteration #	202	202	202	
Prod. Rate UCL MEAN LCL	10.33691 9.18500 8.03309	10.33691 9.18500 8.03309	10.33691 9.18500 8.03309	
RUN TIME	13.92 hrs	14.35 hrs	15.14 hrs	
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	6, 8, 7, 9 7, 9, 8, 5 1, 1,10, 4	6, 8, 7, 9 7, 9, 8, 5 1, 1,10, 4	6, 8, 7, 9 7, 9, 8, 5 1, 1,10, 4	

S2MAX1.1

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         2
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter.#	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833

Ten runs of opt. config. with prod. rate

1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

```
UCLB :      10.984890
MEANB:       9.832500
LCLB :       8.680108

Run Time  : 11 hours and 50 minutes
            386 computer in IE 277 Lab.
```

S2MAX1.2

N (Maximum # of Replications)	:				10							
NSIZE (Size of Neighborhood)	:				2							
JMAX (Max. # of Iterations)	:				500							
N2 (# of Extra Iterations, S2)	:				15							
NC (C value in Tj Equation)	:				15							

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
Ten runs of opt. config. with prod. rate													
1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

UCLB :   10.984890
MEANB: 9.832500
LCLB :   8.680108

Run Time : 12 hours and 14 minutes
           386 computer in IE 441 Lab.

S2MAX1.3

N (Maximum # of Replications) :   10
NSIZE (Size of Neighborhood) :   2
JMAX (Max. # of Iterations) :   500
N2 (# of Extra Iterations, S2) :   20
NC (C value in Tj Equation) :   15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833
Ten runs of opt. config. with prod. rate													
1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

UCLB :   10.984890
MEANB: 9.832500
LCLB :   8.680108

Run Time : 10 hours and 6 minutes
      on the new 386 computer in IE 277 Lab.

S2MAX2.1

N (Maximum # of Replications)	:	10
NSIZE (Size of Neighborhood)	:	2
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.	7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.	5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.	8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.	7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.	9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.	10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.8167

Ten runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.4750

UCLB : 10.336910
MEANB: 9.184999
LCLB : 8.033088

Run Time : 11 hours and 15 minutes
on the new 386 computer in IE 277 Lab.

S2MAX2.2

N (Maximum # of Replications)	:	10
NSIZE (Size of Neighborhood)	:	2
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.	7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.	5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.	8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.	7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.	9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.	10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.8167

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.4750

UCLB :   10.336910
MEANB: 9.184999
LCLB :   8.033088

Run Time : 14 hours and 21 minutes
          on the 386 computer in IE 277 Lab.

S2MAX2.3

N (Maximum # of Replications)	:	10
NSIZE (Size of Neighborhood)	:	2
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	15

Iter. #		# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.		4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.		8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.		4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.		7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.		5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.		8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.		7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.		9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.		10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		10.8167

Ten runs of opt. config. with prod. rate

Iter. #		# machines				Bufin Size				Bufout Size				Production Rate
1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.		9.4750

UCLB : 10.336910
MEANB: 9.184999
LCLB : 8.033088

Run Time : 15 hours and 19 minutes
on the 386 computer in IE 277 Lab.

APPENDIX G. PROGRAM OUTPUTS - N

EXPERIMENT #5.1 : Max. # of Replications, N

Parameter	1	2	3	4
N (Max. # of Replications)	10	15	20	
NSIZE (Neighborhood Size)	2	2	2	
S2 (Extra # of Iterations)	10	10	10	
C (C value in Temperature)	15	15	15	
R (Initial # of Replications)	3	3	3	
JMAX (Max. # of Iterations)	500	500	500	
Optimization achieved at iteration #	43	69	150	
Prod. Rate UCL MEAN LCL	10.98489 9.83250 8.68011	10.20320 9.40667 8.61013	10.58816 9.87875 9.169335	
RUN TIME	11.83 hrs	17.70 hrs	23.00 hrs	
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	3, 7, 4, 4 6, 6, 5, 5 1, 8, 2, 1	7, 2,10, 10 10, 8, 1, 7 7, 1, 3, 4	8, 9, 8, 7 7, 1, 6, 7 2, 6, 5, 2	

EXPERIMENT #5.2 : Max. # of Replications, N

Parameter	1	2	3	4
N (Max. # of Replications)	10	15	20	
NSIZE (Neighborhood Size)	4	4	4	
S2 (Extra # of Iterations)	10	10	10	
C (C value in Temperature)	15	15	15	
R (Initial # of Replications)	3	3	3	
JMAX (Max. # of Iterations)	500	500	500	
Optimization achieved at iteration #	112	19	67	
Prod. Rate UCL MEAN LCL	10.99974 10.18250 9.36526	9.93227 9.15167 8.37106	10.84299 9.97875 9.11450	
RUN TIME	13.5 hrs	12.00 hrs	23.5 hrs	
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	6, 3, 4, 9 4, 7, 3, 7 3, 6, 9,10	4, 6, 3, 5 1, 7, 1, 3 10,1,10, 3	5, 7,10, 5 4, 9,10,10 3, 2, 7, 5	

EXPERIMENT #5.3 : Max. # of Replications, N (Diff. SEEDS)

Parameter	1	2	3	4
N (Max. # of Replications)	10	15	20	
NSIZE (Neighborhood Size)	4	4	4	
S2 (Extra # of Iterations)	10	10	10	
C (C value in Temperature)	15	15	15	
R (Initial # of Replications)	3	3	3	
JMAX (Max. # of Iterations)	500	500	500	
Optimization achieved at iteration #	40	35	77	
Prod. Rate UCL MEAN LCL	11.01988 9.83750 8.65512	10.54704 9.71833 8.88963	10.17371 9.66500 9.15628	
RUN TIME	14.75 hrs	17.33 hrs	16.67 hrs	
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	7, 7, 7, 9 8, 6, 4, 7 1, 3, 9, 5	4, 6, 6, 5 4, 3, 9, 4 1, 1, 6, 7	8, 8, 9, 4 4, 4, 7, 6 9, 3, 4, 5	

EXPERIMENT #5.4 : Max. # of Replications, N (Diff. SEEDS)

Parameter	1	2	3	4
N (Max. # of Replications)	10	15	20	
NSIZE (Neighborhood Size)	2	2	2	
S2 (Extra # of Iterations)	10	10	10	
C (C value in Temperature)	15	15	15	
R (Initial # of Replications)	3	3	3	
JMAX (Max. # of Iterations)	500	500	500	
Optimization achieved at iteration #	202	290	26	
Prod. Rate UCL MEAN LCL	10.33691 9.18499 8.03309	10.43317 9.42500 8.41683	10.07512 9.43000 8.78488	
RUN TIME	13.92 hrs	18.75 hrs	16.31 hrs	
CONFIGURATION # of Machines in Station 1, 2, 3, 4 The size of Input Buffer 1, 2, 3, 4 The size of Output Buffer 1, 2, 3, 4	6, 8, 7, 9 7, 9, 8, 5 3, 9, 5, 5	8, 8, 8, 7 10, 1, 1, 6 10, 4, 1, 7	3, 9, 5, 4 4, 5, 1, 3 6, 7, 2, 3	

NMAX1.1

```
N (Maximum # of Replications)  :        10
NSIZE (Size of Neighborhood)   :         2
JMAX (Max. # of Iterations)    :       500
N2 (# of Extra Iterations, S2) :        10
NC (C value in Tj Equation)    :        15
```

Iter. #	# machines / Rate								Bufin Size		Bufout Size		Production
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.6875
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0333
2	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.0900
3	2.	1.	1.	2.	3.	6.	3.	2.	3.	3.	3.	2.	6.4333
10	1.	6.	1.	2.	1.	7.	1.	1.	4.	1.	6.	1.	4.0500
11	2.	7.	2.	3.	1.	5.	1.	3.	4.	2.	6.	2.	7.9417
12	2.	6.	2.	3.	1.	4.	2.	2.	4.	3.	6.	3.	8.1000
20	4.	8.	5.	3.	1.	1.	1.	1.	3.	7.	4.	2.	9.5125
31	4.	5.	3.	6.	5.	3.	3.	1.	1.	8.	3.	1.	9.9400
41	3.	8.	2.	5.	8.	6.	7.	3.	2.	8.	2.	1.	9.3100
42	3.	8.	3.	5.	7.	7.	6.	4.	1.	8.	1.	1.	10.4583
43	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.9833

Ten runs of opt. config. with prod. rate

Run	# machines / Rate								Bufin Size		Bufout Size		Production
1	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.6750
2	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.4500
3	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.4750
4	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.6250
5	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.8500
6	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	11.2500
7	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	10.2000
8	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	8.9750
9	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.6000
10	3.	7.	4.	4.	6.	6.	5.	5.	1.	8.	2.	1.	9.2250

```
UCLB :      10.984890
MEANB:       9.832500
LCLB :       8.680108
```

Run Time : 11 hours and 50 minutes
           386 computer in IE 277 Lab.

NMAX1.2

```
N (Maximum # of Replications)    :        15
NSIZE (Size of Neighborhood)     :         2
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0650
0	1.	1.	2.	2.	1.	1.	1.	1.	2.	2.	1.	1.	4.0969
1	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.1833
2	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0583
3	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.1200
4	1.	2.	1.	2.	2.	5.	3.	2.	2.	4.	3.	1.	4.0425
5	1.	2.	2.	3.	2.	4.	4.	3.	2.	5.	2.	2.	4.0865
7	3.	1.	2.	1.	1.	7.	2.	2.	3.	4.	5.	2.	3.3567
8	3.	1.	2.	2.	1.	8.	2.	1.	2.	3.	3.	1.	6.5250
10	4.	2.	2.	2.	1.	8.	2.	2.	1.	1.	2.	2.	9.1333
13	5.	3.	2.	3.	1.	8.	3.	1.	1.	2.	1.	4.	9.9531
15	3.	3.	1.	2.	2.	10.	2.	1.	1.	1.	1.	4.	7.1250
16	3.	3.	2.	2.	3.	10.	3.	1.	1.	1.	1.	4.	8.4917
28	3.	4.	2.	3.	7.	8.	7.	3.	1.	1.	1.	1.	9.3200
41	7.	2.	5.	4.	10.	5.	4.	2.	3.	1.	4.	1.	10.0792
45	7.	3.	7.	8.	9.	5.	2.	1.	3.	2.	1.	3.	10.9333
55	7.	2.	10.	8.	9.	2.	1.	2.	4.	1.	6.	1.	10.0714
68	6.	2.	9.	10.	9.	8.	4.	9.	8.	1.	2.	5.	9.7125
69	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	10.6875

Fifteen runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	8.5500
2	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	8.5250
3	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	9.1500
4	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	9.6250
5	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	11.8250
6	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	8.5000
7	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	7.6500
8	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	9.4750
9	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	9.8500
10	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	8.6750
11	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	10.5750
12	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	9.5000
13	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	10.5250
14	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	9.5000
15	7.	2.	10.	10.	10.	8.	1.	7.	7.	1.	3.	4.	9.1750

```
UCLB :      10.203200
MEANB:       9.406667
LCLB :       8.610129
Run Time : 14 hours and 18 minutes,
           on the faster new 386 computer in IE 277 Lab.
```

NMAX1.3

```
N (Maximum # of Replications)    :        20
NSIZE (Size of Neighborhood)     :         2
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0687
0	2.	1.	2.	1.	1.	1.	2.	1.	3.	3.	2.	1.	1.0833
1	1.	2.	1.	1.	1.	2.	1.	1.	4.	3.	1.	1.	4.0083
2	1.	1.	1.	1.	1.	3.	2.	2.	3.	4.	2.	1.	4.0462
3	1.	2.	2.	2.	1.	4.	3.	1.	2.	3.	2.	1.	4.1100
4	1.	2.	1.	2.	2.	5.	3.	2.	2.	4.	3.	1.	4.0667
5	1.	2.	2.	3.	2.	4.	4.	3.	2.	5.	2.	2.	4.1139
6	1.	1.	1.	3.	3.	5.	3.	3.	1.	4.	3.	2.	4.0656
7	1.	1.	1.	2.	3.	5.	4.	4.	1.	5.	4.	1.	4.1250
9	2.	1.	1.	1.	3.	3.	3.	4.	1.	7.	4.	3.	1.6667
10	3.	1.	1.	2.	4.	2.	4.	5.	1.	6.	3.	4.	6.5750
15	2.	1.	1.	3.	4.	2.	2.	3.	3.	5.	3.	5.	6.3438
16	3.	2.	2.	3.	4.	3.	1.	4.	3.	5.	2.	5.	9.0667
49	3.	2.	3.	3.	6.	3.	3.	5.	5.	6.	8.	6.	9.6036
51	4.	2.	2.	3.	4.	1.	3.	6.	5.	6.	8.	5.	9.0292
56	3.	3.	4.	2.	6.	1.	3.	5.	5.	6.	10.	2.	9.3063
148	7.	7.	3.	5.	5.	5.	8.	8.	9.	7.	7.	3.	10.4583
150	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	10.6125

Twenty runs of opt. config. with prod. rate

1	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	3.8750
2	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	6.7250
3	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.4250
4	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.0500
5	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.3500
6	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.7000
7	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	9.7250
8	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	9.8000
9	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.3000
10	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	9.4750
11	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	9.4500
12	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	6.6250
13	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.6250
14	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	10.6750
15	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.9250
16	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	7.5750
17	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	9.4500
18	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.2500
19	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	8.5250
20	8.	8.	4.	3.	5.	6.	9.	9.	9.	8.	7.	3.	9.4000

UCLB :   9.430607

```
MEANB:          8.446250
LCLB :          7.461893
MEANPB > UCLB. SET OPT=MEANPB
 501  7.  8.  6.  4.  7.  6. 10.  9.  8.  6.  5.  4.     9.7612
 504  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.    10.2167
Twenty runs of opt. config. with prod. rate
   1  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.0250
   2  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     8.5500
   3  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     8.4500
   4  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.6000
   5  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.6750
   6  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     7.7000
   7  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     8.4500
   8  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.    10.0500
   9  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.    10.0750
  10  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.    10.8750
  11  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.0500
  12  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.4750
  13  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.6750
  14  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     7.5250
  15  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.    10.7250
  16  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.0500
  17  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.2750
  18  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.5500
  19  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.6000
  20  6.  6.  3.  8.  7.  1.  9.  8.  3.  5.  3.  1.     9.9750
UCLB :          9.905492
MEANB:          9.317501
LCLB :          8.729510
MEANPB > UCLB. SET OPT=MEANPB
 511  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.    10.0000
Twenty runs of opt. config. with prod. rate
   1  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.0500
   2  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     8.8750
   3  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.    11.2000
   4  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.9000
   5  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     8.1500
   6  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     8.9500
   7  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     8.5000
   8  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.5500
   9  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.2750
  10  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.    10.2000
  11  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     8.5750
  12  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     7.5500
  13  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.8250
  14  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.5250
  15  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     8.7000
  16  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.2000
  17  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.2250
  18  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.    10.2000
  19  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.3250
  20  7.  6.  5.  8.  8.  2.  9.  5.  2.  3.  5.  1.     9.5750
```

```
UCLB :       9.807815
MEANB:       9.267500
LCLB :       8.727185

MEANPB > UCLB.  SET OPT=MEANPB
 521  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    10.1762
Twenty runs of opt. config. with prod. rate
   1  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     7.5750
   2  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    10.7500
   3  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     9.0500
   4  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     9.0750
   5  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    10.2000
   6  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    10.1500
   7  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     9.8000
   8  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     9.4750
   9  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     9.8750
  10  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     8.5250
  11  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    10.0750
  12  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    11.4500
  13  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    11.2000
  14  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     9.9000
  15  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     8.7000
  16  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    10.5250
  17  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    11.5750
  18  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.    11.2000
  19  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     8.9500
  20  8.   9.   8.   7.   7.   1.   6.   7.   2.   6.   5.   2.     9.5250
UCLB :      10.588160
MEANB:       9.878749
LCLB :       9.169335

Run Time : 17 hours and 45 minutes
           386 computer in Shezad's office.
```

NMAX2.1

```
N (Maximum # of Replications)   :        10
NSIZE (Size of Neighborhood)    :         4
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0850
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.0167
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	3.6063
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0833
3	1.	3.	3.	3.	1.	6.	4.	1.	3.	3.	3.	1.	4.0000
4	1.	1.	3.	4.	3.	6.	5.	1.	5.	4.	2.	2.	4.0750
5	2.	3.	1.	3.	1.	8.	3.	2.	5.	2.	7.	3.	6.7833
6	3.	3.	3.	3.	4.	6.	6.	3.	5.	1.	9.	2.	10.3000
13	4.	8.	6.	3.	5.	8.	2.	9.	1.	4.	7.	4.	9.5042
15	5.	6.	3.	2.	5.	8.	1.	6.	1.	1.	6.	4.	8.7125
16	4.	8.	4.	4.	4.	9.	1.	8.	3.	1.	8.	4.	9.6375
18	4.	10.	5.	3.	1.	8.	1.	6.	2.	1.	7.	4.	10.6500
24	3.	10.	9.	2.	2.	9.	3.	2.	1.	5.	6.	6.	9.3083
90	3.	8.	4.	5.	7.	10.	8.	10.	8.	2.	10.	7.	9.6750
101	6.	10.	6.	8.	9.	6.	2.	6.	10.	8.	8.	5.	10.2833
102	8.	10.	7.	7.	10.	4.	1.	6.	10.	8.	10.	4.	9.5929
112	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5972

Ten runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3250
2	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.0000
3	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3500
4	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.6750
5	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.9000
6	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.4500
7	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.5250
8	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	11.2000
9	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	9.3000
10	6.	3.	4.	9.	4.	7.	3.	7.	3.	6.	9.	10.	10.1000

```
UCLB :      10.999740
MEANB:      10.182500
LCLB :       9.365261
```

```
Run Time  : 13 hours and 31 minutes
            386 computer in IE 277 Lab.
```

164

NMAX2.2

N (Maximum # of Replications) : 15
NSIZE (Size of Neighborhood) : 4
JMAX (Max. # of Iterations) : 500
N2 (# of Extra Iterations, S2) : 10
NC (C value in Tj Equation) : 15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0650
0	1.	1.	2.	2.	1.	1.	1.	1.	2.	2.	1.	1.	4.0969
1	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	.8167
2	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	4.0833
3	2.	1.	1.	5.	4.	8.	3.	4.	4.	5.	5.	1.	6.4833
4	3.	1.	1.	3.	4.	10.	5.	2.	4.	4.	4.	3.	6.5333
5	2.	1.	1.	2.	3.	9.	5.	3.	6.	6.	4.	4.	6.2150
11	2.	9.	1.	3.	1.	9.	1.	1.	6.	1.	10.	2.	7.2667
13	2.	8.	3.	4.	3.	5.	1.	2.	9.	1.	10.	4.	7.9500
14	2.	6.	3.	4.	2.	4.	2.	1.	10.	2.	10.	5.	7.7173
15	4.	4.	3.	2.	1.	6.	2.	2.	10.	1.	10.	5.	8.4821
16	4.	6.	5.	4.	1.	6.	4.	1.	10.	1.	10.	3.	9.7917
18	5.	4.	2.	3.	1.	6.	2.	1.	8.	1.	8.	3.	9.0781
19	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	10.8375

Fifteen runs of opt. config. with prod. rate

1	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	9.7500
2	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	8.7750
3	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	8.2250
4	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	9.3500
5	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	8.7500
6	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	9.9000
7	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	11.4000
8	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	7.2500
9	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	8.6500
10	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	8.5750
11	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	9.1500
12	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	9.9250
13	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	8.2750
14	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	8.9500
15	4.	6.	3.	5.	1.	7.	1.	3.	10.	1.	10.	3.	10.3500

UCLB : 9.932273
MEANB: 9.151667
LCLB : 8.371060

Run Time : 12 hours
              386 computer in IE 441 Lab.

NMAX2.3

```
N (Maximum # of Replications)   :        20
NSIZE (Size of Neighborhood)    :         4
JMAX (Max. # of Iterations)     :       500
N2 (# of Extra Iterations, S2)  :        10
NC (C value in Tj Equation)     :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0687
0	2.	1.	3.	1.	1.	1.	3.	1.	4.	4.	2.	1.	1.3667
1	1.	2.	2.	1.	1.	3.	1.	1.	6.	3.	1.	1.	4.1167
2	1.	1.	1.	2.	1.	4.	2.	3.	5.	5.	3.	1.	4.0278
4	1.	3.	3.	3.	3.	7.	1.	3.	4.	4.	3.	1.	4.0795
5	1.	3.	5.	5.	4.	7.	2.	2.	4.	5.	3.	1.	4.0222
6	1.	2.	4.	5.	5.	9.	4.	2.	5.	6.	2.	2.	4.0833
7	3.	1.	4.	4.	5.	8.	3.	1.	10.	5.	2.	3.	6.6250
8	2.	2.	3.	6.	3.	10.	1.	1.	8.	4.	1.	2.	7.6250
9	4.	1.	2.	7.	5.	9.	1.	1.	9.	4.	1.	2.	6.5167
10	6.	2.	1.	6.	7.	10.	3.	1.	7.	2.	3.	2.	7.1500
11	8.	2.	3.	7.	5.	10.	2.	1.	4.	2.	3.	4.	9.1750
14	10.	2.	4.	7.	5.	7.	3.	3.	3.	2.	2.	1.	9.7827
44	4.	2.	10.	4.	8.	3.	4.	4.	3.	5.	8.	2.	9.2653
64	6.	6.	9.	7.	4.	10.	3.	7.	3.	3.	5.	5.	9.7850
67	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	10.4300

Twenty runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	10.8500
2	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	9.2500
3	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	8.9750
4	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	8.5000
5	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	8.2000
6	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	9.9250
7	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	11.9500
8	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	10.5750
9	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	8.7500
10	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	10.4000
11	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	11.0000
12	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	9.6500
13	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	9.5000
14	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	8.8000
15	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	9.1500
16	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	11.6000
17	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	10.6250
18	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	9.1500
19	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	9.5000
20	5.	7.	10.	5.	4.	9.	10.	10.	3.	2.	7.	5.	13.2250

```
UCLB : 10.842990     MEANB:  9.978749     LCLB :  9.114504
Run time : 18 hours and 50 minutes
            on 386 computer in Shezad's office.
```

NMAX3.1

N (Maximum # of Replications)   :   10
NSIZE (Size of Neighborhood)   :   4
JMAX (Max. # of Iterations)   :   500
N2 (# of Extra Iterations, S2)   :   10
NC (C value in Tj Equation)   :   15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	3.	7.	3.	3.	2.	2.	1.	2.	5.	3.	1.	1.	9.4583
1	3.	5.	5.	2.	1.	2.	1.	1.	5.	4.	1.	2.	3.9063
2	5.	6.	3.	3.	2.	3.	3.	1.	5.	5.	1.	1.	2.1972
4	7.	5.	3.	4.	3.	3.	1.	3.	4.	4.	1.	1.	4.5778
6	8.	6.	4.	4.	5.	3.	2.	9.	1.	9.	5.	3.	8.4667
7	9.	8.	4.	6.	7.	2.	4.	9.	1.	6.	6.	1.	9.5643
14	10.	9.	4.	10.	7.	7.	10.	5.	1.	5.	1.	3.	10.1750
21	4.	8.	2.	9.	6.	10.	8.	2.	7.	1.	4.	3.	9.5813
40	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8583

Ten runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9500
2	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	7.9250
3	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	11.5250
4	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.8500
5	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5750
6	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.8750
7	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	9.1000
8	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	8.5250
9	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.0750
10	7.	7.	7.	9.	8.	6.	4.	7.	1.	3.	9.	5.	10.9750

UCLB :   11.019880
MEANB: 9.837501
LCLB :   8.655117

Run Time : 14 hours and 44 minutes
          386 computer in IE 277 Lab.

NMAX3.2

```
N (Maximum # of Replications)    :        15
NSIZE (Size of Neighborhood)     :         4
JMAX (Max. # of Iterations)      :       500
N2 (# of Extra Iterations, S2)   :        10
NC (C value in Tj Equation)      :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0267
0	1.	3.	1.	1.	1.	2.	1.	1.	1.	1.	2.	2.	4.1000
1	1.	4.	1.	1.	1.	1.	1.	3.	2.	2.	1.	1.	4.0375
4	4.	4.	2.	1.	1.	1.	5.	3.	2.	2.	3.	2.	1.8000
5	5.	5.	3.	3.	1.	1.	6.	1.	1.	1.	4.	3.	9.7750
6	4.	4.	1.	3.	1.	1.	5.	2.	1.	1.	6.	4.	7.5750
7	5.	6.	3.	3.	1.	3.	5.	1.	1.	1.	8.	4.	9.2562
9	3.	8.	4.	3.	4.	8.	6.	1.	3.	3.	8.	6.	10.1500
10	2.	10.	5.	2.	6.	8.	4.	1.	7.	1.	9.	6.	7.7750
11	4.	10.	4.	4.	6.	6.	3.	1.	7.	1.	10.	8.	10.4583
12	5.	10.	2.	4.	8.	7.	4.	1.	5.	1.	8.	6.	9.0750
15	8.	10.	4.	6.	9.	8.	2.	2.	6.	5.	7.	10.	9.6821
20	5.	10.	7.	6.	6.	1.	5.	6.	1.	5.	1.	7.	10.3125
25	3.	9.	9.	5.	1.	2.	10.	4.	1.	5.	4.	1.	9.7150
31	7.	2.	4.	10.	2.	1.	9.	3.	2.	1.	6.	2.	8.5750
32	6.	4.	6.	10.	1.	1.	8.	4.	3.	1.	8.	4.	10.1036
33	4.	7.	7.	7.	1.	1.	7.	6.	1.	2.	10.	7.	9.3667
35	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	10.5083

Fifteen runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	9.0000
2	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	8.2500
3	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	10.1250
4	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	8.9750
5	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	9.5500
6	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	9.3250
7	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	11.1500
8	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	8.8500
9	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	10.2500
10	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	8.5500
11	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	11.1750
12	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	12.1000
13	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	9.6750
14	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	9.3750
15	4.	6.	6.	5.	4.	3.	9.	4.	1.	1.	6.	7.	9.4250

```
UCLB :     10.547040
MEANB:      9.718334
LCLB :      8.889627
Run Time : 17 hours 20 minutes.
           386 computer in IE 277 Lab (B/D).
```

NMAX3.3

```
N (Maximum # of Replications)     :        20
NSIZE (Size of Neighborhood)      :         4
JMAX (Max. # of Iterations)       :       500
N2 (# of Extra Iterations, S2)    :        10
NC (C value in Tj Equation)       :        15
```

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0338
0	1.	3.	1.	1.	1.	2.	1.	1.	1.	1.	2.	2.	4.0786
1	3.	7.	3.	3.	2.	2.	1.	2.	5.	3.	1.	1.	10.3250
8	8.	3.	5.	4.	5.	4.	3.	3.	8.	9.	2.	3.	8.9583
9	10.	3.	4.	5.	7.	5.	1.	2.	6.	9.	2.	4.	9.4232
11	10.	3.	7.	7.	4.	1.	1.	2.	7.	8.	3.	5.	8.9687
14	10.	5.	5.	10.	6.	1.	2.	3.	5.	4.	10.	10.	9.6100
77	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	11.3750

Twenty runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	10.7500
2	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	7.9250
3	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.4250
4	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.0500
5	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.2750
6	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.9500
7	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.2500
8	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	11.2750
9	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.2250
10	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.8000
11	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.3000
12	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	10.7000
13	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.7250
14	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.2500
15	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	10.6750
16	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	8.9500
17	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.8250
18	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.9250
19	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.4000
20	8.	8.	9.	4.	4.	4.	7.	6.	9.	3.	4.	5.	9.6250

```
UCLB :        10.173710
MEANB:         9.664999
LCLB :         9.156283
```

Run Time : 16 hours and 40 minutes.
          386 computer in IE 441 Lab.

NMAX4.1

N (Maximum # of Replications)	:	10
NSIZE (Size of Neighborhood)	:	2
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0450
0	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	8.0083
1	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	4.0917
2	2.	3.	6.	2.	1.	4.	2.	2.	2.	5.	4.	1.	7.8000
4	3.	5.	5.	2.	1.	6.	1.	2.	1.	7.	5.	1.	5.5750
5	2.	5.	5.	3.	1.	7.	1.	3.	1.	6.	4.	2.	8.0667
10	2.	6.	3.	2.	3.	7.	2.	7.	5.	5.	2.	1.	7.8525
11	3.	7.	4.	3.	4.	8.	2.	6.	4.	6.	3.	2.	9.6125
101	10.	10.	3.	5.	9.	7.	5.	3.	4.	8.	3.	6.	10.1188
202	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.8167

Ten runs of opt. config. with prod. rate

1	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.0250
2	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.9250
3	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5250
4	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.5750
5	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	10.2500
6	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.5000
7	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	7.8000
8	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	11.5750
9	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.2000
10	6.	8.	7.	9.	7.	9.	8.	5.	3.	9.	5.	5.	9.4750

UCLB : 10.336910
MEANB: 9.184999
LCLB : 8.033088

Run Time : 11 hours and 15 minutes
on the new 386 computer in IE 277 Lab.

NMAX4.2

N (Maximum # of Replications)	:	15
NSIZE (Size of Neighborhood)	:	2
JMAX (Max. # of Iterations)	:	500
N2 (# of Extra Iterations, S2)	:	10
NC (C value in Tj Equation)	:	15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0267
0	1.	2.	1.	1.	1.	2.	1.	1.	1.	1.	2.	2.	4.1000
1	1.	3.	1.	1.	1.	1.	1.	2.	1.	2.	1.	1.	4.0313
4	3.	3.	1.	1.	1.	1.	4.	3.	2.	2.	2.	2.	.9250
5	4.	4.	1.	2.	1.	1.	5.	2.	1.	1.	2.	3.	6.9917
6	2.	3.	2.	3.	1.	1.	5.	3.	1.	1.	2.	4.	8.1333
9	2.	2.	3.	3.	3.	2.	6.	3.	3.	4.	1.	4.	7.8850
10	3.	2.	2.	3.	4.	2.	5.	3.	2.	4.	1.	5.	9.5400
12	5.	2.	2.	5.	3.	1.	2.	5.	1.	6.	2.	3.	9.0167
15	4.	2.	4.	7.	6.	1.	1.	5.	2.	6.	2.	3.	10.0000
18	5.	4.	6.	6.	3.	2.	1.	4.	6.	9.	3.	3.	8.8375
19	4.	5.	6.	5.	4.	1.	2.	5.	5.	8.	3.	2.	9.9063
290	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	10.9500

Fifteen runs of opt. config. with prod. rate

	# machines				Bufin Size				Bufout Size				Production Rate
1	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	9.6500
2	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	9.0750
3	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	8.3500
4	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	9.0250
5	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	11.5250
6	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	9.4750
7	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	10.3500
8	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	7.0500
9	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	9.7250
10	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	10.5750
11	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	9.9500
12	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	10.3750
13	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	6.9250
14	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	8.5750
15	8.	8.	8.	7.	10.	1.	1.	6.	10.	4.	1.	7.	10.7500

UCLB	:	10.433170
MEANB	:	9.425000
LCLB	:	8.416828

Run Time : 18 hours and 45 minutes in 277 Lab

NMAX4.3

N (Maximum # of Replications) :   20
NSIZE (Size of Neighborhood) :   2
JMAX (Max. # of Iterations) :   500
N2 (# of Extra Iterations, S2) :   10
NC (C value in Tj Equation) :   15

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
0	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	4.0338
0	1.	2.	1.	1.	1.	2.	1.	1.	1.	1.	2.	2.	4.0786
1	2.	4.	2.	2.	1.	2.	1.	2.	3.	3.	1.	1.	7.8833
2	1.	4.	4.	1.	2.	3.	1.	2.	2.	4.	2.	1.	3.9917
3	1.	4.	5.	1.	1.	2.	1.	1.	1.	3.	3.	1.	4.1250
4	1.	5.	5.	1.	1.	3.	2.	1.	1.	4.	3.	1.	4.0571
5	2.	5.	5.	2.	3.	2.	4.	1.	3.	6.	2.	3.	7.8417
6	3.	6.	5.	3.	2.	3.	4.	1.	3.	7.	2.	2.	9.4812
7	4.	5.	5.	4.	2.	4.	5.	1.	5.	7.	1.	1.	10.0333
8	5.	4.	6.	3.	1.	5.	6.	1.	6.	7.	1.	1.	3.7500
9	5.	4.	7.	4.	1.	5.	5.	1.	7.	8.	2.	1.	7.6000
11	3.	5.	7.	3.	1.	4.	4.	2.	9.	9.	2.	3.	9.7417
12	2.	6.	7.	4.	1.	6.	4.	3.	10.	9.	3.	1.	7.9333
13	3.	5.	6.	4.	2.	7.	4.	4.	9.	10.	3.	1.	9.3300
24	2.	8.	4.	4.	4.	5.	1.	3.	6.	8.	2.	1.	7.9750
25	3.	8.	4.	3.	3.	5.	1.	3.	5.	8.	3.	2.	9.3000
26	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	10.2667

Twenty runs of opt. config. with prod. rate

Iter. #	# machines				Bufin Size				Bufout Size				Production Rate
1	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	11.1750
2	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	9.2500
3	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	10.3250
4	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	9.0000
5	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	10.4250
6	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	9.8500
7	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	8.1500
8	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	9.8250
9	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	10.1750
10	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	8.6750
11	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	10.2000
12	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	8.1750
13	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	10.4250
14	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	7.9250
15	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	8.9750
16	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	9.8500
17	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	9.4500
18	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	8.9750
19	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	7.7000
20	3.	9.	5.	4.	4.	5.	1.	3.	6.	7.	2.	3.	10.0750

UCLB :   10.075120
MEANB: 9.430000
LCLB :   8.784881   Run Time : 16.31 hours.