



YAŞAR UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MASTER THESIS

**A HYBRID FLOW SHOP SCHEDULING PROBLEM IN
INK PRODUCTION**

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MASTER OF INDUSTRIAL ENGINEERING

PRESENTATION DATE: 25.11.2016

BORNOVA / İZMİR
NOVEMBER 2016

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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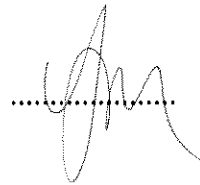
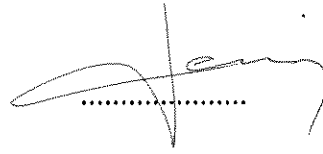
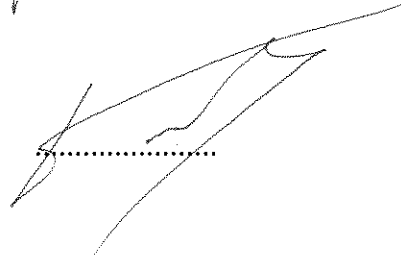
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ABSTRACT

A HYBRID FLOW SHOP SCHEDULING PROBLEM IN INK PRODUCTION

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November 2016

This study concerns with Hybrid Flow Shop Scheduling (HFS) problem and its real world application in a factory that produces ink and related special paints. There are many variations of HFS depending on the machine environment, process (job) characteristics and objective function. This study focus on a special variation that includes the constraints of machine blocking, sequence-dependent setup times, limited buffers and machine eligibility and having an objective of minimizing makespan. This variation is imposed by the properties of real production system in the factory. An original MIP model has been formulated to get the optimal solutions for small scale instances of the problem. The outcomes have been reported for a set of test problems. However, since HFS problems are classified as NP-hard, mathematical models are incapable of solving medium and large instances of the problem which may be seen in real world applications. Therefore, it is necessary to study heuristic methods. Different construction heuristics are used to generate initial schedule such as Shortest Processing Time and Longest Processing Time and their variants. To improve the initial solution, Simulated Annealing and Tabu Search methods are utilized with different control parameters. The performances of the heuristics have been evaluated on small scale problems by comparing with the optimal solutions obtained with MIP model. Finally, large scale problems have been generated to imitate real scheduling problems in the factory and their solutions have been reported.

Key Words: Hybrid Flow Shop Scheduling, Mathematical Modelling, Heuristics, Machine Blocking, Sequence-dependent Setup Times, Limited Buffers, Machine Eligibility

ÖZ

MÜREKKEP ÜRETİMİNDE ESNEK AKIŞ TİPİ ÇİZELGELEME PROBLEMİ

Aylin AKÇALI

Yüksek Lisans, Endüstri Mühendisliği Bölümü

Tez Danışmanı: Yrd. Doç. Dr. Adalet ÖNER

Kasım 2016

Bu çalışmada, Esnek Akış Tipi (EAT) çizelgeleme problemi ve çözüm yöntemleri ile bunların mürekkep üreten bir fabrikadaki gerçek çizelgeleme problemi üzerindeki uygulaması ele alınmıştır. Makine yapısına, işlem özelliklerine ve amaç fonksiyonuna göre EAT çizelgeleme probleminin birçok varyasyonu vardır. Bu çalışmada fabrikadaki gerçek üretim sürecinin dikte ettiği özel bir varyasyon üzerinde durulmuştur. Buna göre modelde makine bloklama, sıra bağımlı hazırlık süreleri, sınırlı kuyruk ve makine uygunluğu kısıtları bulunmalıdır. Amaç fonksiyonu da en son bitirilen işin tamamlanma zamanını en küçük değerine düşürmektir. Bu problemi çözebilmek için bir Karmaşık Tam Sayılı Doğrusal Programlama modeli geliştirildi. Bu model kullanılarak küçük ölçekli problemlerin en iyi çözümleri gösterildi. Ancak EAT çizelgeleme problemlerinin NP-zor karmaşıklık sınıfında olduğu bilindiğinden, bu model orta ve büyük ölçekli problemleri çözmede yetersiz kalmaktadır. Bundan dolayı, genellikle sezgisel yöntemlerin kullanması gerekliliği ortaya çıkar. Bu çalışmada farklı sezgisel yöntemler üzerinde durulmuştur. İlk çizelgeyi üretmek için, En Kısa İşlem Süresi, En Uzun İşlem Süresi ve bunların varyasyonları olan farklı kurucu sezgiseller kullanıldı. İlk çizelgeyi geliştirmek için ise, Tabu Arama (TA) ve Benzetimli Tavlama (BT) meta sezgiselleri farklı kontrol parametreleri ile kullanıldı. Sezgisel yöntemlerin performansı, küçük ölçekli problemlerde, daha önce matematiksel model ile elde edilen en iyi çözümlerle karşılaştırılarak değerlendirildi. Son olarak, fabrikadaki gerçek çizelgeleme problem örnek alınarak, büyük ölçekli problemler oluşturuldu ve bunların sonuçları rapor edildi.

Anahtar Kelimeler: Esnek Akış Tipi Çizelgeleme Problemi, Matematiksel Modelleme, Sezgisel Yöntemler, Makine Bloklama, Sıraya Bağlı Kurulum Süresi.

ACKNOWLEDGEMENTS

I would like to thank to my supervisor Asst. Prof. Dr. Adalet ÖNER for his support, valuable contributions, and advices. He believed in me to complete my thesis successfully.

I would like to thank to Prof. Dr. Levent KANDİLLER and Assoc. Prof. Dr. Raif Serkan ALBAYRAK for their support, advices, and valuable contributions. Most of all they believed in me.

I also want to state from the heart thank my family, and friends for supporting and believe in me. Especially I would like to thank to Emre DALOĞLU who always stand by me, believe in me and encourage me.

Aylin AKÇALI
İzmir, 2016

TEXT OF OATH

I declare and honestly confirm that my study, titled “Hybrid Flow Shop Scheduling Problem” and presented as a Master’s Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions, that all sources from which I have benefited are listed in the bibliography, and that I have benefited from these sources by means of making references.

Aylin Akçalı

Signature

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December 28, 2016

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS:

HFS	Hybrid Flow Shop
FFS	Flexible Flow Shop
M0	Basic Hybrid Flow Shop Model
MM0	Modified Model
M1	Hybrid Flow Shop Model with Machine Blocking
M2	Hybrid Flow Shop Model with Machine Blocking and Sequence Dependent Setup Times
M3	Hybrid Flow Shop Model with Machine Blocking, Sequence Dependent Setup Times and Limited Buffer
M4	Hybrid Flow Shop Model with Machine Blocking, Sequence Dependent Setup Times, Limited Buffers and Machine Eligibility
TS	Tabu Search
SA	Simulated Annealing
SPT	Shortest Processing Time
SPT1	Sorting jobs in ascending order according to their processing time in Stage-1
SPTcomp	Sorting jobs in ascending order according to their total completion times
LPT	Longest Processing Time

LPT1 Sorting jobs in descending order according to their processing time in Stage-1

LPTcomp Sorting jobs in descending order according to their total completion times

SYMBOLS:

C_{max} Makespan

i Processing stage

j Machine in a stage

k, l Jobs

M Number of stages

K Number of jobs

m_i Number of parallel machines in stage i

p_{ik} Processing time for job k in stage i

Q A large number

ε A small number

st_{ik} Starting time of job k at stage i .

x_{ijk} Job k is assigned to machine j in stage i

y_{ikl} Job k precedes job l at stage i

s_{ikl} Setup time for job l if job k is the immediately preceding job in sequence operation on the stage i

B Number of stages that have limited buffers

b_q Index for artificial stage corresponds to buffers

q Buffer

g Job Types

G Number of job types

S_i Set of machines in stage i

F_{ig} Set of machines for job type g in stage i

f_k Job type of job k

CHAPTER ONE

INTRODUCTION

Scheduling is a decision-making process that is used on a regular basis in many manufacturing and service industries. This form of decision-making plays an important role in procurement and production, in transportation & distribution, and in information processing & communication. Scheduling functions in company rely on mathematical techniques and heuristic methods to allocate limited resources to the activities that have to be conducted. The performance measures for scheduling may have different forms such as minimizing completion time of the activities, minimizing the number of tardy activities etc.

Scheduling problems can be classified depending on various factors. For example, they may be divided into two basic classes depending on the nature of the scheduling system:

- Static problems: All the jobs are ready for processing at the beginning of the scheduling period, i.e., ready times are zero.
- Dynamic problems: New jobs are added to the system as time goes on, i.e., nonzero ready times.

If uncertainty is considered, there is another classification of scheduling problems:

- Deterministic problems: All the quantities required to define the problem are known in advance and fixed (number of jobs, processing times, due dates etc.).
- Uncertain problems: All or some quantities required to define the problem have random components.

In manufacturing systems, orders are translated into the jobs which have to be processed on the machines with given order or sequence. Delay, preemption, unexpected events have to be considered because they may impact on the schedule. Manufacturing systems can be characterized by several factors, such as number of machines, configuration of machines, material flow system, and so on. Because of these characteristics, many variations of scheduling problems can be defined. Basic classification of machine scheduling problem is shown in Figure 1.

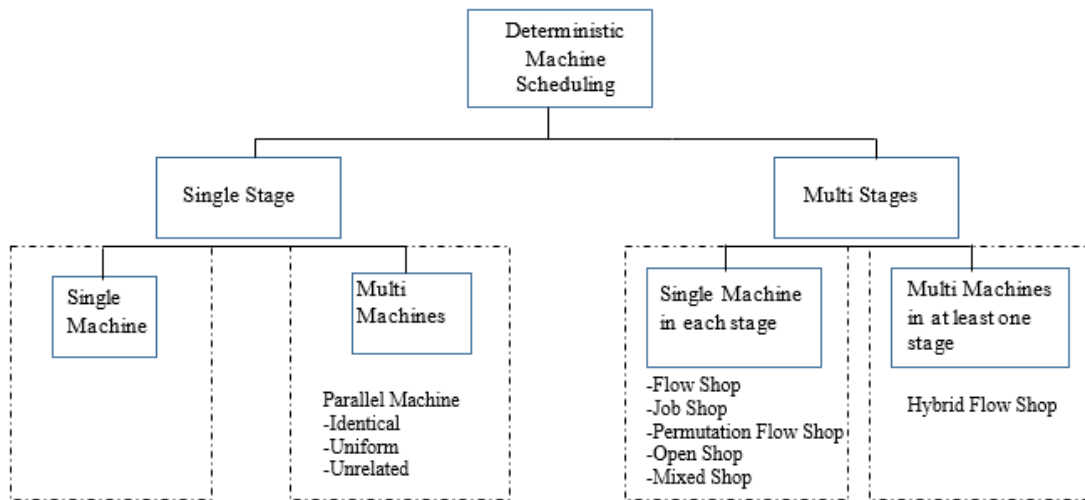


Figure 1. Basic Classification of Machine Scheduling Problems

This study is concerned with a specific variation of scheduling problems, namely, hybrid flow shop scheduling problem (HFS). The technical characteristics of the problem are given in detail in the next chapter. The inspiration came from a real production system at DYO Inks Company that is located in Manisa, Turkey. The company produces ink and related special paints. One of the production lines is designed in the form of HFS.

The rest of this thesis is organized as follows. Basic concepts, notations and detailed definition of HFS are given in Chapter 2. This chapter also includes the description of real production line at the company. Chapter 3 covers literature review of HFS scheduling problem. A mathematical model is formulated and its solutions for sample problems are presented in Chapter 4. Heuristic solution methods are discussed in Chapter 5. Finally, Chapter 6 is devoted to results and conclusion.

CHAPTER TWO

PROBLEM DEFINITION

Production scheduling briefly refers to finding best sequence and timing for processing a set of jobs through one or several machines. Practical and technological constraints such as flow pattern of the jobs through machines lead to different production models which are called flow shop, job shop, open shop, etc. In order to present a detailed definition of HFS, basic concepts and notation in scheduling are reviewed first.

2.1. Basic Concepts & Notations

The number of jobs is denoted by K , the number of stages denoted by M and the number of machines is denoted by N . The subscripts “ k ” and “ l ” refer to distinct jobs while subscripts “ i ” and “ j ” refer to stages and machines respectively. The following input data are associated with job k :

- **Processing time** is represented by p_{jk} and it represent the processing time of job k on machine j .
- **Release date** is represented by r_k and it is also known as ready time. It is time the job arrives at the system.
- **Due date** is symbolized by d_k and it represents the committed shipping and completion date. After due date, if job k is not completed, a penalty cost will be incurred.
- **Weight** is denoted by w_k and it is priority factor, reflecting the importance of job k relative to other jobs in the system.
- **Starting time** is represented by st_{jk} and it refers to job k starts its processing on machine j .
- **Completion time** is denoted by C_{jk} and it refers job k is completed on machine j .

There are many variations of machine scheduling problem depending on the machine environment, process (job) characteristics and objective. In literature, the taxonomy of scheduling problems is described by triplet $\alpha/\beta/\gamma$ (Graham et. Al, 1979). The first symbol α represent machine environment. The symbol β represents the

characteristics of processes (jobs) which refers to practical & technological constraints and assumptions. The symbol γ represents the objective function or performance measure of the problem.

2.1.1. Machine Environment

The first symbol α represent machine environment with two entries in the form of $\alpha_1\alpha_2$. Depending on the values of these two entries, possible machine environments can be described as follows.

If $\alpha_1 = \alpha_2 = 1$, then it indicates **single machine** problem which is the simplest of all possible machine environments. If there are more than one machine, then the environment is defined as $\alpha_2 = n$ where n indicates the number of machines. It implies that we have a **multi-machine** problem. In this situation, it assumed that the machines configured in parallel. If there is only one operation to be conducted on the jobs, and if any machine can perform the operation, then the problem is subdivided into three different environments.

- **Identical machines in parallel ($\alpha_1 = P$ and $\alpha_2 = n$)** : (Pn) : There are n identical machines and a job can be processed on any one of the machines. Then processing time of a job p_{jk} can be simplified into p_k since the processing time of a job is the same on any one of the machine.
- **Uniform machines in parallel ($\alpha_1 = Q$ and $\alpha_2 = n$)** : (Qn) : There are n machines in parallel with different speeds. Let v_j represent the speed of the machine, then the processing time of a job $p_{jk} = p_k/v_j$.
- **Unrelated machines in parallel ($\alpha_1 = R$ and $\alpha_2 = n$)** : (Rn) : There are n machines in parallel. The speeds of the machines are dependent on the jobs, such as machine j can process job k at speed v_{jk} . Thus the processing time of job k can be found as $p_{jk} = p_k/v_{jk}$.

On the other hand, if there are multiple operations to be conducted on the jobs, then the machines are assumed to be configured in “m” stages or blocks in series. It means that the jobs follow a flow pattern (route) through the machines. Depending on the flow pattern, different machine environments can be defined as follows:

- **Flow Shop ($\alpha_1 = F$ and $\alpha_2 = n$) :** (Fn) : There are n machines in series in the order of the operations. Each job should be processed on each one of the machines. Each job has the same flow pattern.

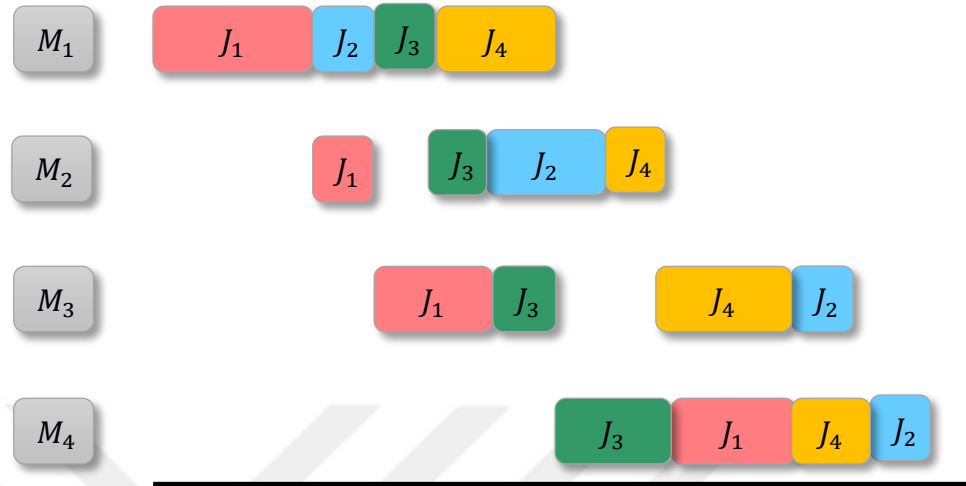


Figure 2. A Sample Schedule for Flow Shop

- **Permutation Flow Shop ($\alpha_1 = F$ and $\alpha_2 = n$) :** (Fn/permu) : There are n machines in series in the order of the operations. Each job should be processed on each one of the machines. Each job has the same flow pattern. Additionally, each machine has the same sequence of jobs. In other words, a permutation of jobs is applied to all machines. The problem here is to find an optimal sequence (permutation), applicable to all machines with respect to some performance measures.

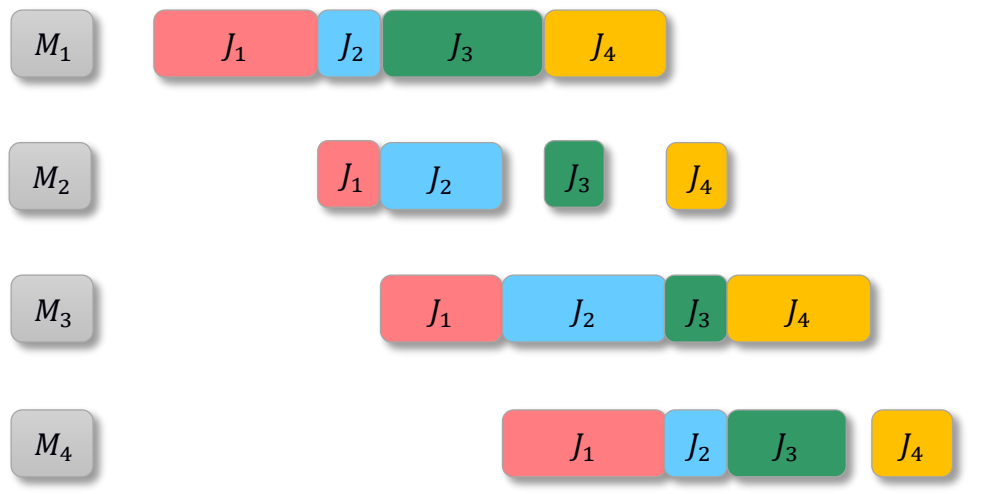


Figure 3. A Sample Schedule for Permutation Flow Shop

- **Job Shop** ($\alpha_1 = J$ and $\alpha_2 = n$) : (Jn) : There are n machines in series in the order of the operations. There are k jobs. Each job may not need to be processed on each one of the machines, however each job has to be processed more than one machine and the order does not have to be the same. It means, each job has unique processing sequence.

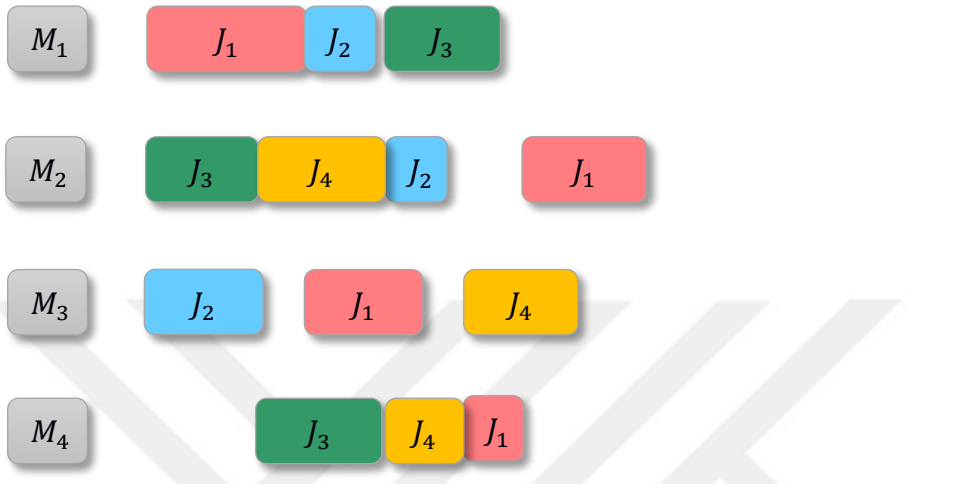


Figure 4. A Sample Schedule for Job Shop

- **Open Shop** ($\alpha_1 = O$ and $\alpha_2 = n$) : (On) : There are n machines in series in the order of the operations. There are k jobs. Each job should be processed on each one of the machines and the order does not have to be the same. It means, any ordering will do.

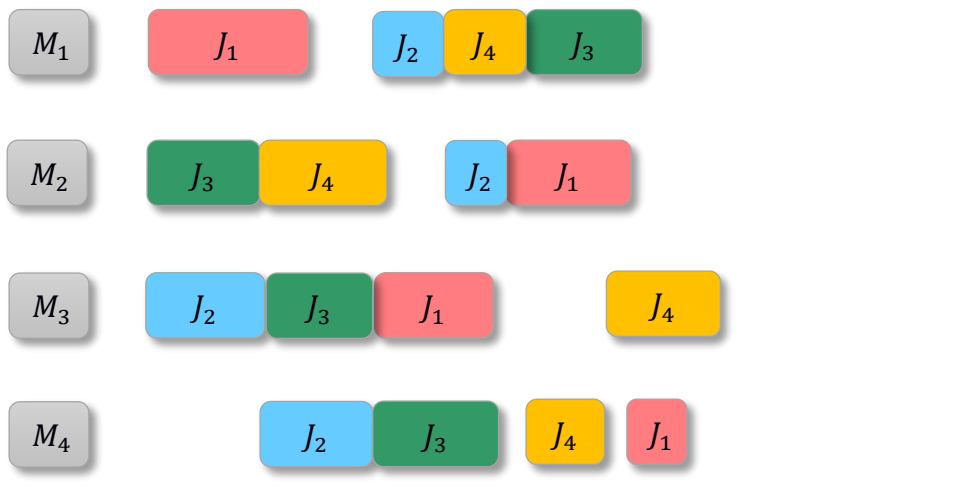


Figure 5. A Sample Schedule for Open Shop

- **Mixed Shop ($\alpha_1 = X$ and $\alpha_2 = n$) :** (Xn) : There is a subset of jobs and this gives fixed processing path which is specified. Jobs which are out of this subset being scheduled in order to minimize the objective function.

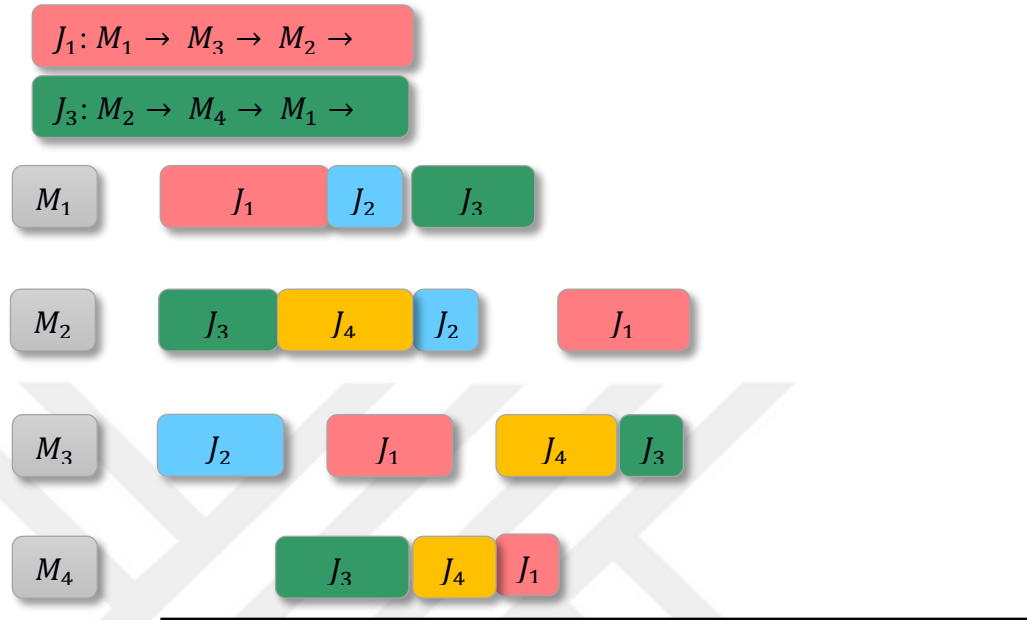


Figure 6. A Sample Schedule for Mixed Shop

- **Hybrid (Flexible) Flow Shop Models ($\alpha_1 = FH$ and $\alpha_2 = n$):** (FHn) :

A hybrid (flexible) flow shop is a combination of the flow shop and the parallel machine environments. Basic framework of HFS may be presented as follows:

- Manufacturing processes can be divided into “ m ” stages or blocks in series.
- Each job has to be processed first at stage 1, then at stage 2, and so on.
- Each stage has a number of machines in parallel. Different operating characteristics of the machines define different variants of the problem. If the processing speeds of all machines are the same for a job in a stage, the machines are called *identical* otherwise they are called *uniform*. If machines have different processing speeds depending on the jobs, then they are called *unrelated*.
- A job requires processing on only one machine in a stage. In a given stage, any machine or only a predetermined subset of machines can process the job (machine eligibility restrictions). Each case defines a different variant of the problem.

- Setup time may or may not incur between two successive jobs. Setup time may be constant or it may vary depending on the job sequence and/or machines. (sequence and/or machine dependent setup times)
- The queues between the various stages may have different structures. The system may have limited or unlimited buffer in between two successive stages. In other case, jobs may not allow to wait between stages (No wait)
- The objective is generally minimizing makespan or total tardiness or total completion time. There are also some other performance measures defined in literature.

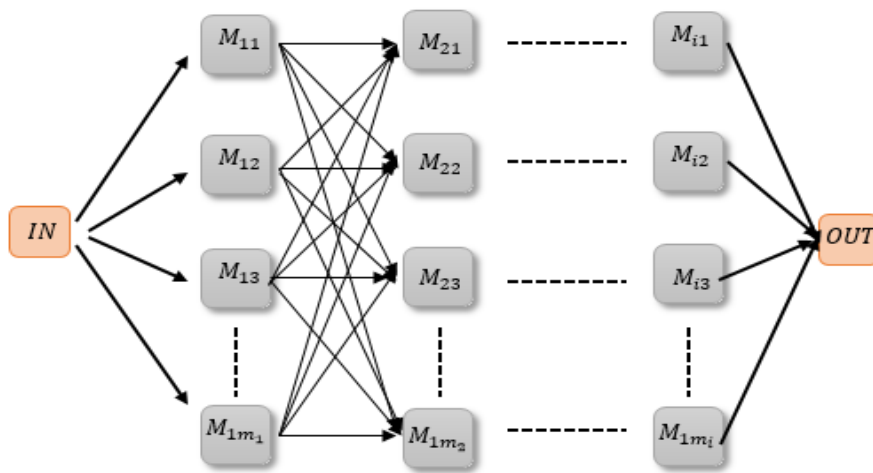


Figure 7. Process Flow in Hybrid Flow Shop Problem

2.1.2. Process (Job) Characteristics

The symbol β represents the characteristics of processes (jobs) which refers to practical & technological constraints and assumptions. Job characteristics may be listed as follows:

- $\beta = prmp$ presence of preemption.

Preemption is related to the priority of jobs. During execution of a job on a machine, for some reason, if it requires to interrupt the processing of that job before finishing the process and to start a new job immediately on that machine, then preemption occurs. There are different forms of preemption such as *preemptive-resume* and *preemptive-repeat*.

- $\beta = prec$ precedence constraints.

Precedence constraints refer to some technological constraints which contain the sequence and dependence relations between jobs. A job often can start only after a given set of other jobs has been completed. For example, job 4 in Figure 8 cannot be processed until job 1 and job 2 are completed and also job 6 cannot be started until job 4 and job 5 are completed.

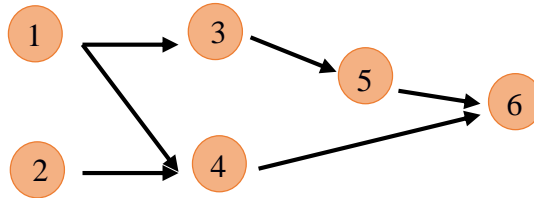


Figure 8. Example Precedence Constraint

- **$\beta = s_{kl}$ sequence dependent setup times**

Machines often have to be reconfigured and be cleaned between jobs. It takes some time which is called setup time. If the length of setup times depends on the job just completed and on about to be started, then the setup time is *sequence dependent*. If there is a setup time between job k and next job l on machine j , then setup time is represented by s_{jkl} .

- **$\beta = s_j$ machine dependent setup times**

If the length of setup times depends on the machine instead of sequence of the jobs, then the setup time is *machine dependent*.

- **$\beta = M_k$ machine eligibility restrictions**

Machine eligibility constraint is restriction of assignment. In other words, job k cannot be assigned machine j even if it is available. Job k can only be assigned to a machine which is a member of a specific subset of machines.

- **$\beta = \text{buffer}$, $\beta = \text{block}$**

During job processing, a queue may temporarily be formed before a machine. It requires a storage area before that machine. The size of the storage area determines the nature of the buffer. It may be zero, limited or unlimited. If the storage space between two machines is zero or limited and when the buffer is full, first machine cannot release the job which is completed and also cannot process other jobs. It leads to machine blocking.

- $\beta = no\ wait$

Jobs are not allowed to wait between two successive machines. It is due to either no buffer space between two machines or a technological requirement that implies the jobs shouldn't be waited between machines.

- **Workforce constraint** emerges in different situations. For example, the number of workers may be less than the number of machines. In the other case, some machines may require some skill set to operate and the number of workers that have required specific skill set may be less than the number of those machines. Therefore, a worker may be responsible more than one machine. It implies that job k would wait for processing on a machine until one of the operators become available.

- **Routing constraint** is relevant with the route that a job must follow through the system. The routing constraint specify the order of machines which a job must visit. This constraint applies especially when the jobs may skip some machines for processing.

2.1.3. Performance Measures (Objective Functions)

The symbol γ represents the objective. There are various basic objectives. Some of the best known basic objectives are explained below. In practice, overall objective is often expressed as a composite of several basic objectives.

- **Throughput**

Throughput is equivalent output rate and it is desired to be maximized. It is frequently determined by the bottleneck machine. There is a several ways to achieve. First one is, the bottleneck machine is never idle and all jobs wait in queue of these machine. Second, if there are sequence dependent setup times on the bottleneck machine, then the scheduler has to sequence the jobs in such a way that the sum of setup times or the average setup times, is minimized.

- **Makespan**

Makespan is defined as the time when the last job is completed and leaves the system. It is denoted by C_{max} .

$$C_{max} = \max (C_1, C_2, \dots, C_k, \dots, C_K) \text{ where } C_k \text{ is the completion time of job } k.$$

- **Due Date Related Objectives**

There are several objectives related with due dates. First one is minimizing the maximum lateness. The lateness of job k is defined by L_k and maximum lateness define by L_{max} .

$$L_{max} = \max (L_1, L_2, \dots, L_k, \dots, L_K)$$

$$L_k = C_k - d_k ,$$

where C_k : the completion time of job k

d_k : due date of job k

Another objective may be defined on the tardiness of jobs. This objective does not focus on how tardy a job actually is, but only on whether or not it is tardy. It concerns with the total tardiness, or the average tardiness. Tardiness is denoted by T_k .

$$T_k = \max (C_k - d_k, 0)$$

The objective function may be to minimize total or average tardiness:

$$\min \sum_{k=1}^K T_k \quad \text{Total tardiness}$$

$$\min \frac{\sum_{k=1}^K T_k}{K} \quad \text{Average tardiness}$$

If jobs have different priority weights, the larger weight of the job, the more important it is. In this case, the objective may be modified to include priority weights and represents the weighted total tardiness.

$$\min \sum_{k=1}^K w_k T_k \quad \text{Weighted total tardiness}$$

Due date objectives above do not penalizes the early completion of jobs. However, it is usually not advantageous to complete a job early, because storage cost and additional handling cost may occur. The earliness of job k is defined by E_k

$$E_k = d_k - C_k,$$

where C_k is the completion time of job k and d_k is due date of job k

- **Setup Costs**

If the throughput rate has to be maximized or makespan has to be minimized, it often occurs spontaneously that the setup times are minimized. Therefore, setup costs would also be minimized in that case, provided that setup costs are proportional with setup times. Unfortunately, it may not be true in practice. For

instance, setup time on a machine that has a lot of idle times may not be important, but a large amount of material waste may be occurred because of setup. For that reason, setup costs may be defined separately and the objective may be defined as minimizing total setup cost.

2.2. Case Study: Ink Production

In this study, a part of a real production system is considered as a case study. It involves in a specific production line of DYO Inks Company, Manisa, Turkey.

The company produces different types of inks such as newspaper and magazine inks, solvent-based ink, water-based ink, can coating, screen inks, sheet-fed inks. There are different production lines for each ink group. The case study focuses on the specific line which produces sheet-fed inks. Sheet-fed inks are used in printing books and journals in the publishing sector, posters and publications in the advertisement and graphic sector, paper and folio labels and all kind of cardboard packages in the packaging sector. Finished product is basically ink, but it is separated into different product types depending on the color. The machine environment, process (job) characteristics and flow of jobs in the sheet-fed line implies a Hybrid Flow Shop Scheduling (HFS) problem.

There are 4 stages and each stage has more than one machine in parallel. The first stage is called “**Pre-mix**”. In this stage, liquid raw materials such as varnish, oils and viscous materials (pigments) are mixed in containers. Processing time is different for each product type, however average process time is 60 minutes. The second stage is called “**Dispersion**”. The liquid and pigment mixture from first stage is grinded by ternary cylinders in this stage. In the next stage, some liquid agents are added into the mixture and vacuum operation is done. This stage is called “**Formula Completion**”. The fourth and the final stage is called “**Filling**” in which the mixture is blended first and then filled into dye vessels as finished product. The number of machines in parallel at each stage is 3, 8, 3 and 2, respectively. This production line is defined as **hybrid flow line** and its simplified structure is shown in Figure 9. The squares in the figure

represent the parallel machines. Each stage has its own operating characteristics which are discussed below.

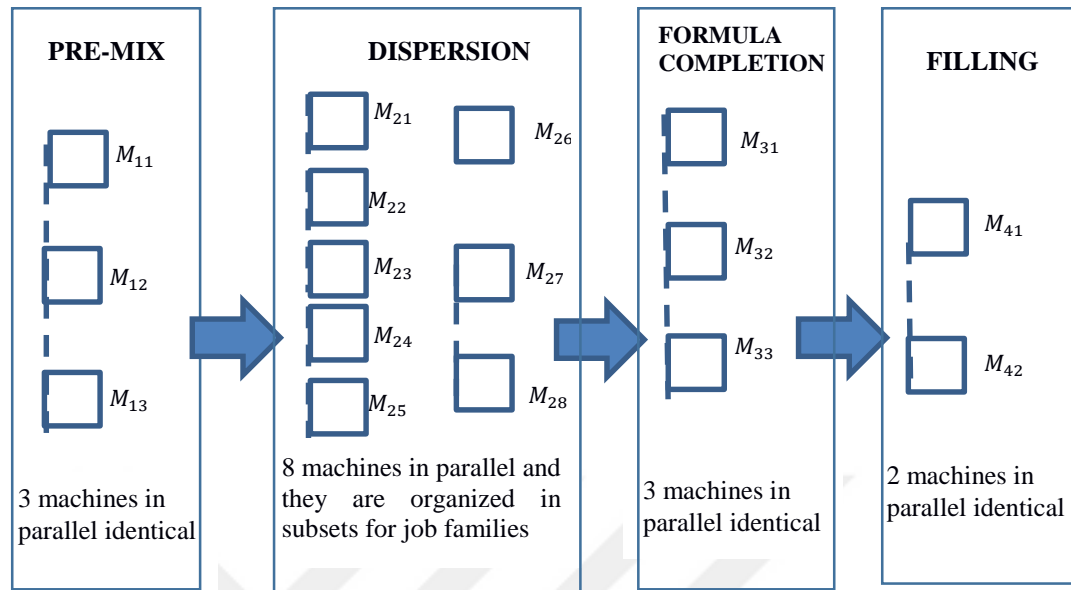


Figure 9. Structure of DYO Ink's Production Line

- **Setup Times**

Finished products are divided into 4 different color series (job families) which are yellow, red, blue and black. The jobs from the same family (color) may have different processing times, but they can be processed on a machine one after another without requiring any setup in between. However, if the machine switches over from one family (color) to another, then a set up time may incur. Therefore, we have **sequence dependent setup times**. It applies only for the first and third stage.

Table 1. Setup Time in DYO Ink's Production Line

	1. Stage	2. Stage	3. Stage	4. Stage
Setup	Sequence-Dependent	No	Sequence-Dependent	No

- **Precedence constraints:** There is no precedence constraint in the system.
- **Priorities:** Each job has the same priority throughout the system.
- **Preemptions** is not allowed in the system.
- **Machine Eligibility Restriction**

Stage 1, stage 3 and stage 4 have parallel identical machines on the other hand, there is machine eligibility restriction in stage 2 which has 4 machine groups related with job families. It refers that not all machines in this stage are capable of processing all jobs. It is due to dedication of subsets of machines for specific job families and each subset has parallel identical machines. A job coming from stage-1 is directed to the predetermined subset of machines depending on the family of job.

Table 2. Machine Eligibility in DYO Ink's Production Line

	1. Stage	2. Stage	3. Stage	4. Stage
Machine Eligibility	No	Yes	No	No

- **Limited Buffer:** The mixture obtained at stage-1 should not be waited too long before stage-2, otherwise chemical decomposition (decaying) may occur, and it is not desired. Tolerable waiting times can be converted into “limited buffers” in front of the machines at Stage-2. However, each machine group has different buffer capacities.

Table 3. Buffer in DYO Ink's Production Line

	Between Stage 1 and Stage 2	Between Stage 2 and Stage 3	Between Stage 3 and Stage 4
Limited Buffer	Yes	No	No

- **Machine Blocking:** Due to buffers between stage 1 and stage 2, machines in stage 1 can be blocked.

Table 4. Machine Blocking in DYO Ink's Production Line

	Stage 1	Stage 2	Stage 3	Stage 4
Machine Blocking	Yes	No	No	No

Based on the detailed description given above, the problem may be stated as follows:

$$\frac{FH4}{A} \left(\frac{P3^{(1)}, [P1_{(1)}, P3_{(2)}, P2_{(3)}, P2_{(4)}]^{(2)}, P3^{(3)}, P2^{(4)}}{B} \mid \frac{S_{sd}^{(1)}, block^{(1)}, buffer, M_k^{(2)}, S_{sd}^{(3)}}{C} \mid \frac{C_{max}}{D} \right)$$

- A: To state Hybrid Flow Shop Scheduling with 4 stages
- B: To represent machine types and machine numbers for each stage
- Part C: To indicate Job Characteristics of the System
- Part D: To show Objective Function (minimizing makespan)



CHAPTER THREE

LITERATURE SURVEY

Hybrid flow shop scheduling problem is encountered in many real world applications in different forms. Due to its relevance it has been studied extensively and hence has a wide range of literature.

First research about hybrid flow shop was introduced by Salvador (1970). His paper led other researchers to study on HFS problem. Garey and Johnson (1979) shown that the HFS problem with makespan minimization is NP-complete. The NP- nature of HFS problem has been studied along the years. In 1988, Gupta showed that the 2-stages HFS scheduling problem for makespan minimization NP- hard even if one stage has only one machine.

Many heuristics and approximation algorithms have been proposed for different variations of HFS depending on the machine configurations, job characteristics and objectives.

Ruiz and Vazquez- Rodriguez (2010) provided a comprehensive literature overview of HFS scheduling problem. They categorized studies depending on model structures and solution approaches. Their study provides the basis for our literature review. The list of studies included in their work has been extended by adding all relevant studies published after their work. However, some older papers (published before 1997) have not been taken into our list. Thus a list of 99 papers has been obtained. Their categorization has also been extended to obtain further information on modelling structures of the studies included in the list.

Two categorization tables have been prepared and presented in Appendix 1 and Appendix 2. The first table concerns with the modeling structures including the detail such as machine environments, job characteristics and objectives. In other words, this table shows which variant of HFS problem is considered in the respective study.

If that table is reviewed, it can be seen that the studies mostly consider parallel identical machines in machine environments. The distribution of machine environments is shown in Figure 10.

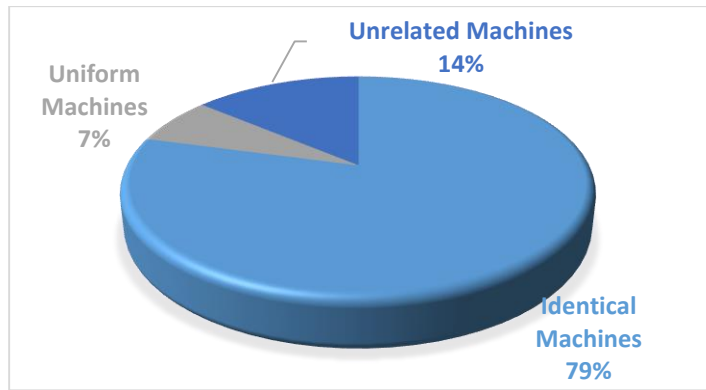


Figure 10. Distribution of Machine Types in Literature

If buffer limitation is considered, most of studies concerns with unlimited buffer condition. It is assumed that it is due to complications arose with limited buffers. Even if limited buffers are studied, it is usually assumed that buffer size is 0. The distribution of buffer constraints is shown in Figure 11.

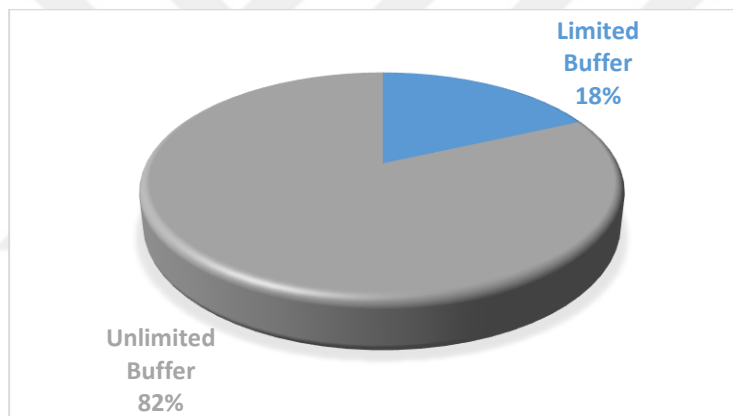


Figure 11. Distribution of Buffer Size in Literature

When setup times are considered, there are three categories which are “no setup times”, “sequence dependent setup times”, and “machine dependent setup times”. Researchers studied “no setup times” situation more than the others. The distribution of categories is shown in Figure 12.

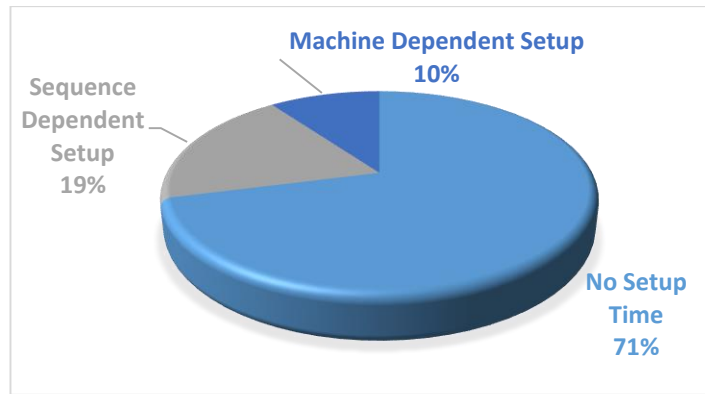


Figure 12. Distribution of Setup Time in Literature

There may be many different performance measures for hybrid flow shop scheduling problem. However, an overwhelming majority of studies considers the objective of “minimizing makespan”. Distribution of performance measures is shown in Figure 13.

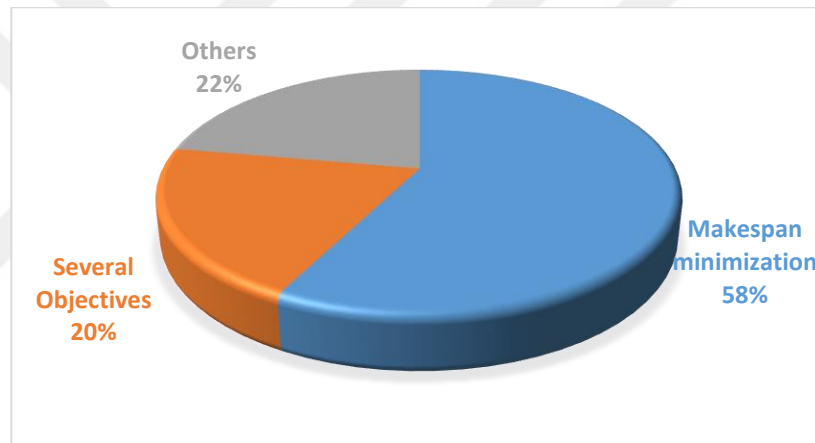


Figure 13. Distribution of Performance Measures in Literature

There are other constraints such as machines eligibility, preemption and precedence. There are few researches consider these constraints.

On the other hand, the table in Appendix-2 is related to solution methods, which are grouped as mathematical models, exact algorithms, heuristics and meta-heuristics. Distribution of solution approaches is shown in Figure 14.

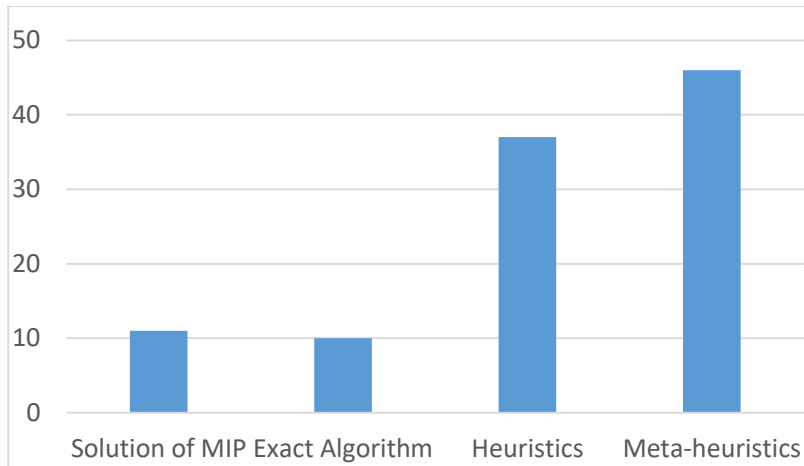


Figure 14. Distribution of Solution Methodology in Literature

If a study is attributed to “mathematical model” with respect to solution methodology, then its model structure has been further investigated. Table 5 shows the properties of those studies.

Table 5. Properties of Mathematical Models in Literature

Paper	Year	Model Structure	Solution Approach
Liu et al	2000	Basic Model + Sequence-dependent setup times (Minimizing tardiness, work in process and setup cost)	Lagrangian relaxation
Liu et al	2008	Basic Model + Batch Process, no buffers	
Sawik	2000	Basic Model + Limited Buffer (Blocking Scheduling)	
Sawik	2001	Basic Model + Limited Buffer (Blocking Scheduling)	
Sawik et al	2002	Basic Model + Limited Buffer (Blocking Scheduling)	
Sawik	2002	Basic Model + Limited Buffer (Batch Scheduling)	
Sawik	2005	Basic Model + Batch Process and Limited Buffer (Minimizing Tardy Jobs)	
Tang et al	2006	Basic Model + Limited Buffer (Total weighted completion time minimization))	Lagrangian relaxation
Tang et al	2006	Basic Model (Total weighted completion time minimization))	Lagrangian relaxation
Tavakkoli-Moghaddam et al	2007	Basic Model + Sequence-dependent setup times and Machine Blocking	
Xuan et al	2007	Basic Model + Sequence-independent setup times and Batch production (the weighted completion time and the penalty of job waiting minimization)	Lagrangian relaxation

If a study is attributed to “meta-heuristics” with respect to solution methodologies, then it is required to identify which particular heuristics is meant such as Simulated Annealing (SA), Tabu Search (TS), Genetic Algorithms (GA), and Neural Networks (NN). The following figure shows the distribution of particular meta-heuristics utilized in the studies.

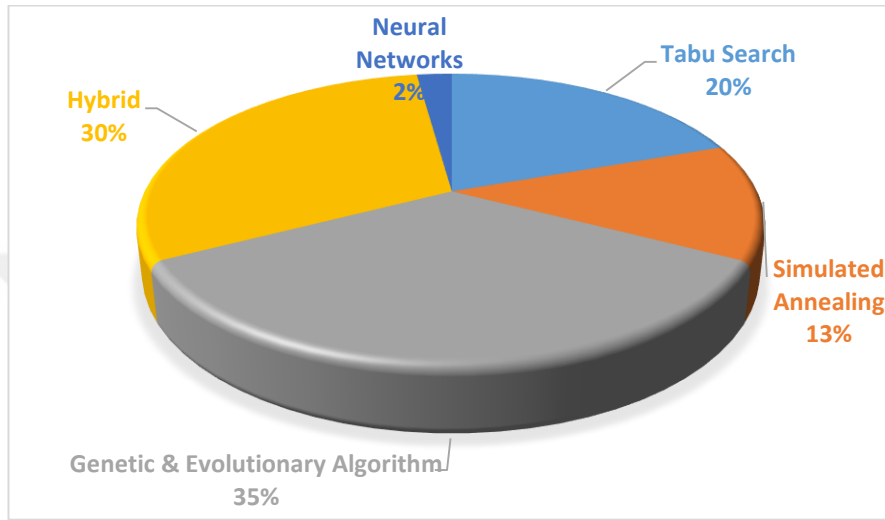


Figure 15. Distribution of Solution Methodologies in Literature

It is obvious that genetic and evolutionary algorithms take the greatest share. Tabu search and simulated annealing methods are the individual meta heuristic methods which follow genetic algorithm respectively. On the other hand, hybrid heuristics also take a considerable share. Neural network is the least preferred method among others.

CHAPTER FOUR

MATHEMATICAL MODEL

In literature, although it may be found many studies that concern with the HFS problem, there are only a few papers involve in developing a detailed mathematical model since it is shown that even “basic” HFS problem is proven to be NP-hard in Gupta (1988). Gupta defined a “basic” HFS problem and formulated a MIP model. The basic model includes the following properties:

- Manufacturing processes is divided into “m” stages or blocks in series.
- Each job has to be processed first at stage 1, then at stage 2, and so on.
- Each stage has a number of identical machines in parallel
- Machine eligibility is not considered.
- Setup time is ignored.
- Buffer is unlimited.
- Machine Blocking is not considered.
- The objective is minimizing makespan.

One of the studies which discusses the mathematical formulation of the basic model was presented by Wang et al (2003). Kurz and Askin (2004) improved the mathematical model to include sequence-dependent setup times. Furthermore, Tavakkoli et al (2007) extended their model by inserting “machine blocking” constraints. A detailed breakdown of their model, assumptions, input parameters, indices, decision variables, and mathematical formulation as follows:

- Machines are available at all times, with no breakdowns or scheduled or unscheduled maintenance.
- Job processing cannot be interrupted.
- There is no buffer between stages, and processors can be blocked.
- There is no travel time between stages.
- The ready time for all jobs is zero.

- Machines in parallel are identical in capability and processing rate.
- Non-anticipatory sequence-dependent setup times exist between jobs at each stage. After completing processing of one job and before beginning processing of the next job, some sort of setup must be performed.

Input Parameters

m = number of processing stage.

K = number of jobs.

n_i = number of parallel processors in stage i .

p_{ik} = processing time for job k in stage i .

s_{ilk} = processor setup time for job k if job l is the immediately preceding job on the processor i .

Indices

i = processing stage, where $i = 1, \dots, m$.

j = processor in stage, where $j = 1, \dots, n_i$.

k, l = job, where $k, l = 1, \dots, K$.

Decision Variables

C_{max} = makespan.

c_{ik} = completion time of job k at stage i .

d_{ik} = departure time of job k from stage i .

$x_{ijlk} = 1$, if job k is assigned to processor j in stage i where job l is its predecessor job; otherwise $x_{ijlk} = 0$. Two nominal jobs 0 and $K+1$ are considered as the first and last jobs, respectively (Kurz and Askin, 2004). It is assumed that nominal jobs 0 and $K+1$ have zero setup and process time and must be processed on each processor in each stage.

Mathematical Formulation

$Min C_{max}$

Subject to

$$\sum_{j=1}^{n_i} \sum_{l=0, l \neq k}^K x_{ijlk} = 1 \quad \forall i, k \quad (1)$$

$$\sum_{l=0, l \neq k}^K x_{ijlk} = \sum_{q=1, q \neq k}^{K+1} x_{ijkq} \quad \forall i, j, k \quad (2)$$

$$c_{1k} \geq p_{1k} + \sum_{j=1}^{n_i} x_{1j0k} S_{i0k} \quad \forall k \quad (3)$$

$$c_{ik} - c_{(i-1)k} \geq p_{ik} + \sum_{j=1}^{n_i} \sum_{l=0}^K x_{ijlk} S_{ilk} \quad \forall i > 1, k \quad (4)$$

$$c_{ik} \geq p_{ik} + \sum_{j=1}^{n_i} \sum_{l=0, l \neq k}^K x_{ijlk} (S_{ilk} + d_{il}) \quad \forall i, k = 1, \dots, K + 1 \quad (5)$$

$$c_{ik} = d_{(i-1)k} + p_{ik} + \sum_{j=1}^{n_i} \sum_{l=0}^K x_{ijlk} S_{ilk} \quad \forall i > 1, k \quad (6)$$

$$c_{mk} = d_{mk} \quad \forall k \quad (7)$$

$$C_{max} \geq c_{mk} \quad \forall k \quad (8)$$

$$x_{ijlk} \in \{0,1\} \quad \forall i, j, l, k \quad (9)$$

$$c_{ik}, d_{ik} \geq 0 \quad \forall i, k \quad (10)$$

The objective is to minimize the makespan. Constraint-1 ensures that each job k in every stage is assigned to only one processor immediately after job l . Constraint-2 is complementary to constraint 1. It is a flow balance constraint and it determines which processors at each stage must be scheduled. Constraint-3 calculates the complete time for the first available job on each processor at stage-1. Likewise, Constraint-4 calculates the completion time for the first available job on each processor in other stages, and also guarantees that each job is processed in all downstream stages with regard to setup time related to both the job to be processed and the immediately preceding job. Constraint-5 controls the machine blocking. Constraint-6 calculates the processing of a job depending on the processing of its predecessor on the same processor in a given stage. This constraint controls creating the processor's idle time. Both constraint sets 5 and 6 ensure that a job cannot begin setup until it is available and the previous job at the current stage is complete. Constraint-6 indicates that the processing of each job in every stage starts immediately after its departure from the previous stage and plus the setup time of the immediately preceding job. Constraint-7 ensures that each product leaves the system when it is completed in the latest stage. Constraint-8 defines the maximum completion time.

In our case study, operational characteristics of HFS problem implies that it includes limited buffers and machine eligibility restrictions in addition to machine blocking and sequence-dependent setup times. To the best of our knowledge, there is no formulation in literature which considers all those operational characteristics (constraints) together. Therefore, an original mathematical model is proposed to represent true properties of our real HFS problem. The model has the following assumptions.

1. Machines are available at all times. There are no breakdowns or maintenance.
2. Job processing cannot be interrupted (i.e., no preemption is allowed) and jobs have no associated priority values.
3. There are limited buffers between stage 1 and stage 2. Therefore, machines in stage 1 may be blocked if all machines are busy at stage 2 when jobs are finished at stage 1.
4. There is no travel time between stages; jobs are available for processing at a stage immediately after departing at previous stage.
5. The ready time for all jobs is zero.
6. Machines in parallel are identical at stage 1, stage 3 and stage 4 in capability and processing rate.
7. There are machine groups at stage 2 and these groups have parallel machines which are identical in capability and processing rate. Machine groups are defined since certain jobs can be processed only on certain machines or only a predetermined subset of machines. This requirement imposes “machine eligibility” constraints.
8. Sequence-dependent setup times exist between jobs at stage 1 and stage 3.

Development of proposed model will be presented in phases. In the first phase, all job characteristics are ignored and a standard (basic) model is defined. In the following phases, job characteristics will be inserted one by one to represent more realistic environments.

4.1. Basic Hybrid Flow Shop Model (M0)

The details of input parameters, indices, decision variables and mathematical formulation of the basic model are presented below.

Input Parameters

M = number of stages.

K = number of jobs.

n_i = number of parallel machines in stage i .

p_{ik} = processing times for job k in stage i .

Q = a large number.

Indices

i = processing stage, where $i = 1, \dots, M$.

j = machine in stage, where $j = 1, \dots, n_i$.

k, l = jobs, where $k, l = 1, \dots, K$.

Decision Variables

C_{max} = makespan.

st_{ik} = starting time of job k at stage i .

$x_{ijk} = \begin{cases} 1, & \text{if job } k \text{ is assigned to machine } j \text{ in stage } i \\ 0, & \text{otherwise} \end{cases}$

$y_{ijkl} = \begin{cases} 1, & \text{if job } k \text{ precedes job } l \text{ on machine } j \text{ at stage } i \\ 0, & \text{otherwise} \end{cases}$

Mathematical Formulation

Min C_{max}

Subject to

$$C_{max} \geq st_{ik} + p_{ik} \quad \forall i, k \quad (1)$$

$$y_{ijkl} \leq x_{ijk} \quad \forall i, j, k, l \text{ if } k \neq l \quad (2)$$

$$y_{ijkl} \leq x_{ijl} \quad \forall i, j, k, l \text{ if } k \neq l \quad (3)$$

$$1 + \sum_{k=1}^K \sum_{l=1, l \neq k}^K y_{ijkl} = \sum_{k=1}^K x_{ijk} \quad \forall i, j \quad (4)$$

$$\sum_{j=1}^{n_i} y_{ijkl} + \sum_{j=1}^{n_i} y_{ijlk} \leq 1 \quad \forall i, k, l \text{ if } k \neq l \quad (5)$$

$$\sum_{l=1, l \neq k}^K y_{ijkl} \leq 1 \quad \forall i, j, k \quad (6)$$

$$\sum_{k=1, k \neq l}^K y_{ijkl} \leq 1 \quad \forall i, j, l \quad (7)$$

$$\sum_{j=1}^{n_i} x_{ijk} = 1 \quad \forall i, k \quad (8)$$

$$\sum_{k=1}^K x_{ijk} \geq 1 \quad \forall i, j \text{ such that } K \geq n_i \quad (9)$$

$$\sum_{k=1}^K \sum_{j=1}^{n_i} j x_{ijk} \geq \frac{K(K+1)}{2} \quad \forall i \text{ such that } K < n_i \quad (10)$$

$$Q\left(1 - \sum_{j=1}^{n_i} y_{ijkl}\right) + st_{il} \geq st_{ik} + p_{ik} \quad \forall i, k, l \text{ if } k \neq l \quad (11)$$

$$st_{(i+1)k} \geq st_{ik} + p_{ik} \quad \forall i < M, k, l \quad (12)$$

$$st_{ik} \geq 0 \quad \forall i, k \quad (13)$$

$$x_{ijk} \in \{1, 0\} \quad \forall i, j, k \quad (14)$$

$$y_{ijkl} \in \{1, 0\} \quad \forall i, j, k, l \quad (15)$$

The objective is minimizing the completion time of last job (makespan). Constraint-1 finds the makespan. Constraints 2 and 3 are used for finding relationship between two jobs. It means if two jobs are assigned to same machine at any stage, these control that one of these jobs precedes the other. Precedence number is brought under control with constraint-4. Constraint-5 is also related to precedence and it provides that two jobs cannot precede each other. Constraints 6 and 7 are complementary to constraint 5. These make sure that one job can precede only one job and one job can be preceded by only one job. Constraint-8 guarantees all operations are assigned only one machine in each stage. Usage of each machine in each stage is controlled by constraints 9 and 10. One of these constraints is used according to job numbers and machine numbers. Constraints 11 and 12 control start times of each job in each stage. Constraint-11 provides that any job can be started at a stage if preceding job completes the process. Constraint-12 ensures that each job can be started at a stage if it has been completed at previous stage.

The number of decision variables and the number of constraints for this model (M0) can be expressed in terms of input parameters. Let N be total number of machines in the overall system, where

$$N = \sum_{i=1}^M n_i$$

Table 6. Number of Decision Variables in Model (M0)

	Source	Number Of Variables
Binary	x_{ijk} and y_{ijkl}	$(K^2N + KN)$
Real	st_{ik} and C_{max}	$(KM + 1)$

$$\begin{aligned}
\text{Number of Constraints} &= (3KM) + 2N + 2[K(K-1)N] + 2[(K-1)N] \\
&\quad + [K(M-1)] + 3 \left[\frac{K(K-1)M}{2} \right] \\
&= (3KM) + [(2N(1+K^2 - K + K - 1)] \\
&\quad + \left[K \left(\frac{(2M)-2+(3KM)-(3M)}{2} \right) \right] \\
&= (3KM) + (2K^2N) + \left[K \left(\frac{(3KM)-M-2}{2} \right) \right] \\
&= K \left[\frac{(5M) + (4KN) + (3KM) - 2}{2} \right]
\end{aligned}$$

For example, consider a HFS problem such that there are four stages. Stages 1 & 2 both have 2 identical machines in parallel. Stage-3 has one machine whereas Stage-4 has 3 identical machines in parallel. Assume that there are 100 jobs. This problem would have 80.800 binary variables, 401 real variables and 220.900 constraints.

The basic model above is reviewed whether it is possible to reduce the number of decision variables and number of constraints. It has been shown that a modified model (MM0) can be formulated using a different perspective. Modified model is based on the basic one, however the following changes have been made.

$\varepsilon =$ a small number

$$y_{ikl} = \begin{cases} 1, & \text{if job } k \text{ precedes job } l \text{ at stage } i \\ 0, & \text{otherwise} \end{cases}$$

Notice that decision variable y has now 3 indices instead of 4 as in previous basic model.

$$\left(\left(\left(\sum_{j=1}^{n_i} x_{ijk} \right) - \left(\sum_{j=1}^{n_i} x_{ijl} \right) \right) - 1 + \varepsilon \right) - Q(1 - y_{ikl}) \leq 0 \quad \forall i, k, l \text{ such that } k \neq l \quad (2')$$

$$\left(\left(\sum_{j=1}^{n_i} x_{ijk} \right) - \left(\sum_{j=1}^{n_i} x_{ijl} \right) \right) + 1 - \varepsilon + Q(1 - y_{ikl}) \geq 0 \quad \forall i, k, l \text{ such that } k \neq l \quad (3')$$

$$\sum_{k=1}^K \sum_{l=1, l \neq k}^K y_{ikl} = K - n_i \quad \forall i \quad (4')$$

$$y_{ikl} + y_{ilk} \leq 1 \quad \forall i, k, l \text{ such that } k \neq l \quad (5')$$

$$\sum_{l=1, l \neq k}^K y_{ikl} \leq 1 \quad \forall i, k \quad (6')$$

$$\sum_{k=1, k \neq l}^K y_{ikl} \leq 1 \quad \forall i, l \quad (7')$$

$$Q(1 - y_{ikl}) + st_{il} \geq st_{ik} + p_{ik} \quad \forall i, k, l \text{ such that } k \neq l \quad (11')$$

$$y_{ijk} \in \{1, 0\} \quad \forall i, j, k \quad (15')$$

Constraints 2' and 3' are used for finding relationship between two jobs. Precedence number is brought under control with constraint-4'. Constraint-5' provides that two jobs cannot precede each other. Constraints 6' and 7' are complementary to constraint 5 and these ensure one job can precede only one job and one job can be preceded by only one job. Constraint-11' controls start times of each job in each stage. It means any job can be started at a stage if preceding job completes the process.

The number of decision variables and the number of constraints for modified basic model (MM0) can be found as follows.

Table 7. Number of Decision Variables in Modified Model (MM0)

	Source	Number Of Variables
Binary	x_{ijk} and y_{ijkl}	$(K^2M) + N$
Real	st_{ik} and C_{max}	$(KM) + 1$

$$\text{Number of Constraints} = (3KM) + 11 \left(\frac{K(K-1)M}{2} \right) + [K(M-1)] + M + N$$

$$= \frac{(6KM) + (11K^2M) - (11KM) + (2M) + (2N) + (2KM) - (2K)}{2}$$

$$= \frac{(11K^2M) - (3KM) + 2(M + N - K)}{2}$$

If the same previous example is considered, the problem would have 40.008 binary variables, 401 real variables and 219.312 constraints.

Table 8. Comparison of Structure of Basic Model and Modified Basic Model

	Number of Decision Variables		Number of Constraints
	Binary	Real	
Basic Model (M0)	80.800	401	220.900
Modified Basic Model (MM0)	40.008	401	219.312

It is clear that the number of variables in modified basic model are much less than those of basic model. It leads to the expectation that the solution time in modified basic model would be decreased. In order to test this assumption, a sample problem has been designed. Sample problem involves 3 stages having 3, 2 and 4 identical machines in parallel respectively. Processing times are chosen randomly. Sample problem has been solved using both models and it is seen that the solution time is decreased considerably. The outcomes are summarized in the following table.

Table 9. Performance Comparison of Basic and Modified Basic Models

	Solution (C_{max})	Solution Time (seconds)
Basic Model (M0)	33	82.12
Modified Basic Model (MM0)	33	8.53

Henceforth we will use the modified basic model (MM0) in order to construct extended models by inserting additional constraints that represent more realistic environments.

4.2. Hybrid Flow Shop Model With Machine Blocking (M1)

When a job on a machine in any stage completes its operation, it moves to next stage for the next operation but all the machines at the next stage may be busy and hence unavailable at that time. In that case, the job is put in a queue in front of the next stage. However, there may be no space for a job queue (no buffer). Even if there is a space to allow a job queue, it is usually limited (limited buffer). If two successive stages have no buffer in between or if there is a limited buffer and the job queue is full, then the job does not move to next stage and it remains on and block the machine until a downstream machine or queue becomes available. It is called machine blocking. In order to include machine blocking situation in our model, a new constraint is inserted as follows:

Min C_{max}

Subject to

MM0 constraints (1) – (15)

$$Q(1 - y_{ikl}) + st_{il} \geq st_{(i+1)k} \quad \forall i < M \quad \forall k, l \text{ such that } k \neq l \quad (16)$$

Constraint-16 work with constraints 11 and 12 in model (MM0) and it provides that any job can be started if precedence job in downstream machine completes process.

Please note that machine blocking constraint works if there is no buffer between stages. If there is limited buffer, then the model has to be modified further. That situation is mentioned below in the model (M3).

4.3. Hybrid Flow Shop Model With Machine Blocking And Sequence Dependent Setup Times (M2)

Setup time is divided by two parts which are sequence dependent setup times, and machine dependent setup times. Sequence-dependent times depends on both the current and preceding job, and machine-dependent times depends on the current job to be processed. In our study only sequence dependent setup times are considered. In order to incorporate setup times, the model is modified as follows.

New Input Parameter

s_{ikl} = setup time for job l if job k is the immediately preceding job in sequence operation on the stage i .

Min C_{max}

Subject to

Model (M1) constraints (1) – (10) and (13) – (15)

$$Q(1 - y_{ikl}) + st_{il} \geq st_{ik} + p_{ik} + s_{ikl} y_{ikl} \quad \forall i, k, l \text{ such that } k \neq l \quad (11'')$$

$$st_{(i+1)k} \geq st_{ik} + p_{ik} + s_{(i+1)lk} y_{(i+1)lk} \quad \forall i < M \quad \forall k, l \text{ such that } k \neq l \quad (12')$$

$$Q(1 - y_{ikl}) + st_{il} \geq st_{(i+1)k} + s_{ikl} y_{ikl} \quad \forall i < M \quad \forall k, l \text{ such that } k \neq l \quad (16')$$

Setup time part is included in constraints 11', 12, and 16 in M1. As it is explained before, these constraints control start times of each job at each stage.

4.4. Hybrid Flow Shop Model With Machine Blocking, Sequence Dependent Setup Times And Limited Buffer (M3)

In this phase, "limited buffer" constraint will be inserted into the model. Please remember that the model (M2) above assumes that there is no buffer between stages. This assumption is inherited from model (M1). Sawik (2000) proposed an idea to surpass the difficulty and hence insert a "limited buffer" constraint. The idea is simple: add a dummy stage in between two true successive stages. Dummy stage has dummy machines with zero processing times. The number of dummy machines is equal to the size of buffer. In that case, you may still assume no buffer between stages, however dummy stage imitates "limited buffer". Sawik's idea may be incorporated in our model as follows.

New Input Parameters

B = number of stages that have limited buffers

b_q = index for artificial stage corresponds to buffers

New Indices

i = processing stage, where $i = 1, \dots, (M+B)$

q = buffer, where $q = 1, \dots, B$

Min C_{max}

Subject to

M2 constraints (1) – (11) and (13) – (15)

$$st_{(i+1)k} \geq st_{ik} + p_{ik} + s_{(i+1)lk} y_{(i+1)lk} \quad \forall i < M + B, k, l \quad (12'')$$

$$Q(1 - y_{ikl}) + st_{il} \geq st_{(i+1)k} + s_{ikl} y_{ikl} \quad \forall i < M + B \quad \forall k, l \text{ such that } k \neq l \text{ and } (b_q - 1) \leq i \leq b_q \quad \forall q \quad (16'')$$

Buffer stages are included in limits of 12'' and 16''. In addition, execution area of constraint 16'' is restricted.

4.5. Hybrid Flow Shop Model With Machine Blocking, Sequence Dependent Setup Times, Limited Buffers And Machine Eligibility (M4)

In a hybrid flow shop line, sometimes a job may not be processed on some of the machines at a stage because of some technical or technological limitations. In other words, parallel machines at a stage may not be capable of processing all jobs. This requirement (constraint) is defined as “machine eligibility”. In our case study, there are family groups (job types) and jobs can be processed only on the machines which are dedicated to the corresponding family groups. This rule applies only at Stage-2. In that stage, parallel machines are grouped depending on the family groups (job types). Machine eligibility constraint is inserted in our model as follows.

New Input Parameters

G = number job types

S_i = set of machine in stage i

F_{ig} = set of machines for job type g in stage i , $F_{ig} \in S_i$

f_k = job type of job k

New Indices

g =job types, where $g = 1, \dots, G$

$Min C_{max}$

Subject to

$M3$ constraints (1) – (16)

$$\sum_{j \in F_{ig}} x_{ijk} = 1 \quad \forall i, j, k, g \text{ such that } f_k = g \quad (17)$$

Constraint-17 guarantees that all jobs are assigned to machines according job types and machine groups at each stage.

4.6. Model Verification

For testing our model, 38 different test problems were generated. Test problems have the common characteristics shown in the following table.

Table 10. Common Characteristics of Test Problems

1	There are 3 stages.
2	Each stage has 2 machines in parallel. Stage-1 & Stage-3 has identical machines. On the other hand, machine eligibility constraint applies in Stage-2 which means each machine is dedicated to a specific job family.
3	There are 2 job families.
4	Buffer size is unlimited between Stage-2 and Stage-3. However, buffer size between Stage-1 and Stage-2 may change.
5	Sequence dependent setup times may occur in Stage-1. However, it happens only if two successive jobs are from different job families (having different color).

Test problems differ in the numbers of jobs & their job families and buffer capacities between Stage-1 and Stage-2. By this design, it is intended to test whether machine eligibility, limited buffer, machine blocking and setup time constraints actually work. Process times and setup times are determined randomly.

Table 11. Summary of Test Problems

Problem #	Number of Jobs	Distribution of Job Families	Processing and Setup Times	Buffer
1	6	KKKMMM=3K+3M	Random	Unlimited ^(*)
2				Limited (size 0)
3				Limited (size 1)
4				Limited (size 2)
5	6	KKKKMM=4K+2M	Random	Unlimited ^(*)
6				Limited (size 0)
7				Limited (size 1)
8				Limited (size 2)
9	7	KKKKMMM=4K+3M	Random	Unlimited ^(*)
10				Limited (size 0)
11				Limited (size 1)
12				Limited (size 2)
13	7	KKKKKMM=5K+2M	Random	Unlimited ^(*)
14				Limited (size 0)
15				Limited (size 1)
16				Limited (size 2)

Table 11 (cont'd). Summary of Test Problems

Problem #	Number of Jobs	Distribution of Job Families	Processing and Setup Times	Buffer
17	8	KKKMMMMM=3K+5M	Random	Unlimited ^(*)
18				Limited (size 0)
19				Limited (size 1)
20				Limited (size 2)
21	8	KKKKMMMM=4K+4M	Random	Unlimited ^(*)
22				Limited (size 0)
23				Limited (size 1)
24				Limited (size 2)
25	9	KKKKKMMMM=5K+4M	Random	Unlimited ^(*)
26				Limited (size 0)
27				Limited (size 1)
28				Limited (size 2)
29	9	KKKKKKMMM=6K+3M	Random	Unlimited ^(*)
30				Limited (size 0)
31				Limited (size 1)
32				Limited (size 2)
33	10	KKKMMMMMMM=3K+7M	Random	Unlimited ^(*)
34				Limited (size 0)
35				Limited (size 1)
36	10	KKMMMMMMMM=2K+8M	Random	Unlimited ^(*)
37				Limited (size 0)
38				Limited (size 1)

(*) If we remove Constraint (16'') then model can solve problems with unlimited buffer

Test problems were solved using IBM ILOG CPLEX Optimization Studio on a PC with Intel® Core™ i7-5500U CPU @ 2.40GHz (4 CPUs) and 8.00 GB RAM. The outcomes were examined carefully whether machine eligibility, limited buffer, machine blocking, and setup time constraints work properly. It has been confirmed that all constraints are working and the model provides consistent and reasonable solutions. The outcomes are reported in detail in Appendix-3. However, in order to show the details, problem # 17, 18 and 19 are selected as showcase examples and their outcomes are discussed below. Remember that these problems are all having 8 jobs and having the same distribution of job families. Only buffer sizes are different. Input values and outcomes are listed in the following tables.

Table 12. Processing Times and Job Families of Jobs in Showcase Examples

Jobs:	1	2	3	4	5	6	7	8
1. Stage	18	1	2	2	1	3	1	15
2. Stage	7	7	1	18	8	14	1	10
3. Stage	20	6	5	18	11	5	1	7
Job Family	M	M	K	M	K	M	M	K

Table 13. Setup Times in Showcase Examples

Jobs	1	2	3	4	5	6	7	8
1	0	0	0	0	1	0	0	4
2	0	0	5	0	3	0	0	0
3	3	3	0	1	0	1	2	0
4	0	0	4	0	5	0	0	1
5	4	5	0	1	0	3	1	0
6	0	0	1	0	1	0	0	2
7	0	0	2	0	1	0	0	4
8	3	4	0	3	0	1	1	0

Table 14. Solutions of Showcase Problems

Problem #	Machine #	Job Sequence			C_{max}	Solution Time (seconds)
		First Stage	Second Stage	Third Stage		
17 (unlimited buffer)	1	7-5-3-6-2-8	3-5-8	7-5-1-6	53	7.80
	2	4-1	7-4-1-2-6	3-4-2-8		
18 (No buffer)	1	7-3-5-8-6	3-5-8	7-3-5-1-6	53	29.22
	2	4-1-2	7-4-1-2-6	4-2-8		
19 (limited buffer=1)	1	7-3-5-8-6	3-5-8	7-3-5-1-6	53	318.11
	2	4-1-2	7-4-1-2-6	4-2-8		

The starting and completion times of jobs at different machines and stages are shown in Figure 16, Figure 17 and Figure 18.

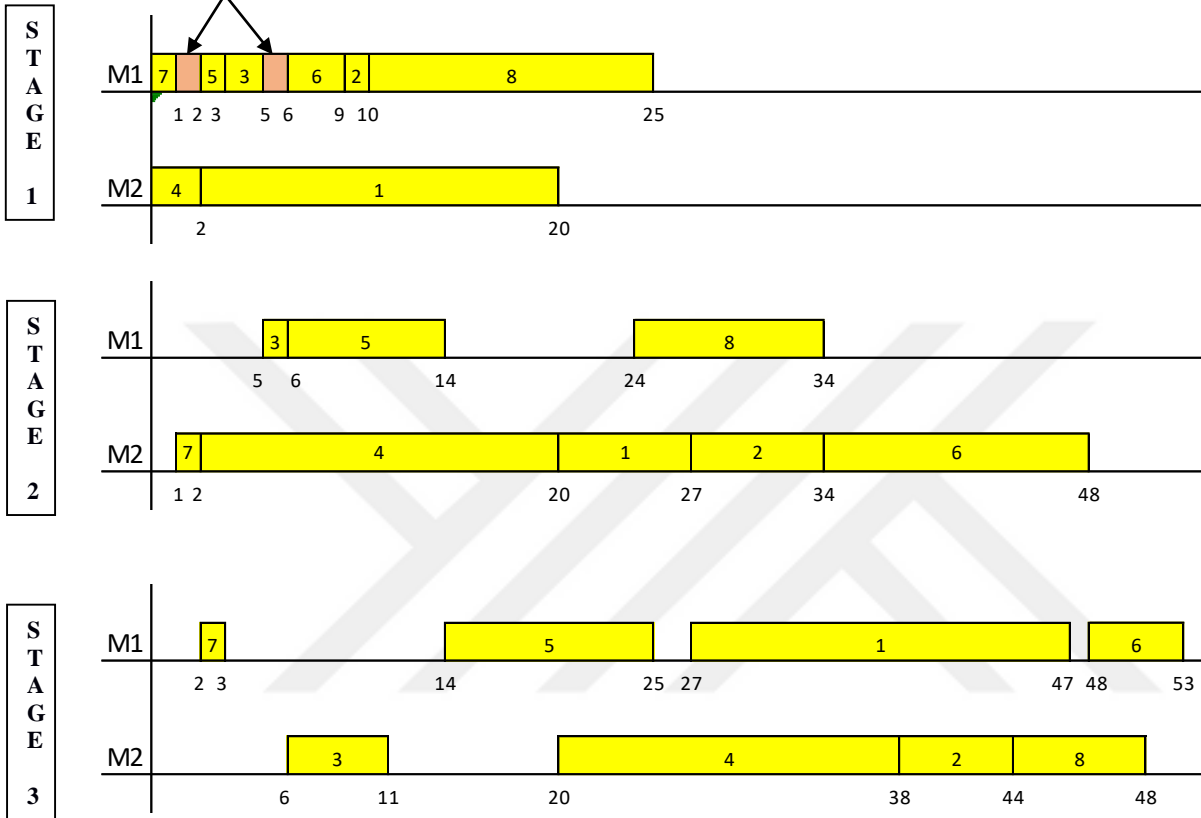


Figure 16. Solution of Problem 17 (Unlimited Buffer)

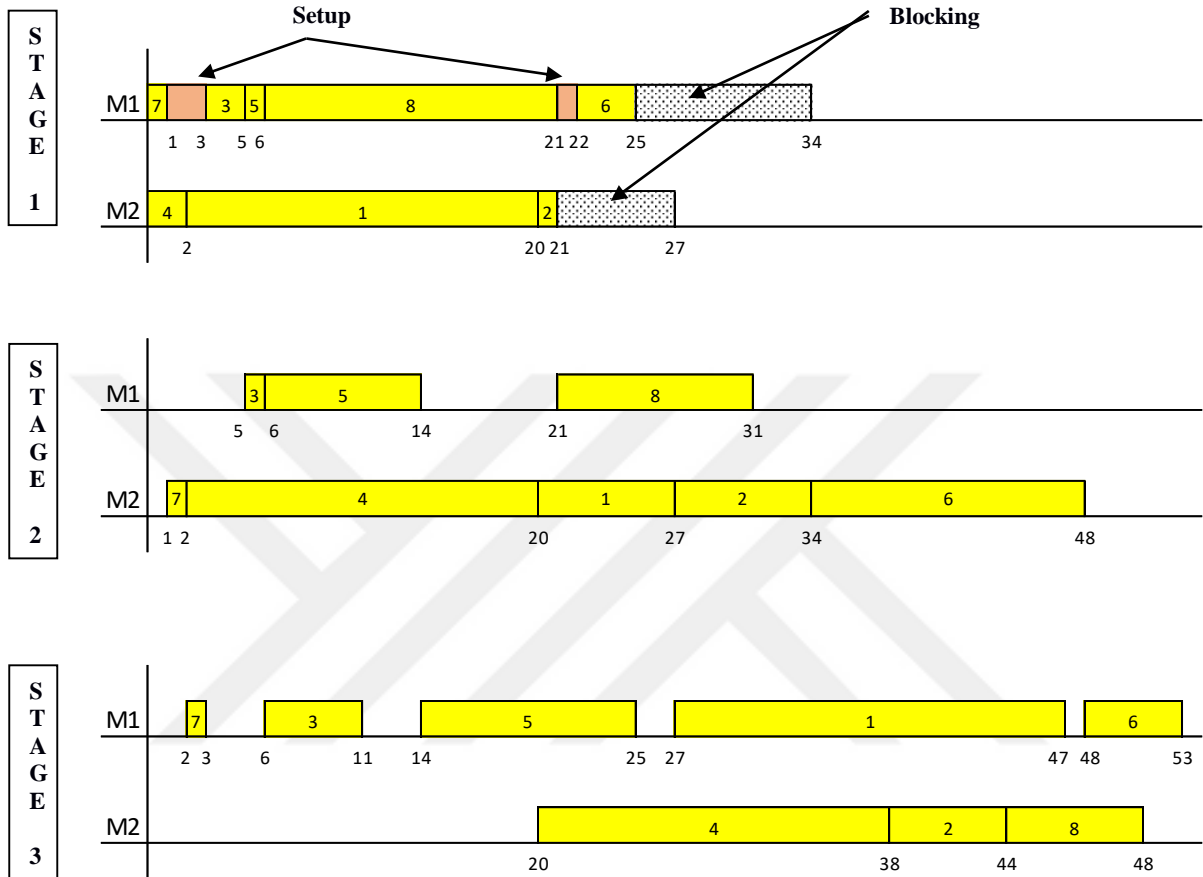


Figure 17. Solution of Problem 18 (Limited Buffer Size 0)

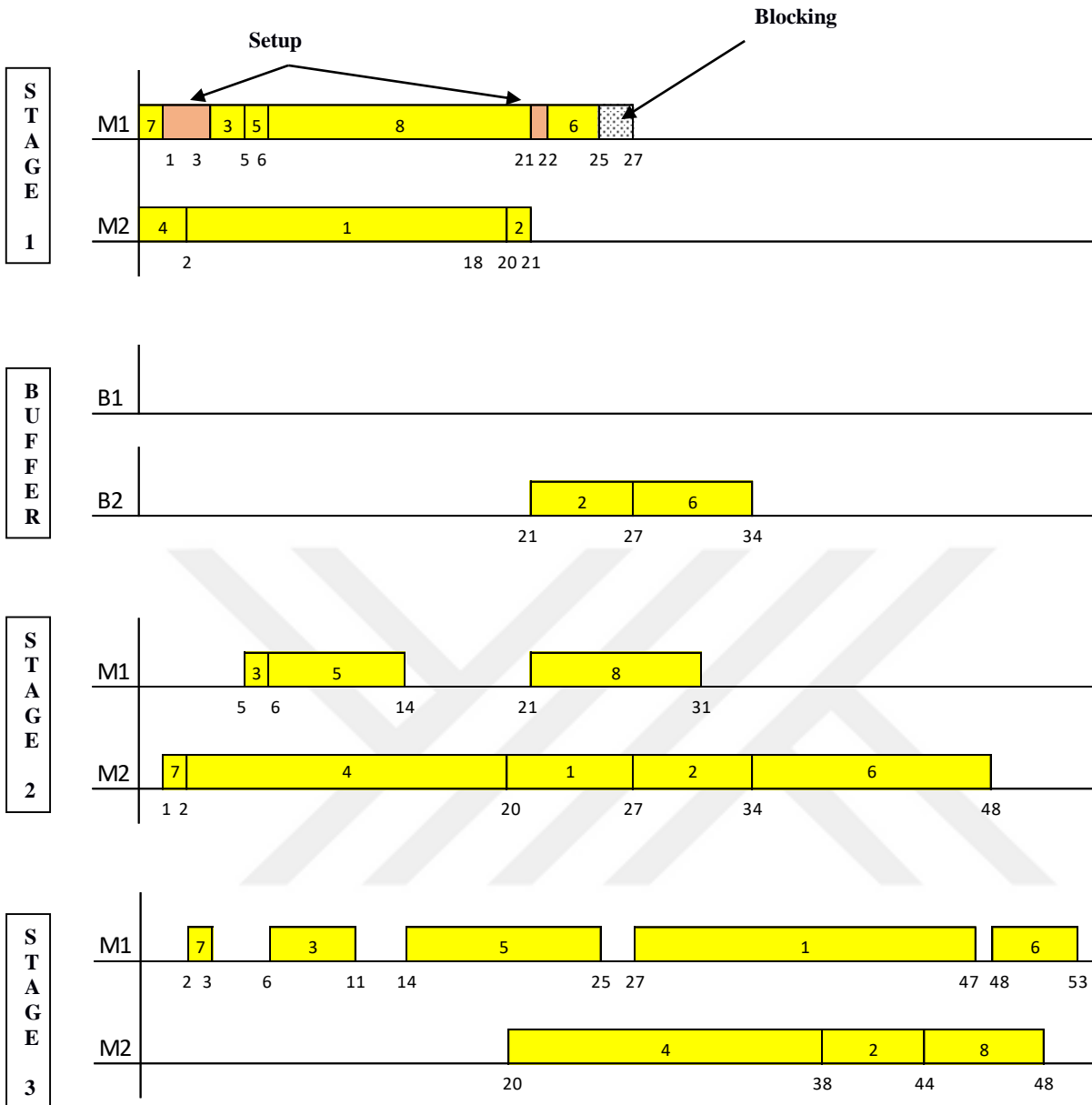


Figure 18. Solution of Problem 19 (Limited Buffer Size 1)

4.7. Experimentation On The Solution Times

Solution times of the test problems discussed in the verification section above have been recorded and presented in the table below. As expected, the solution times increase as the number of jobs increases. Even when the number of jobs is just 10, solution time is high enough and therefore we did not try to solve HFS problems using that mathematical model if we have more than 10 jobs. It imposes that MIP model is impractical to solve HFS problems if we consider real life environments in which the number of jobs may easily be around 100 or more than that. Another observation is

that solution times are generally higher if buffer size is 1 when compared to buffer size is 0 or infinite.

Table 15. Solution Times of Test Problems

	Number of Jobs	6	6	7	7	8	8	9	9	10	10
		Solution Times (seconds)									
Buffer Size	Infinite	1.12	2.40	3.23	4.82	7.80	10.14	22.42	1135.18	5404.16	7459.63
	0 (No buffer)	1.00	1.03	3.20	5.12	29.22	11.46	8.17	193.50	1145.48	9092.84
	1	3.33	5.09	3.45	13.12	318.11	290.61	361.38	859.60	13365.39	13365.39
	2	0.98	4.27	7.26	77.19	366.27	378.47	301.24	11205.89	-	-

In order to determine the effects of other factors on solution times, it is decided to prepare some supplementary sets of test problems. The idea is to investigate the effects of changing the number of stages and the number of machines in those stages. The first problem set has 2 stages whereas the second one has 3 stages. The numbers of machines in the stages are changed inside the sets. Common characteristics of each set and solution times are given in the following tables.

Table 16. Common Characteristics of Supplementary Test Problems – Set 1

1	There are 2 stages.
2	Each stage has identical machines.
3	Sequence dependent setup times may occur in Stage-1. However, it happens only if two successive jobs are from different job families

Table 17. Solution Times of Supplementary Test Problems – Set 1

Problem #	Number of Jobs	Number of Machines		Buffer Size	Solution Time (Seconds)
		Stage 1	Stage 2		
1	7	2	1	0	18.92
2		2	1	1	3546.45
3		1	2	0	3.48
4		1	2	1	22.29
5		2	2	0	2.64
6		2	2	1	102.95
7		3	4	0	1.45
8		3	4	1	2.85

Table 17 (cont'd). Solution Times of Supplementary Test Problems – Set 1

Problem #	Number of Jobs	Number of Machines		Buffer Size	Solution Time (Seconds)
		Stage 1	Stage 2		
9	8	2	1	0	111.53
10		2	1	1	4931.14
11		1	2	0	91.87
12		1	2	1	416.71
13		2	2	0	79.15
14		2	2	1	147.36
15		3	4	0	3.79
16		3	4	1	13.15
17	9	2	1	0	4315.76
18		2	1	1	11533.15
19		1	2	0	355.69
20		1	2	1	3823.12
21		2	2	0	244.95
22		2	2	1	3623.20
23		3	4	0	6.00
24		3	4	1	261.90

Table 18. Common Characteristics of Supplementary Test Problems – Set 2

1	There are 3 stages.
2	Stage-1 & Stage-3 have identical machines. On the other hand, machine eligibility constraint applies in Stage-2 which means each machine is dedicated to a specific job family.
3	There are 2 job families.
4	Sequence dependent setup times may occur in Stage-1. However, it happens only if two successive jobs are from different job families.
5	There is no buffer between Stage-2 & Stage-3.

Table 19. Solution Times of Supplementary Test Problems – Set 2

Problem #	Number of Jobs	Number of Machines			Buffer Size	Solution Time (Seconds)
		Stage 1	Stage 2	Stage 3		
1	7	2	2	1	0	16.98
2		2	2	1	1 ^(*)	66.39
3		2	2	2	0	3.04
4		2	2	2	1 ^(*)	4.33
5		2	2	3	0	2.18
6		2	2	3	1 ^(*)	7.32
7		2	2	4	0	2.02
8		2	2	4	1 ^(*)	2.54
9	8	2	2	1	0	372.84
10		2	2	1	1 ^(*)	1463.36
11		2	2	2	0	13.90
12		2	2	2	1 ^(*)	15.62
13		2	2	3	0	5.20
14		2	2	3	1 ^(*)	6.02
15		2	2	4	0	5.37
16		2	2	4	1 ^(*)	6.21
17	9	2	2	1	0	25561.42 (out of memory)
18		2	2	1	1 ^(*)	19264.95 (out of memory)
19		2	2	2	0	73.41
20		2	2	2	1 ^(*)	467.87
21		2	2	3	0	49.24
22		2	2	3	1 ^(*)	325.48
23		2	2	4	0	80.74
24		2	2	4	1 ^(*)	2000.78

(*) There are limited buffers with size =1 for each job type

After examining the tables, the following observations may be stated.

- The solution time increases rapidly as the number of jobs increases.
- If one of the stage other than the first stage has only one machine, solution time increases.
- If there is a limited buffer between stages and if its size is equal to 1, then solution time is increased. Please remember that the buffers are represented as dummy stages with dummy machines in parallel. The size of the buffer equal to the number of dummy machines. Therefore, a buffer with size equal to 1 means a stage with one machine in between other stages. This situation is in compliance with the previous observation.

If the number of stages is increased, then solution time increase in general, however its effect is limited if the number of parallel machines increases.

CHAPTER FIVE

HEURISTIC METHODS

Since HFS problems are NP-hard, it is not practical to use MIP models to solve large scale HFS problems. Furthermore, there are no simple rules or exact algorithms to find optimal solutions in a reasonable time. Therefore, heuristic solution methods are used in literature to solve HFS problems.

The heuristic algorithms can be classified as “construction heuristics” and “improvement heuristics”. Dispatching rules are examples of the construction heuristics in which an initial solution (schedule) is generated. On the other hand, improvement heuristics start with the initial schedule and try to find better schedules. Local search methods are examples of improvement heuristics.

The aim of this chapter is to review how heuristic methods can be used to solve HFS problems. The main idea is to implement some “construction heuristics” to generate an initial single solution (schedule) and then to use meta-heuristic methods to improve the initial schedule gradually and eventually provide a sufficiently good solution (schedule).

5.1. Construction Heuristics – Dispatching Rules

A dispatching rule is a rule that give priority to all the jobs that are waiting for processing. When a machine has been freed, a dispatching rule checks the waiting jobs, selects the job with the highest priority and adds the job in schedule. Job’s attributes and machine’s attributes may be considered for prioritization.

Dispatching rules can be divided two categories which are static and dynamic rules. Static rules are not time dependent and they are only a function of machine and job data. On the other hand, dynamic rules are time dependent. Other classification of dispatching rules is according to job information and it is divided two categories which are local rules and global rules. Local rules use only connection to either the queue where the job is waiting or the machine where the job is queued. On the other hand, global rules use information connection to other machines like the processing time of the job on the next machines or the current queue length at that machine.

There are various dispatching rules. However, two specific dispatching rules and their variations have been used in this study. These rules are “Shortest Processing Time First” rule (SPT) and “Longest Processing Time First” rule (LPT) since they are the most common and most widely used rules if the objective function is minimizing makespan. SPT rule refers that jobs are sequenced in such a way that the job with least processing time is picked up-first, followed by the job with the next smallest processing time and so on. On the other hand, LPT rule says that jobs are sequenced in such a way that the job with highest processing time is picked up-first, followed by the job with the next highest processing time and so on. In this study, both methods and their variations are used as construction heuristics.

5.2. Improvement Heuristics

Improvement heuristics operate on the initial schedule generated by construction heuristics and then try to obtain better schedules by modifying initial one. There are various improvement heuristics. An important class of these methods involves local search algorithms. Local search algorithms do not ensure to find an optimal solution, but they give better schedule than current schedule in the neighborhood of the current one. At each iteration, local search algorithms search within neighborhood and generate various neighborhood schedules. The algorithms have a decision module in which a candidate schedule is either accepted or rejected, and this decision is made by a given “acceptance – rejection” criterion.

The way of defining the neighborhood is a distinguishing aspect of local search procedures. To generate a new schedule, a single “pairwise interchange” of places of jobs in the original schedule, or in other words, swapping is one of the methods of defining neighboring schedules. This process implies that there are $n-1$ new schedules in the neighborhood of the original schedule. Insertion is other technique for getting new schedules and each job can be inserted in $n-1$ other position. According to this, there are $n(n-1)$ neighbors and some of them are same.

In this study, Simulated Annealing (SA) and Tabu Search (TS) methods are used as improvement algorithms. SA uses both insertion and swap techniques whereas TS uses only swap technique for searching neighboring schedules.

5.2.1. Simulated Annealing

Simulated Annealing (SA) algorithm was developed by Kirkpatrick et al (1983). The concept of SA algorithm comes from the field of material science in which a solid is first melted in high temperature, and then it is slowly cooled. Acceptance – rejection criteria of SA is based on probabilistic process.

SA algorithm goes through a number of iterations. These iterations are represented by k , current schedule is defined by S_k . The best schedule on hand so far is shown by S_0 . $G(S_k)$ and $G(S_0)$ denote the cost functions (or objective function values) of respective schedules. The candidate schedule S_c is the schedule chosen from neighborhood of S_k . At each iteration $G(S_k)$ and $G(S_c)$ are compared. If $G(S_c) < G(S_k)$, current schedule is moved such that $S_{k+1} = S_c$. After that, $G(S_0)$ and $G(S_c)$ are compared and if $G(S_c) < G(S_0)$ then $S_0 = S_c$. However, if $G(S_c) \geq G(S_k)$, a move to new solution S_c is made with probability

$$P(S_c, S_k) = \exp\left(\frac{G(S_k) - G(S_c)}{\beta_k}\right)$$

and reject with probability $1 - P(S_c, S_k)$.

$\beta_1 \geq \beta_2 \geq \dots \geq 0$ are control parameters which is called temperatures (T). At any stage $\beta_k = \beta_{k-1}\alpha$ or $\beta_k = \beta_1\alpha^{k-1}$ where (α) is a number between 0 and 1.

According to description, a move to a worse solution is allowed. Hence it gives opportunity to move away from a local minimum and find a better solution at following iterations. There are several stopping criteria. One of these criteria is to use specific number of iterations to stop the algorithm. Another one is to allow until no improvement has been obtained for a given number of successive iterations.

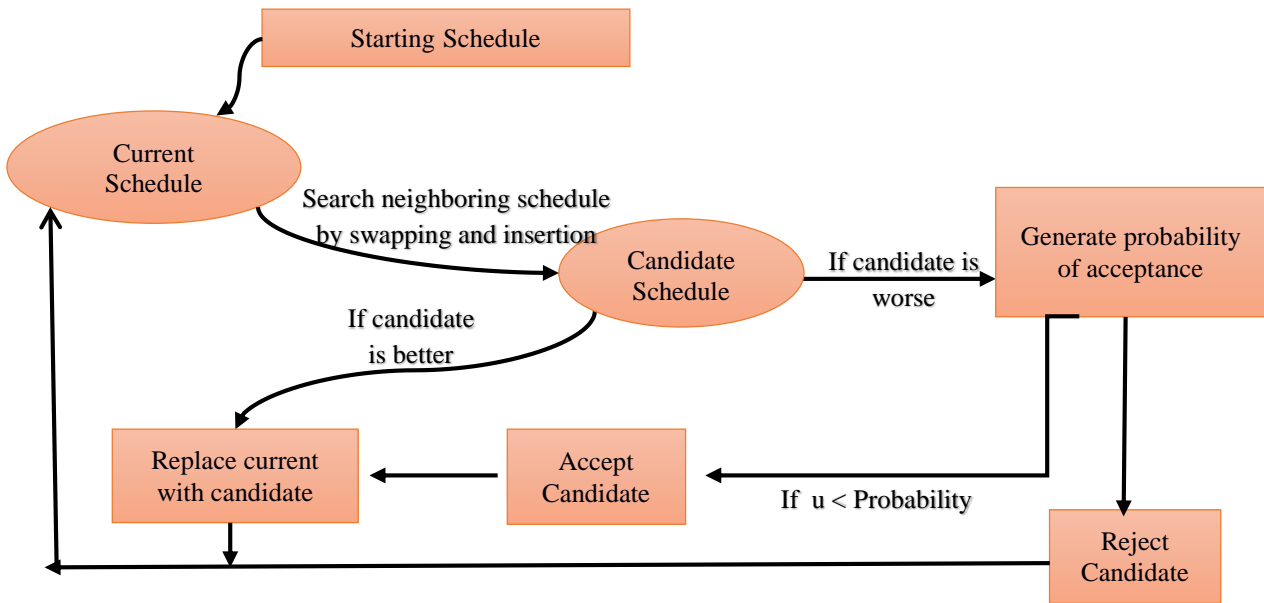


Figure 19. Structure of SA Algorithm

Pseudo-code of SA algorithm is presented in follow (Pinedo, 2005):

Step 1

Set $k=1$ and select β_1

Select an initial schedule S_1 using some heuristics.

Set $S_0=S_1$

Step 2

Select a candidate schedule S_c from the neighborhood of S_k

If $G(S_0) < G(S_c) < G(S_k)$, set $S_{k+1} = S_c$ and go to step 3

If $G(S_c) < G(S_0)$, set $S_0 = S_{k+1} = S_c$ and go to step 3

If $G(S_c) > G(S_k)$,

generate random number U_k from a Uniform(0,1) distribution
(Acceptance criteria)

If $U_k \leq P(S_c, S_k)$ set $S_{k+1} = S_c$ and go to step 3

If $U_k > P(S_c, S_k)$ set $S_{k+1} = S_k$ and go to step 3

Step 3

Select $\beta_{k+1} \leq \beta_k$

Increment k

If $k = N$ (Stop criteria) then STOP, otherwise go to Step 2

5.2.2. Tabu SEARCH

Tabu Search (TS) algorithm was developed by Glover (1986). It is similar SA. It also moves one schedule to another. The basic difference between TS and SA lies in the procedure for approving a candidate schedule. As it is mentioned before, acceptance – rejection criterion of SA is based on probabilistic process. However, TS uses a deterministic process in acceptance-rejection criterion.

The TS algorithm escapes from a local minimum by selecting the neighboring solution is allowed to consider, even if that neighbor is worse than that of the current solution. The set of allowed neighbors is restricted by a tabu list designed to prevent going back to solutions recently visited. At any stage of the process a tabu list of mutations is kept. Every move is generated by a mutation in current schedule. The reverse mutation is put on the tabu list because it is avoided returning to a local minimum that has been visited.

Pseudo-code of TS algorithm is presented in follow (Pinedo, 2005):

Step 1

Set $k=1$

Select an initial schedule S_1 using a construction heuristics (LPT1, LPTcomp. etc)

Set $S_0=S_1$

Tabu list comprised of prohibited schedules. The size of the list is determined by the number of jobs multiplied by a factor γ and the list is initially empty.

Step 2

By swapping generate a candidate schedule S_c from the neighborhood of S_k

S_c is a mutation of S_k

If the move $S_k \rightarrow S_c$ is prohibited by a mutation on the tabu list, set $S_{k+1} = S_k$ and go to step 3

If the move $S_k \rightarrow S_c$ is not prohibited by any mutation on the tabu list set

$S_{k+1} = S_c$ and enter reverse mutation at the top of the tabu list; push all other entries in the tabu list one position down; delete the entry at the bottom of the tabu list

If $G(S_c) < G(S_0)$, set $S_0 = S_c$ and go to step 3

Step 3

Increment k

If $k = N$ (Stop criteria) then STOP, otherwise go to Step 2

5.3. Solving Small Scale HFS Problems

The heuristic methods explained above are coded in C programming language in Visual Studio™ on a PC with Intel® Core™ i7-5500U CPU @ 2.40GHz (4 CPUs) and 8.00 GB RAM and operating system with Windows 10 Education 64-bit.

In order to test and evaluate the performance of heuristics methods, small scale test problems defined in Section 4.6 were used. Please remember that properties of those test problems are explained in detail in that section and they are summarized in Table 11. Furthermore, all other details including input values and optimal solutions are presented in Appendix-3. For generating the initial schedule, “Shortest Processing Time First (SPT)” and “Longest Processing Time First (LPT)” construction heuristics and their variations are used. Brief explanations and denomination of construction heuristics are given in the following table.

Table 20. Denomination of Construction Algorithms

SPT1	Sorting jobs in ascending order according to their processing time in stage-1
SPTcomp	Sorting jobs in ascending order according to their total completion times
LPT1	Sorting jobs in descending order according to their processing time in stage-1
LPTcomp	Sorting jobs in descending order according to their total completion times

For improving current schedule, Tabu Search and Simulated Annealing methods have been used. For both algorithms, maximum number of iterations is set to 50 and 100 to be used as the stopping criterion.

In Simulated Annealing algorithm, the control parameter (temperature) β_k is calculated at each step in acceptance-rejection criterion. The temperature is used by setting $\beta_1 = 1$ and choosing a value for the parameter (α) between 0 and 1. In our tests we use different values for (α) such as 0.8, 0.9, 0.99 respectively, in compliance with the advices in literature.

In Tabu Search algorithm, the size of the tabu list should be determined in advance as a parameter. We have used different sizes of tabu list. The sizes are determined as 1, 2 and 3, respectively.

All the test problems have been solved using both SA and TS with different parameters. The outcomes have been presented in detail in Appendix-4. Those outcomes is reviewed in order to ompare the performance of the heuristics and mathematical model.

It is observed that heuristics methods have attained optimal solutions for some instances whereas they underperform for some others and deviate from optimal solutions. The following table shows the cases where heuristics achieve optimal solutions.

Table 21 . Number of Cases Where Heuristics Achieve Optimal Solutions
(Out of 38 problems)

	SPT1	SPTcomp	LPT1	LPTcomp
Simulated Annealing	0	0	4	4
Tabu Search	18	17	16	13

Furthermore, percentage deviations of heuristic solutions are calculated when compared to the optimal solutions. The comparison table is presented in the Table 22.

Table 22. Mean Percentage Deviations from Optimal Solutions

Construction Heuristics	Simulated Annealing						Tabu Search					
	$\alpha=0.80$		$\alpha=0.90$		$\alpha=0.99$		Tabulist size=1		Tabulist size=2		Tabulist size=3	
	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100
SPT1	12%	13%	13%	13%	13%	13%	6%	5%	6%	4%	7%	5%
SPTcomp	16%	16%	15%	15%	15%	15%	6%	4%	6%	4%	6%	5%
LPT1	20%	20%	20%	20%	20%	20%	6%	4%	7%	4%	7%	5%
LPTcomp	13%	13%	13%	13%	13%	13%	6%	5%	6%	5%	6%	4%

MI: Maximum number of iterations (stopping condition in SA and TS)

The best outcomes are provided by Tabu Search when tabu list size is equal to 2 and maximum number of iterations is chosen as 100. Construction heuristics do not have much impact on the quality of outcome if Tabu Search method is used as improvement algorithm. On the other hand, SPT1 and LPTcomp methods outperform other construction heuristics when Simulated Annealing is utilized. Furthermore, it will not be wrong if it is stated that Tabu Search performs better than Simulated Annealing method when dealing with the small scale problems.

5.4. Solving Large Scale Generic HFS Problems

The performance of heuristics has been evaluated on the small scale problems. However, it should be repeated on large scale problems which emerges in real world applications as in the ink factory production system. Before solving the instances of real scheduling problem, some large scale generic test problems are generated to

evaluate the performance of the heuristics. Job characteristics and machine environments in test problems are very similar to the real scheduling problem, however there are some differences since our intention is still to generalize the model at this stage.

The real scheduling problem in the ink factory has 4 stages and each stage has more than one machines in parallel. The number of machines in parallel at each stage is 3, 8, 4 and 2 respectively. Each stage has different characteristics. For example, Stage-4 represents an ordinary workstation which has two identical machines in parallel and there is no setup time. On the other hand, Stage-1 and Stage-3 have identical parallel machines and there are sequence-dependent setup times in those stages. Furthermore, there are “machine eligibility restrictions” in Stage-2. It is due to dedication of subsets of machines for specific job families. A job coming from Stage-1 is directed to the predetermined subset of machines depending on its job family. There is no setup time in this stage. There is buffer limitation between Stage 1 & 2. The buffers are set in front of each machine group (not in front of each individual machine) and the sizes of all buffers are equal to the number of machines in each group. Limited buffers can cause machine blocking in Stage-1.

Generic test problems include all those features defined above, however they differ in the following characteristics.

Table 23. Comparison of Real Scheduling Problem and Generic Test Problems

	Generic Test Problems	Real Scheduling Problem
Process Times	Random ~ U (1,20)	Different process times for different jobs. Process times are known in advance.
Setup Times	Random ~ U (0,5) Sequence dependent setup time for every two consecutive jobs.	Setup times are known in advance. Sequence dependent setup incurs only if two consecutive jobs are from different job families.
Number of Product Types (Number of Job Families)	4 The assignments of family attribute on the jobs are done randomly	4
Limited Buffers between Stage-1 and Stage-2	Equal to 1	Equal to the number of machines in each group

We have used different sizes of tabu list. The sizes are determined by multiplying the number of jobs with 0.1, 0.2 and 0.3, respectively. Control parameters of the heuristics are defined in Table 24.

Table 24. Heuristics Control Parameters and Their Levels For Large Scale Problems

Control Parameter	Levels
Number of Jobs (K)	20, 50, 100
Maximum Iteration Number for Meta-Heuristics	50, 100, 150
value of α (for SA algorithm)	0.8, 0.9, 0.99
Tabu List Size (for TS)	(K 0.1), (K 0.2), (K 0.3)

Different sets of problems have been prepared for each level of number of jobs (K), i.e. K=20, K=50 and K=100. Each set contains of 20 individual problems. It means that we have 60 large scale generic test problems in total and they are divided into 3 different sets.

Large scale generic test problems have been solved by utilizing heuristics and the outcomes are reported in detail in the Appendix-5. However, summary or simplified versions of outcomes are presented in the following tables. The entries in these tables represent the best solution of respective heuristics across different control parameters.

Table 25. Best Results of Heuristics Across Different Control Parameters with K=20

Problem #	Number of Jobs, K = 20							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
1	125	134	150	149	126	132	135	140
2	121	120	134	132	124	127	125	126
3	129	132	139	138	129	133	132	133
4	117	121	130	129	120	117	123	118
5	134	130	140	135	129	129	130	126
6	128	128	154	139	124	123	123	128
7	103	109	116	111	104	102	105	105
8	133	129	140	139	130	134	129	133
9	128	133	143	136	127	131	133	134
10	137	145	161	151	134	136	137	133
11	128	143	159	142	131	134	130	133
12	126	132	136	135	129	130	128	127
13	135	136	149	140	133	135	137	134
14	113	115	139	129	99	108	107	107
15	138	136	166	157	140	139	138	140
16	139	140	143	141	138	141	138	138
17	113	120	130	131	110	111	112	113

Table 25 (cont'd). Best Results of Heuristics Across Different Control Parameters
with K=20

Problem #	Number of Jobs, K = 20							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
18	140	140	163	163	141	142	141	141
19	124	133	150	150	132	133	133	133
20	142	147	155	154	147	145	145	146

Table 26. Best Results of Heuristics Across Different Control Parameters with K=50

Problem #	Number of Jobs, K = 50							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
1	286	287	315	313	295	293	296	301
2	283	288	297	296	287	292	293	294
3	297	302	337	312	300	296	309	305
4	283	286	312	295	285	286	289	287
5	301	306	336	326	306	313	316	314
6	277	291	276	277	259	258	264	266
7	274	274	306	301	284	280	287	285
8	297	306	334	323	299	305	305	304
9	271	278	308	304	285	291	293	295
10	286	267	307	283	274	269	271	267
11	321	320	333	325	324	322	326	327
12	273	264	309	290	265	269	271	275
13	284	295	335	305	289	294	300	292
14	263	276	296	294	267	273	278	273
15	272	276	331	305	272	278	282	281
16	280	289	303	305	280	291	291	290
17	272	270	325	317	273	270	283	279
18	274	277	311	293	275	280	282	281
19	282	278	319	299	282	286	290	289
20	282	286	311	308	282	291	294	291

Table 27. Best Results of Heuristics Across Different Control Parameters with K=100

Problem #	Number of Jobs, K = 100							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
1	588	594	620	608	596	592	594	596
2	544	556	588	576	551	557	558	549
3	527	532	593	551	533	536	539	543
4	562	565	602	615	571	575	573	571
5	515	515	572	542	521	518	520	528
6	598	586	622	605	590	596	592	597
7	540	545	561	555	547	552	549	548
8	549	552	601	572	556	557	554	554
9	550	550	574	571	556	556	555	558
10	493	504	561	552	495	505	507	512
11	568	575	619	599	570	581	575	577
12	539	545	588	579	545	549	559	549
13	558	560	603	587	558	562	572	565
14	490	494	548	558	486	492	513	502
15	508	498	589	535	520	506	507	506
16	547	542	585	578	548	545	552	546
17	517	532	612	549	524	536	528	534
18	507	513	597	541	513	513	518	522
19	522	522	580	550	532	530	531	530
20	523	526	565	542	527	530	531	531

Remember that Tabu Search seemed better when dealing with small-scale problems in previous section (number of jobs up to 10). After reviewing the new tables involving the results of large scale problems, it is interesting to observe that Simulated Annealing algorithm performs much better as the number of jobs increased. On the other hand, SPT1 and LPTcomp are better than the other construction heuristics no matter which improvement heuristics is chosen.

5.5. Solving Real HFS Problem

In this section, the instances of real scheduling problem have been solved using heuristic methods. Three different sets of instances of real scheduling problem are prepared for each level of number of jobs (K), i.e. K=20, K=50 and K=100. Each set contains of 20 individual problems. Each individual problem represents every characteristic of real scheduling problem. They differ only in number of jobs and combination of job types. Control parameters of the heuristics are presented in Table 28. Detailed outcomes are presented in Appendix-6.

Table 28. Heuristics Control Parameters and Their Levels For Real Problems

Control Parameter	Levels
Number of Jobs (K)	50, 75, 100
Maximum Iteration Number for Meta-Heuristics	50, 100, 150
value of α (for SA algorithm)	0.8, 0.9, 0.99
Tabu List Size (for TS)	(K 0.1), (K 0.2), (K 0.3)

Summary of outcomes are presented in the following tables. The entries in these tables represent the best solution of respective heuristics across different control parameters.

Table 29. Best Results of Heuristics for Real HFS Problem Across Different Control Parameters with K=50

Problem #	Number of Jobs, K = 50							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
1	4606.3	4183.1	4726.0	5097.3	4034.4	4034.4	4015.9	4035.5
2	7980.4	7995.5	8141.6	8415.7	7979.3	7979.3	7984.8	7979.3
3	15583.1	15571.2	15639.6	15733.9	15550.3	15550.3	15550.3	15550.3
4	8414.6	8228.6	13328.9	13328.9	8325.6	8228.6	8323.1	8323.1
5	5636.9	6260.9	5758.2	6151.4	5628.0	5606.4	5624.7	5639.5
6	4998.1	5154.4	5008.6	4987.4	4973.1	4973.1	4973.1	4974.4
7	4456.3	4151.3	5099.2	5012.2	4010.3	4279.9	4000.9	4163.4
8	4754.5	3848.2	4913.9	4899.2	3500.5	3500.9	3500.9	3500.9
9	5938.1	5866.3	5879.3	6987.0	5847.8	5849.1	5849.1	5853.3
10	5209.8	5269.7	4510.6	8213.4	4832.0	4832.0	4385.2	4679.6
11	6364.5	6502.2	6211.4	5934.3	6173.0	6173.0	6173.0	5723.6
12	5941.8	5509.1	5879.0	5188.4	5840.6	5840.6	5841.0	5644.9
13	4520.8	6887.7	6067.5	4968.6	4592.0	4592.0	4592.0	4592.0
14	7208.1	7804.6	6920.3	6960.4	6845.3	6845.3	6847.0	6813.8
15	4425.6	3991.1	2841.0	2787.4	2769.9	3143.4	2738.3	2834.9
16	3765.6	5187.5	4658.7	5060.3	3330.2	3330.2	3200.9	3330.2
17	7058.1	6725.1	6505.8	6842.6	6258.8	6258.8	6258.8	6258.8
18	4754.5	3814.8	4456.3	4590.7	3552.1	3631.4	3593.7	4316.0
19	5078.8	5829.4	5703.3	4942.3	4576.9	4576.9	4576.9	4576.9
20	4633.6	4633.6	4506.8	4970.1	4598.3	4598.3	4187.4	4600.0

Table 30. Best Results of Heuristics for Real HFS Problem Across Different Control Parameters with K=75

Problem #	Number of Jobs, K = 75							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
1	8050.8	8235.8	7953.3	8489.6	7642.6	7881.8	7881.8	7881.8
2	9137.6	9050.3	9100.6	9695.2	8995.2	9010.8	8995.2	9000.7
3	15963.6	15570.1	15639.6	16197.3	15555.8	15551.6	15550.3	15552.0
4	8321.8	6139.3	13284.4	13271.8	8323.1	5856.8	8319.3	8329.6
5	7067.5	5876.2	6104.9	7473.3	5735.6	5697.7	5706.6	6615.1
6	7999.1	8758.6	8025.0	8537.9	7974.1	7975.4	7988.4	7975.4
7	7935.3	7960.1	9056.7	10105.3	7034.4	7034.4	7040.5	7040.5
8	7581.6	5690.2	7701.7	7581.6	5452.4	5452.0	5556.9	5412.2
9	9176.3	9004.6	9039.9	10250.6	8984.8	8986.1	8984.8	8649.0
10	8042.5	7978.0	7670.8	9635.6	7594.7	7590.9	7606.9	7590.5
11	9228.1	9920.6	8984.7	9712.9	8946.3	8949.2	8946.3	8946.7
12	9398.3	8719.1	8342.9	9457.9	8694.1	8697.0	8694.1	7963.2
13	11838.7	11562.9	7725.5	10797.7	7137.9	7137.9	6900.6	7137.9
14	11576.3	12093.5	11255.7	14422.3	11217.3	11216.0	11216.0	11216.0
15	7488.8	7215.7	8380.9	9085.6	7488.8	4830.8	4830.8	7585.4
16	8402.0	7768.6	6793.7	7972.4	4483.6	4904.2	5290.4	4878.6
17	7132.4	7841.6	8448.0	9187.2	6605.3	6605.3	6605.3	6605.3
18	5353.6	6346.6	5455.5	6412.8	4825.9	4886.3	4882.1	4201.0
19	6251.8	5814.2	6377.8	7580.4	5427.1	5428.4	5428.4	5112.9
20	8156.9	6932.0	8437.7	8202.3	6375.0	5513.5	5584.9	5615.0

Table 31. Best Results of Heuristics for Real HFS Problem Across Different Control Parameters with K=100

Problem #	Number of Jobs, K = 100							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
1	7800.4	8507.1	8031.2	8572.5	7742.0	7897.8	7886.0	7887.3
2	11724.6	11451.7	11450.6	12146.2	11396.6	11412.2	11396.6	11412.0
3	16279.7	15605.4	15604.3	16588.0	15551.6	15550.3	15552.0	15555.8
4	11555.8	8094.9	8698.9	12227.3	6152.3	7592.6	8218.9	8329.6
5	9850.6	7571.4	7433.5	8664.1	5818.1	5729.7	5793.7	5733.0
6	9753.7	10975.6	9764.2	12081.9	9728.7	9728.7	9743.0	9730.0
7	10761.5	11350.2	12645.6	12830.7	7690.6	7358.1	8403.7	8397.6
8	10113.3	6781.3	10195.9	10611.2	6540.6	6559.0	6410.5	6555.2
9	11533.0	11520.4	10533.8	11762.2	10661.0	10694.4	11260.8	10379.3
10	12179.1	9994.3	9656.9	12150.5	9776.3	9772.1	9679.2	9772.1
11	12396.0	12276.8	11998.8	15009.8	11928.6	11929.0	11958.8	11596.5
12	12546.2	14641.6	12374.4	11631.9	11353.1	11549.7	11549.7	11363.1
13	10099.4	11379.6	12079.3	15081.5	9320.1	9320.1	9320.1	9253.4

Table 31 (cont'd). Best Results of Heuristics for Real HFS Problem Across Different Control Parameters with K=100

Problem #	Number of Jobs, K = 100							
	SA				TS			
	SPT1	SPTcomp	LPT1	LPTcomp	SPT1	SPTcomp	LPT1	LPTcomp
14	14426.0	17233.7	14229.8	19000.2	14172.6	14172.6	14172.6	14160.0
15	10457.7	11863.7	9878.9	12019.3	6145.7	6242.3	6151.8	9766.9
16	10929.7	11455.1	10155.6	13107.5	6321.3	6426.2	6480.0	6289.6
17	10396.9	9973.7	9755.8	13333.9	7537.8	7575.4	8087.3	8029.1
18	10893.9	10666.4	8634.4	12034.6	7430.3	7793.7	7793.7	7793.7
19	6823.6	8883.4	8294.3	9463.7	6541.5	6542.8	6541.5	6541.5
20	11184.4	11296.9	9159.2	16932.9	8970.3	8969.0	7358.5	8668.0

Remember that SA usually provides better solutions when dealing with large scale generic test problems. On the other hand, when we review the results of real HFS problems, it seems now TS algorithm outperforms SA. Furthermore, it is observed that construction heuristics can't have a clear superiority over each other. These observations are not consistent with the observations that we have in generic test problems.

In order to solve that contradiction, a new experiment is designed. The idea is coupling TS and SA heuristics such that solution of a heuristics is fed to the other one as the starting solution. For example, a problem is solved by SA and then the solution is fed to TS as the starting solution. The opposite order of the heuristics is also in consideration. The schematic display of coupling is presented in the following figure:

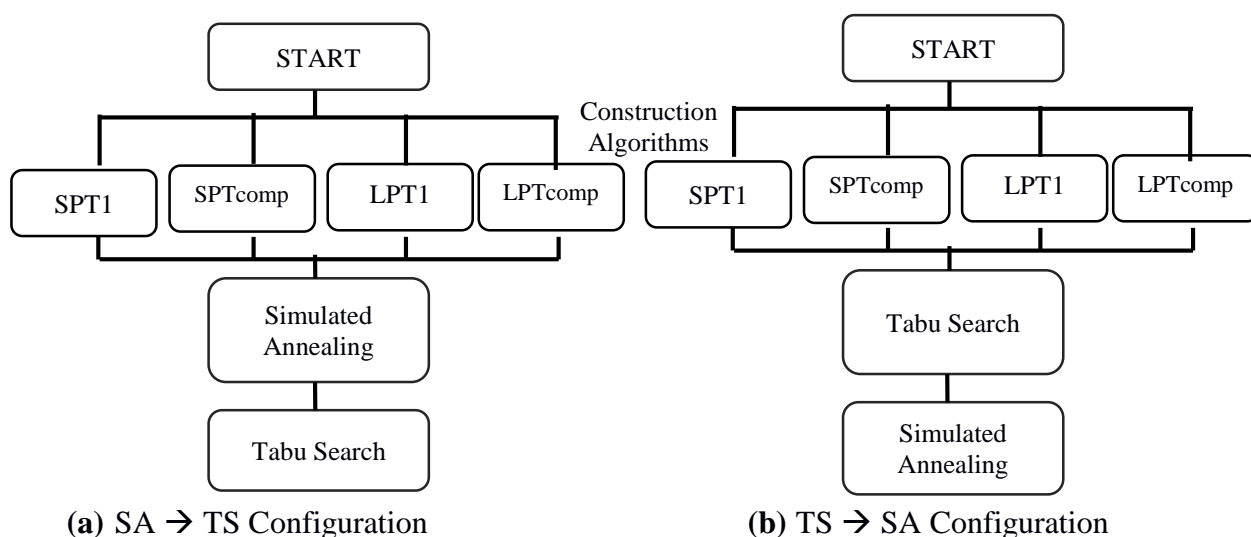


Figure 20. Using an Improvement Algorithm as a Construction Algorithm

All the large scale generic test problems and large scale real scheduling problems have been solved again using new coupling approach. Detailed solutions are given in Appendix-7 and Appendix-8. The summaries of outcomes are presented in the following tables.

Table 32. Effect of Coupling Configuration, K=50, Large Scale Generic Problems

Regular Heuristics Solutions		Solutions After Coupling Configuration		Percentage Improvement
Value of best solution with regular construction algorithms	Heuristics that yields the best solution	Value of best solution with coupling configuration	Structure of coupling that yields the best solution	
286	SA	286	both	0.00%
283	SA	280	both	1.06%
296	TS	296	both	0.00%
283	SA	277	SA→TS	2.12%
301	SA	300	SA→TS	0.33%
258	TS	252	TS→SA	2.33%
274	SA	272	SA→TS	0.73%
297	SA	292	SA→TS	1.68%
271	SA	271	SA→TS	0.00%
267	SA or TS	258	SA→TS	3.37%
320	SA	313	TS→SA	2.19%
264	SA	258	both	2.27%
284	SA	282	TS→SA	0.70%
263	SA	262	TS→SA	0.38%
272	SA or TS	271	SA→TS	0.37%
280	SA or TS	277	SA→TS	1.07%
270	SA or TS	267	SA→TS	1.11%
274	SA	267	TS→SA	2.55%
278	SA	272	TS→SA	2.16%
282	SA or TS	278	both	1.42%

It is obvious that coupling approach usually improves the solutions. Mean improvement percentage is 1.29%. Furthermore, any coupling structure does not have a clear superiority over the other one in yielding the best solution.

Table 33. Effect of Coupling Configuration, K=100, Large Scale Generic Problems

Regular Heuristics Solutions		Solutions After Coupling Configuration		Percentage Improvement
Value of best solution with regular construction algorithms	Heuristics that yields the best solution	Value of best solution with coupling configuration	Structure of coupling that yields the best solution	
588	SA	585	SA→TS	0.51%
544	SA	542	SA→TS	0.37%
527	SA	520	SA→TS	1.33%
562	SA	558	SA→TS	0.71%
515	SA	509	SA→TS	1.17%
586	SA	581	SA→TS	0.85%
540	SA	537	SA→TS	0.56%
549	SA	545	TS→SA	0.73%
550	SA	546	TS→SA	0.73%
493	SA	490	SA→TS	0.61%
568	SA	564	SA→TS	0.70%
539	SA	539	SA→TS	0.00%
558	SA or TS	554	SA→TS	0.72%
486	TS	485	TS→SA	0.21%
498	SA	496	TS→SA	0.40%
542	SA	533	SA→TS	1.66%
517	SA	512	SA→TS	0.97%
507	SA	506	SA→TS	0.20%
522	SA	516	SA→TS	1.15%
523	SA	520	both	0.57%

It can be seen that coupling approach almost always improves the solutions and SA→TS configuration gives better solution than TS→SA configuration. Mean improvement percentage is 0.71%.

Table 34. Effect of Coupling Configuration, K=50, Real Problem

Regular Heuristics Solutions		Solutions After Coupling Configuration		Percentage Improvement
Value of best solution with regular construction algorithms	Heuristics that yields the best solution	Value of best solution with coupling configuration	Structure of coupling that yields the best solution	
4015.9	TS	3703.5	SA→TS	7.78%
7979.3	TS	7979.3	both	0.00%
15550.3	TS	15550.3	both	0.00%
8228.6	SA or TS	8228.6	both	0.00%
5606.4	TS	5606.3	SA→TS	0.00%
4973.1	TS	4973.1	both	0.00%
4000.9	TS	3961.6	TS→SA	0.98%
3500.5	TS	3500.5	TS→SA	0.00%
5847.8	TS	5060.6	SA→TS	13.46%
4385.2	TS	3830.6	TS→SA	12.65%
5723.6	TS	5303.5	TS→SA	7.34%
5188.4	SA	5162.1	SA→TS	0.51%
4520.8	SA	4383.6	SA→TS	3.03%
6813.8	TS	6813.8	TS→SA	0.00%
2738.3	TS	2738.3	both	0.00%
3200.9	TS	3024.2	TS→SA	5.52%
6258.8	TS	6258.8	both	0.00%
3552.1	TS	3524.1	SA→TS	0.79%
4576.9	TS	4576.9	both	0.00%
4187.4	TS	4174.8	TS→SA	0.30%

It is obvious that coupling approach usually improves the solutions and any coupling structure does not have a clear superiority over the other one in yielding the best solution. Mean improvement percentage is 2.62%.

Table 35. Effect of Coupling Configuration, K=100, Large Scale Real Problems

Regular Heuristics Solutions		Solutions After Coupling Configuration		Percentage Improvement
Value of best solution with regular construction algorithms	Heuristics that yields the best solution	Value of best solution with coupling configuration	Structure of coupling that yields the best solution	
7742.0	TS	6878.7	SA→TS	11.15%
11396.6	TS	11396.6	both	0.00%
15550.3	TS	15550.3	both	0.00%
6152.3	TS	6036.0	SA→TS	1.89%
5729.7	TS	5660.4	SA→TS	1.21%
9728.7	TS	9308.8	SA→TS	4.32%
7358.1	TS	7256.1	SA→TS	1.39%
6410.5	TS	6410.5	both	0.00%
10379.3	TS	10251.3	TS→SA	1.23%
9656.9	SA	8763.4	TS→SA	9.25%
11596.5	TS	11338.0	SA→TS	2.23%
11353.1	TS	9680.9	TS→SA	14.73%
9253.4	TS	8284.2	SA→TS	10.47%
14160.0	TS	13884.9	SA→TS	1.94%
6145.7	TS	6145.7	both	0.00%
6289.6	TS	5771.9	SA→TS	8.23%
7537.8	TS	7496.4	SA→TS	0.55%
7430.3	TS	7072.0	TS→SA	4.82%
6541.5	TS	6119.4	SA→TS	6.45%
7358.5	TS	7358.5	TS→SA	0.00%

Solutions shows that coupling approach almost always improves the solutions and SA→TS configuration always gives better solution than TS→SA configuration. Mean improvement percentage is 4.0%.

After reviewing the summary tables involving the results of coupling configurations, it is interesting to observe that SA→TS configuration performs much better as the number of jobs increased.

CHAPTER SIX

CONCLUSION & DISCUSSIONS

In this study, Hybrid Flow Shop Scheduling (HFS) problem and a real world application has been studied. At the beginning of the study, basic terminology and notation of scheduling problems were introduced. Subsequently, the definition and properties of basic Hybrid Flow Shop Scheduling problem were presented. It has been underlined that there may be many variations of HFS problem depending on the machine environment, process (job) characteristics and objective function. In order to identify the particular variation of a real scheduling problem of an ink factory; its products, process flow, machine configurations and job characteristics were explained. The problem was identified as an HFS problem involving machine blocking, sequence-dependent setup times, limited buffers and machine eligibility constraints. From this point forward, the study focused on that particular variation of HFS problem.

A MIP model has been formulated to get the optimal solution of the problem. To the best of our knowledge, there is no formulation in literature which considers all those operational characteristics (constraints) together. Therefore, an original mathematical model was proposed to represent true properties of our real HFS problem. The optimal solutions have been shown for small scale problems. Solutions were interpreted and some observations have been made. However, since HFS problems are NP-hard, it is impractical to use mathematical models for solving medium and large instances of the problem. Therefore, heuristic methods were studied in the next step.

The combinations of construction and improvement heuristics have been utilized to get the solutions. The role of the construction heuristics is to generate the initial schedule (solution). Although there exist many heuristics in that class, SPT, LPT and their variants has been used in this study. On the other hand, the improvement heuristics pick up the initial solution and modify it systematically in an iterative process in the pursuit of better solutions. In this study, Simulated Annealing and Tabu Search methods are chosen to be used as improvement heuristics. They have been utilized with different control parameters.

The performances of the heuristics were evaluated on small scale problems by comparing their solutions with the optimal solutions provided by MIP model. Observations were stated by reviewing the comparisons.

In the next stage, large scale generic test problems were generated to imitate real scheduling problems in the factory. An experimentation was conducted to determine the effects of input and control parameters. The outcomes have been reported.

Finally, instances of real scheduling problems have been created to evaluate the performances of the heuristics. A systematic experiment has been conducted by changing control parameters. The outcomes have been reported.

Observations on the performances of the heuristics were contradictory when the results of large scale generic test problems are compared to those of real scheduling problems. Therefore, a new experiment is designed. The idea is coupling TS and SA heuristics such that solution of a heuristics is fed to the other one as the starting solution. All generic and real scheduling problems have been solved using this coupling approach. It is seen that coupling approach can actually improve the best solution generated by regular heuristics methods. Furthermore, it is observed that best solutions can be retrieved using SA→TS coupling which means use Simulated Annealing heuristics first and feed its solution as the starting schedule for the Tabu Search method. This setting is proposed for the factory to schedule the jobs in real life.

In the future, the mathematical model can be extended to include some other operational characteristics such as pre-emption and precedence constraints. Setup constraints can be adapted to include or substitute machine-dependent setup times. In the heuristics side, the effects of the control parameters may be scrutinized to increase the quality of the solutions.

On the other hand, genetic and evolutionary algorithms may be used and can be compared to TS and SA in the future works.

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CURRICULUM VITAE

Aylin Akçalı was born in İzmir. She finished BS degree in Industrial Engineering from Yaşar University. After graduation, she started MS degree in Industrial Engineering at Yaşar University and she continues. She is a research assistant in the Industrial Engineering Department at Yaşar University. She has taken such various courses as System Simulation, Optimization Models and Algorithms, Heuristic Optimization, Probabilistic Analysis, Mathematics of Operational Research and Supply Chain Processes and Management. In the light of these courses, she decided to study scheduling problems and heuristic method





APPENDIX 1 – MODEL STRUCTURES OF STUDIES IN THE LITERATURE

Paper	Year	Intermediate Buffer		Machine Eligibility	Preemption	Precedence	Setup Time			Machine Types			Objective Function
		Limited	Unlimited				No Setup Time	Sequence Dependent	Machine Dependent	Identical	Uniform	Unrelated	
Acero-Domínguez et al	2004		YES				YES			YES			Makespan minimization
Alaykýra el al	2007		YES				YES			YES			Makespan minimization
Alfieri	2009		YES					YES				Non identical	Several objective
Allahverdi et al	2006	YES					YES			YES			average completion time minimization
Allaoui er al	2004		YES					YES		YES	YES	YES	Several objectives
Azizoğlu et al	1999		YES				YES			YES			Total Flow Time Minimization
Behnamian et al	2011		YES					YES			YES		Several objective
Bertel et al	2004		YES				YES				YES		Weighted number of tardy jobs minimization
Botta-Genoulaz	1997		YES			YES	YES			YES			Makespan minimization
Botta-Genoulaz	2000		YES			YES			YES	YES			Maximum Lateness minimization
Brah et al	1999		YES			YES	YES			YES			Several objectives
Carlier et al	2000		YES			YES				YES			Makespan minimization
Chen et al	2009		YES				YES					YES	Number of tardy jobs minimization

APPENDIX 1 - MODEL STRUCTURES OF STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Intermediate Buffer		Machine Eligibility	Preemption	Precedence	Setup Time			Machine Types			Objective Function
		Limited	Unlimited				No Setup Time	Sequence Dependent	Machine Dependent	Identical	Uniform	Unrelated	
Cheng et al	2001		YES				YES			YES			Maximum Lateness minimization
Choi et al	2007		YES		YES (orders not lot)		YES			YES			Total Tardiness minimization
Dios et al	2015		YES				YES			YES			Makespan minimization
Djellab et al	2002		YES		YES	YES	YES			YES			Makespan minimization
Ebrahimi et al	2014		YES					YES		YES			Several objectives
Engin et al	2004		YES				YES			YES			Makespan minimization
Fattahi et al	2013		YES						YES	YES			Makespan minimization
Gue et al	1997		YES				YES			YES			Several objectives
Gupta et al	2002		YES				YES			YES			Several objectives
Havill et al	1998		YES				YES			YES			Makespan minimization
Hong et al	2001		YES				YES			YES			Makespan minimization
Huang et al	2007		YES				YES			YES			Total weighted completion time minimization
Janiak et al	2007		YES				YES			YES			Several objectives
Jenabi et al	2007		YES						YES	YES		YES	Several objectives
Jin et al	2006		YES						YES	YES			Makespan minimization
Jun et al	2015	YES					YES					YES	Total Tardiness minimization

APPENDIX 1 - MODEL STRUCTURES OF STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Intermediate Buffer		Machine Eligibility	Preemption	Precedence	Setup Time			Machine Types			Objective Function
		Limited	Unlimited				No Setup Time	Sequence Dependent	Machine Dependent	Identical	Uniform	Unrelated	
Jungwattanakit et al	2008		YES					YES	YES			YES	Several objectives
Jungwattanakit et al	2009		YES					YES	YES			YES	Several objectives
Kaczmarczyk et al	2004	YES					YES			YES			Makespan minimization
Kis et al	2005		YES				YES			YES			Makespan minimization/ Mean Flow Time
Kuo et al	2008		YES			YES	YES			YES			Several objectives
Kurz et al	2003		YES					YES		YES			Makespan minimization
Kurz et al	2004		YES					YES		YES			Makespan minimization
Kyparisis et al	2001		YES				YES			YES			Weighted completion time minimization
Kyparisis et al	2006		YES				YES				YES		Makespan minimization
Lee et al	2004		YES				YES			YES			total tardiness minimization
Lee	2009		YES				YES			YES			Estimation lead times
Leon et al	1997		YES						YES	YES			Several objectives
Liao et al	2012		YES				YES			YES			Makespan minimization
Li et al	2015	YES					YES					YES	Makespan minimization
Li et al	2014		YES				YES			YES			Makespan minimization
Liu et al	2000		YES			YES		YES		YES			Several objectives
Liu et al	2008	YES					YES			YES			Several Objectives

APPENDIX 1 - MODEL STRUCTURES OF STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Intermediate Buffer		Machine Eligibility	Preemption	Precedence	Setup Time			Machine Types			Objective Function
		Limited	Unlimited				No Setup Time	Sequence Dependent	Machine Dependent	Identical	Uniform	Unrelated	
Logendran et al	2005		YES						YES	YES			Makespan minimization
Logendran et al	2006		YES					YES					Makespan minimization
Low	2005		YES						YES			YES	Total Flow Time minimization
Marichelvam et al	2014		YES				YES (included in Processing T)			YES			Makespan minimization
Mirsanei et al	2011		YES				YES			YES			Makespan minimization
Morita et al	2005		YES				YES			YES			Makespan minimization
Moursli et al	2000		YES				YES			YES			Makespan minimization
Naderi et al	2008		YES					YES		YES			Several objectives
Naderi et al	2009		YES					YES		YES			Several objectives
Negenman	2001		YES				YES			YES			Makespan minimization
Neron et al	2001		YES				YES			YES			Makespan minimization
Niu et al	2012		YES				YES			YES			Makespan minimization
Nowicki et al	1998		YES				YES			YES			Makespan minimization
Oğuz et al	2004		YES				YES			YES			Makespan minimization
Oğuz et al	2005		YES				YES			YES			Makespan minimization
Portmann et al	1998		YES				YES			YES			Makespan minimization
Ruiz et al	2006		YES	YES				YES				YES	Makespan minimization

APPENDIX 1 - MODEL STRUCTURES OF STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Intermediate Buffer		Machine Eligibility	Preemption	Precedence	Setup Time			Machine Types			Objective Function
		Limited	Unlimited				No Setup Time	Sequence Dependent	Machine Dependent	Identical	Uniform	Unrelated	
Ruiz et al	2008		YES	YES		YES			YES			YES	Makespan minimization
Ruiz et al	2015		YES				YES			YES			weighted earliness and tardiness minimization
Santos et al	2001		YES				YES			YES			Makespan minimization
Sawik	2000	YES					YES			YES			Makespan minimization
Sawik	2001	YES					YES			YES			Makespan minimization
Sawik et al	2002	YES					YES			YES			Makespan minimization
Sawik	2002	YES					YES			YES			Makespan minimization
Sawik	2005		YES				YES			YES			Total tardiness/ maximum tardiness minimization
Şerifoğlu et al	2004		YES				YES			YES			Makespan minimization
Sevastianov	2002		YES				YES				YES		Makespan minimization
Shiau et al	2008		YES				YES			YES			Total Weighted Completion Time Minimization
Sirikrai et al	2006	YES					YES					YES	Several Objectives
Tang et al	2005		YES				YES			YES			Several Objectives
Tang et al	2006	YES					YES			YES			Total Weighted Completion Time Minimization

APPENDIX 1 - MODEL STRUCTURES OF STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Intermediate Buffer		Machine Eligibility	Preemption	Precedence	Setup Time			Machine Types			Objective Function
		Limited	Unlimited				No Setup Time	Sequence Dependent	Machine Dependent	Identical	Uniform	Unrelated	
Tang et al	2006		YES				YES			YES			Total Weighted Completion Time Minimization
Tavakkoli-Moghaddam et al	2007	YES						YES		YES			Makespan minimization
Tavakkoli-Moghaddam et al	2009	YES					YES			YES			Makespan minimization
Thornton et al	2004	YES					YES			YES			Makespan minimization
Tseng et al	2008		YES				YES			YES			Makespan minimization
Vazquez Rodriguez et al	2005		YES				YES (included in Processing T)			YES			Several objectives
Vazquez Rodriguez et al	2006		YES				YES			YES			Makespan minimization
Verma et al	1999		YES				YES				YES		Makespan minimization
Vignier et al	1997		YES				YES			YES			Makespan minimization
Voss et al	2007		YES					YES			YES		Weighted Tardiness minimization
Wang et al	2003		YES							YES			Makespan minimization
Wang et al	2009	YES					YES			YES			Total Weighted Completion Time Minimization

APPENDIX 1 - MODEL STRUCTURES OF STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Intermediate Buffer		Machine Eligibility	Preemption	Precedence	Setup Time			Machine Types			Objective Function
		Limited	Unlimited				No Setup Time	Sequence Dependent	Machine Dependent	Identical	Uniform	Unrelated	
Wardono et al	2004	YES					YES (included in Processing T)			YES			Makespan minimization
Wu et al	2003		YES	YES			YES					YES	Makespan minimization
Xiao et al	2000		YES				YES			YES			Makespan minimization
Xuan et al	2007		YES					YES		YES			Makespan minimization
Yang et al	2004		YES				YES			YES			Total Tardiness minimization
Yang et al	2007		YES				YES			YES			Total Tardiness minimization
Yaurima et al	2009	YES		YES				YES				YES	Makespan minimization
Ying et al	2006		YES				YES (included in Processing T)			YES			Makespan minimization
Zandieh et al	2006		YES					YES		YES			Makespan minimization
Zandieh et al	2009	YES						YES		YES			Makespan minimization

APPENDIX 2 – SOLUTION METHODOLOGIES USED IN THE STUDIES IN THE LITERATURE

Paper	Year	Mathematical Model	Exact Algorithm	Heuristics	Meta-heuristics				
					Tabu Search	Simulated Annealing	Genetic & Evolutionary Algorithm	Hybrid	Neural Networks
Acero-Domínguez et al	2004			YES					
Alaykýran et. al	2007						Yes		
Alfieri	2009				YES				
Allahverdi et al	2006			YES					
Allaoui er al	2004			YES					
Azizoğlu et al	1999		YES						
Behnamian et al	2011							YES	
Bertel et al	2004			YES					
Botta-Genoulaz	1997			YES					
Botta-Genoulaz	2000			YES					
Brah et al	1999			YES					
Carlier et al	2000		YES						
Chen et al	2009			YES					
Cheng et al	2001			YES					
Choi et al	2007			YES					
Dios et al	2015			YES					
Djellab et al	2002	YES							
Ebrahimi et al	2014	YES						YES	
Engin et al	2004						YES		
Fattahi et al	2013		YES						
Gue et al	1997	YES	YES						
Gupta et al	2002			YES					
Havill et al	1998			YES					
Hong et al	2001			YES					
Huang et al	2007			YES					
Janiak et al	2007							YES	
Jenabi et al	2007	YES						YES	

APPENDIX 2 - SOLUTION METHODOLOGIES USED IN THE STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Mathematical Model	Exact Algorithm	Heuristics	Meta-heuristics				
					Tabu Search	Simulated Annealing	Genetic & Evolutionary Algorithm	Hybrid	Neural Networks
Jin et al	2006							YES	
Jun et al	2015							YES	
Jungwattanakit et al	2008	YES		YES	YES	YES	YES		
Jungwattanakit et al	2009	YES		YES			YES		
Kaczmarczyk et al	2004	YES	YES	YES					
Kis et al	2005	YES	YES						
Kuo et al	2008			YES					
Kurz et al	2003			YES					
Kurz et al	2004	YES		YES					
Kyparisis et al	2001			YES					
Kyparisis et al	2006			YES					
Lee et al	2004			YES					
Lee	2009			YES					
Leon et al	1997			YES					
Liao et al	2012							YES	
Li et al	2015							YES	
Li et al	2014							YES	
Liu et al	2000	YES							
Liu et al	2008	YES							
Logendran et al	2005			YES					
Logendran et al	2006				YES				
Low	2005					YES			
Marichelvam et al	2014							YES	
Mirsanei et al	2011					YES			
Morita et al	2005	YES						YES	
Moursli et al	2000		YES						
Naderi et al	2008					YES			
Naderi et al	2009					YES			
Negenman	2001				YES	YES			
Neron et al	2001		YES						
Niu et al	2012	YES						YES	
Nowicki et al	1998				YES				
Oğuz et al	2004				YES				

APPENDIX 2 - SOLUTION METHODOLOGIES USED IN THE STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Mathematical Model	Exact Algorithm	Heuristics	Meta-heuristics				
					Tabu Search	Simulated Annealing	Genetic & Evolutionary Algorithm	Hybrid	Neural Networks
Oğuz et al	2005						YES		
Portmann et al	1998		YES						
Ruiz et al	2006						YES		
Ruiz et al	2008	YES		YES					
Ruiz et al	2015			YES					
Santos et al	2001			YES					
Sawik	2000	YES							
Sawik	2001	YES							
Sawik et al	2002	YES							
Sawik	2002	YES							
Sawik	2005	YES							
Şerifoğlu et al	2004						YES		
Sevastianov	2002			YES					
Shiau et al	2008			YES					
Sirikrai et al	2006			YES					
Tang et al	2005								YES
Tang et al	2006	YES							
Tang et al	2006	YES							
Tavakkoli-Moghaddam et al	2007	YES							
Tavakkoli-Moghaddam et al	2009			YES					
Thornton et al	2004			YES					
Tseng et al	2008						YES		
Vazquez Rodriguez et al	2005						YES		
Vazquez Rodriguez et al	2006							YES	
Verma et al	1999			YES					
Vignier et al	1997		YES						
Voss et al	2007	YES		YES					
Wang et al	2003	YES					YES		
Wang et al	2009				YES				

APPENDIX 2 - SOLUTION METHODOLOGIES USED IN THE STUDIES IN THE LITERATURE (CONTINUED)

Paper	Year	Mathematical Model	Exact Algorithm	Heuristics	Meta-heuristics				
					Tabu Search	Simulated Annealing	Genetic & Evolutionary Algorithm	Hybrid	Neural Networks
Wardono et al	2004				YES				
Wu et al	2003						YES		
Xiao et al	2000						YES		
Xuan et al	2007	YES							
Yang et al	2004				YES				
Yang et al	2007						YES		
Yaurima et al	2009						YES		
Ying et al	2006						YES		
Zandieh et al	2006						YES		
Zandieh et al	2009							YES	

APPENDIX 3 – SOLUTIONS OF PROBLEM SETS FOR VERIFICATION
OF MATHEMATICAL MODEL

PROBLEM SET-1

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6
1. Stage	5	19	3	5	19	2
2. Stage	1	13	6	14	3	3
3. Stage	3	15	9	17	3	16
Job Family	K	K	K	M	M	M

Setup Times

Jobs	1	2	3	4	5	6
1	0	0	0	4	0	1
2	0	0	0	0	3	1
3	0	0	0	2	3	0
4	3	3	5	0	0	0
5	1	3	1	0	0	0
6	4	4	2	0	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C_{max}	Solution Time (seconds)
				Stage 1	Stage 2	Stage 3		
1	6	Unlimited	1	3-6-4-1-5	3-1-2	6-2	47	1.12
			2	2	6-4-5	3-1-4-5		
2		Limited (size 0)	1	3-6-4-1-5	3-1-2	6-2	47	1.00
			2	2	6-4-5	3-1-4-5		
3		Limited (size 1)	1	3-6-4-1-5	3-1-2	6-2	47	3.33
			2	2	6-4-5	3-1-4-5		
4		Limited (size 2)	1	3-6-4-1-5	3-1-2	3-1-2	47	0.98
			2	2	6-4-5	6-4-5		

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-2

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6
1. Stage	7	5	9	15	10	3
2. Stage	5	3	2	14	10	14
3. Stage	4	13	8	7	16	7
Job Family	K	K	K	K	M	M

Setup Times

Jobs	1	2	3	4	5	6
1	0	0	0	0	1	0
2	0	0	5	0	3	0
3	3	3	0	1	0	1
4	0	0	4	0	5	0
5	4	5	0	1	0	3
6	0	0	1	0	1	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C_{max}	Solution Time (seconds)
				Stage 1	Stage 2	Stage 3		
5	6	Unlimited	1	3-4	3-2-4-1	3-2-4	47	2.40
			2	6-5-2-1	6-5	6-5-1		
6		Limited (size 0)	1	5-2-6-1	3-2-4-1	3-2-6-1	47	1.03
			2	3-4	5-6	5-4		
7		Limited (size 1)	1	3-4	3-2-4-1	3-2-4	47	5.09
			2	6-5-2-1	6-5	6-5-1		
8		Limited (size 2)	1	3-4	3-2-4-1	3-2-4	47	4.27
			2	6-5-2-1	6-5	6-5-1		

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-3

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7
1. Stage	4	10	8	2	16	10	8
2. Stage	8	5	8	6	14	15	15
3. Stage	13	12	4	4	7	7	1
Job Families	K	K	K	K	M	M	M

Setup Times

Jobs	1	2	3	4	5	6	7
1	0	0	0	0	0	4	0
2	0	0	0	0	1	0	2
3	0	0	0	0	0	5	0
4	0	0	0	0	3	0	3
5	1	2	4	3	0	0	0
6	1	1	3	1	0	0	0
7	3	4	5	2	0	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C_{max}	Solution Time (seconds)
				Stage 1	Stage 2	Stage 3		
9	7	Unlimited	1	4-1-5-7	4-1-2-3	2-5-7	55	3.23
			2	6-2-3	6-5-7	4-1-6-3		
10		Limited (size 0)	1	4-1-5-7	4-1-2-3	4-2-5-7	55	3.20
			2	6-2-3	6-5-7	1-6-3		
11		Limited (size 1)	1	4-1-5-7	4-1-2-3	4-2-5	55	3.45
			2	6-2-3	6-5-7	1-6-3-7		
12		Limited (size 2)	1	6-2-3	4-1-2-3	2-5	55	7.26
			2	4-1-5-7	6-5-7	4-1-6-3-7		

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-4

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7
1. Stage	17	7	14	18	18	12	4
2. Stage	13	5	9	20	8	17	5
3. Stage	3	19	18	10	4	18	6
Job Families	K	K	K	K	K	M	M

Setup Times

Jobs	1	2	3	4	5	6	7
1	0	0	0	0	0	0	0
2	0	0	0	0	0	5	0
3	0	0	0	0	0	3	1
4	0	0	0	0	0	4	5
5	0	0	0	0	0	2	0
6	4	5	5	3	2	0	0
7	2	2	4	1	1	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C_{\max}	Solution Time (seconds)	
				Stage 1	Stage 2	Stage 3			
13	7	Unlimited	1	3-7-6-1	2-3-4-5-1	7-3-6-1	69	4.82	
			2	2-4-5	7-6	2-4-5			
14		Limited (size 0)	1	3-7-6-1	2-3-4-5-1	7-3-6-1	69		
			2	2-4-5	7-6	2-4-5			
15		Limited (size 1)	1	2-4-5	2-3-4-5-1	2-4-5-1	69		
			2	3-7-6-1	7-6	7-3-6			
16		Limited (size 2)	1	3-7-6-1	2-3-4-5-1	2-4-5	69		77.19
			2	2-4-5	7-6	7-3-6-1			

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-5

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7	8
1. Stage	18	1	2	2	1	3	1	15
2. Stage	7	7	1	18	8	14	1	10
3. Stage	20	6	5	18	11	5	1	7
Job Families	M	M	K	M	K	M	M	K

Setup Times

Jobs	1	2	3	4	5	6	7	8
1	0	0	0	0	1	0	0	4
2	0	0	5	0	3	0	0	0
3	3	3	0	1	0	1	2	0
4	0	0	4	0	5	0	0	1
5	4	5	0	1	0	3	1	0
6	0	0	1	0	1	0	0	2
7	0	0	2	0	1	0	0	4
8	3	4	0	3	0	1	1	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C_{max}	Solution Time (seconds)
				Stage 1	Stage 2	Stage 3		
17	8	Unlimited	1	3-7-6-1	2-3-4-5-1	7-3-6-1	53	7.80
			2	2-4-5	7-6	2-4-5		
18		Limited (size 0)	1	3-7-6-1	2-3-4-5-1	7-3-6-1	53	29.22
			2	2-4-5	7-6	2-4-5		
19		Limited (size 1)	1	2-4-5	2-3-4-5-1	2-4-5-1	53	318.11
			2	3-7-6-1	7-6	7-3-6		
20		Limited (size 2)	1	2-4-5	2-3-4-5-1	2-4-5-1	53	366.27
			2	3-7-6-1	7-6	7-3-6		

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-6

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7	8
1. Stage	3	10	16	12	17	8	8	5
2. Stage	12	7	12	18	11	12	9	2
3. Stage	4	1	15	10	10	16	4	16
Job Families	K	K	K	K	M	M	M	M

Setup Times

Jobs	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	2	0
2	0	0	0	0	0	4	0	3
3	0	0	0	0	2	3	0	1
4	0	0	0	0	5	0	3	0
5	4	1	5	3	0	0	0	0
6	3	2	2	5	0	0	0	0
7	2	1	1	1	0	0	0	0
8	5	5	5	1	0	0	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C_{max}	Solution Time (seconds)
				Stage 1	Stage 2	Stage 3		
21	8	Unlimited	1	1-8-6-5-7	1-3-4-2	1-3-5-7	58	10.14
			2	3-4-2	8-6-5-7	8-6-4-2		
22		Limited (size 0)	1	3-4-2	1-3-4-2	1-6-5-7	58	11.46
			2	1-8-6-5-7	8-6-5-7	8-3-4-2		
23		Limited (size 1)	1	1-8-6-5-7	1-3-4-2	8-6-4-2	58	290.61
			2	3-4-2	8-6-5-7	1-3-5-7		
24		Limited (size 2)	1	1-8-6-5-7	1-3-4-2	8-6-4-2	58	378.47
			2	3-4-2	8-6-5-7	1-3-5-7		

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-7

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7	8	9
1. Stage	3	1	5	12	11	5	12	18	8
2. Stage	1	20	10	17	18	17	9	13	9
3. Stage	9	8	2	6	15	9	13	1	8
Job Families	K	K	K	K	K	M	M	M	M

Setup Times

Jobs	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	2	0	0
2	0	0	0	0	0	4	0	5	1
3	0	0	0	0	0	0	0	0	3
4	0	0	0	0	0	0	1	0	0
5	0	0	0	0	0	2	3	4	0
6	1	1	3	4	5	0	0	0	0
7	2	4	1	5	3	0	0	0	0
8	2	3	1	5	4	0	0	0	0
9	2	3	4	5	1	0	0	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C _{max}	Solution Time (seconds)
				Stage 1	Stage 2	Stage 3		
25	9	Unlimited	1	2-1-3-5-4	2-1-3-5-4	6-9-7-4-3	69	22.42
			2	6-9-7-8	6-9-7-8	2-1-5-8		
26		Limited (size 0)	1	9-5-4-3	2-1-5-4-3	2-7-6-8-3	69	8.17
			2	2-7-1-6-8	9-7-6-8	9-1-5-4		
27		Limited (size 1)	1	2-1-6-7-8	2-1-5-4-3	9-1-5-8-4-3	69	361.38
			2	9-5-4-3	9-6-7-8	2-6-7		
28		Limited (size 2)	1	2-1-5-4-3	2-1-5-4-3	2-1-5-3	69	301.24
			2	6-9-7-8	6-9-7-8	6-9-7-8-4		

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-8

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7	8	9
1. Stage	13	9	20	14	6	3	15	4	19
2. Stage	13	5	20	8	3	18	13	12	18
3. Stage	4	6	18	19	18	15	19	7	18
Job Families	K	K	K	K	K	K	M	M	M

Setup Times

Jobs	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	5	0	0
2	0	0	0	0	0	0	0	2	6
3	0	0	0	0	0	0	4	0	0
4	0	0	0	0	0	0	1	0	3
5	0	0	0	0	0	0	0	5	0
6	0	0	0	0	0	0	2	0	0
7	2	4	5	2	1	4	0	0	0
8	1	3	5	2	1	1	0	0	0
9	3	4	3	1	4	4	0	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C _{max}	Solution Time (seconds)	
				Stage 1	Stage 2	Stage 3			
29	9	Unlimited	1	5-3-2-4	5-6-3-2-4-1	5-7-2-4-1	83	1135.18	
			2	6-8-7-9-1	8-7-9	8-6-3-9			
30		Limited (size 0)	1	8-7-9-4	5-6-3-2-4-1	5-7-2-4-1	85	193.50	
			2	5-6-3-2-1	8-7-9	8-6-3-9			
31		Limited (size 1)	1	5-3-2-4	6-5-3-2-4-1	8-5-3-4	83	859.60	
			2	6-8-7-9-1	8-7-9	6-7-2-9-1			
32		Limited (size 2)	1	OUT OF MEMORY					11205.89
			2						

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-9

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7	8	9	10
1. Stage	5	2	8	11	2	7	13	9	5	2
2. Stage	9	8	2	4	10	7	8	5	6	6
3. Stage	8	9	5	9	1	2	10	7	4	2
Job Families	K	K	K	M	M	M	M	M	M	M

Setup Times

Jobs	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	5	0	2
2	0	0	0	0	5	0	3	0	0	0
3	0	0	0	2	0	2	1	4	0	0
4	1	5	2	0	0	0	0	0	0	0
5	2	1	3	0	0	0	0	0	0	0
6	2	5	1	0	0	0	0	0	0	0
7	3	1	4	0	0	0	0	0	0	0
8	2	2	1	0	0	0	0	0	0	0
9	1	2	2	0	0	0	0	0	0	0
10	5	4	3	0	0	0	0	0	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C _{max}	Solution Time (seconds)	
				Stage 1	Stage 2	Stage 3			
33	10	Unlimited	1	2-1-7-8-5	2-1-3	10-2-1-7-4-5	49	5404.16	
			2	10-9-6-3-4	10-9-6-7-8-4-5	9-6-3-8			
34		Limited (size 0)	1	10-9-7-4-5	2-1-3	10-9-7-4-5	49		
			2	2-6-1-8-3	10-9-6-7-8-4-5	2-6-1-8-3			
35		Limited (size 1)	1	OUT OF MEMORY					13365.39
			2	OUT OF MEMORY					

APPENDIX 3 - SOLUTIONS OF PROBLEM SETS FOR VERIFICATION OF
MATHEMATICAL MODEL (CONTINUED)

PROBLEM SET-10

Processing Times and Job Families of Jobs

Jobs:	1	2	3	4	5	6	7	8	9	10
1. Stage	3	6	1	18	3	11	1	16	4	7
2. Stage	14	5	19	14	2	3	9	2	4	1
3. Stage	4	4	9	3	6	9	11	18	13	1
Job Families	K	K	K	M	M	M	M	M	M	M

Setup Times

Jobs	1	2	3	4	5	6	7	8	9	10
1	0	0	0	1	0	5	1	0	0	4
2	0	0	2	0	3	4	0	3	2	0
3	2	4	0	0	0	0	0	0	0	0
4	1	2	0	0	0	0	0	0	0	0
5	2	1	0	0	0	0	0	0	0	0
6	3	4	0	0	0	0	0	0	0	0
7	2	2	0	0	0	0	0	0	0	0
8	5	2	0	0	0	0	0	0	0	0
9	2	1	0	0	0	0	0	0	0	0
10	1	1	0	0	0	0	0	0	0	0

Solutions

Problem #	# of Jobs	Buffer	Machine #	Job Sequence			C _{max}	Solution Time (seconds)		
				Stage 1	Stage 2	Stage 3				
36	10	Unlimited	1	7-3-5-9-6-4	2-1	2-5-1-3-6-4	57	7459.63		
			2	2-1-10-8	7-5-9-3-8-6-4-10	7-9-8-10				
37		Limited (size 0)	1	7-1-9-5-2-6-10	1-2	7-1-2-9-3-4	57			
			2	8-3-4	7-9-5-8-3-6-4-10	5-8-6-10				
38		Limited (size 1)	1	OUT OF MEMORY						13365.39
			2							

APPENDIX 4 – SOLUTIONS OF SMALL SCALE PROBLEMS BY UTILIZING HEURISTICS

Comparison of Meta-Heuristics When Construction Rule = SPT1

Problem #	Mathematical Model	Value of C_{max}											
		Simulated Annealing						Tabu Search					
		$\alpha=0.80$		$\alpha=0.90$		$\alpha=0.99$		Tabulist size=1		Tabulist size=2		Tabulist size=3	
		MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100
1	47	52	52	52	52	52	52	52	50	49	47	50	49
2	47	54	54	54	54	54	54	47	47	50	47	49	47
3	47	52	52	52	52	52	52	47	47	49	47	50	49
4	47	52	52	52	52	52	52	47	49	47	47	49	47
5	47	49	49	49	48	48	48	48	47	48	47	47	47
6	47	51	51	51	51	50	50	48	48	48	47	48	48
7	47	49	49	49	49	48	48	48	47	48	48	48	48
8	47	49	49	49	49	48	48	50	48	48	48	47	48
9	55	61	61	61	61	61	61	55	58	55	55	55	55
10	55	61	61	61	61	61	61	56	55	55	57	55	55
11	55	61	61	61	61	61	61	56	55	55	55	56	55
12	55	61	61	61	61	61	61	55	55	55	55	59	55
13	69	85	85	85	85	85	85	73	72	73	71	75	74
14	69	85	85	85	85	85	85	73	73	74	72	72	74
15	69	85	85	85	85	85	85	73	69	74	71	72	72
16	69	85	85	85	85	85	85	73	72	71	69	72	72
17	53	68	68	68	68	68	68	56	55	58	54	60	55
18	53	70	70	70	70	70	70	57	55	57	56	60	56
19	53	68	68	68	68	68	68	60	54	55	55	62	58
20	53	68	68	68	68	68	68	56	55	58	53	61	55
21	58	68	69	69	69	69	69	65	67	66	62	63	59
22	58	69	78	78	78	78	78	64	71	70	62	70	63
23	58	68	69	69	69	69	69	67	64	67	66	66	66
24	58	68	69	69	69	69	69	65	65	61	62	67	66
25	69	73	73	73	73	73	73	72	71	73	72	69	69
26	69	80	80	80	80	80	80	81	74	77	75	75	76
27	69	73	73	73	73	73	73	73	69	73	72	73	73
28	69	73	73	73	73	73	73	72	73	72	73	69	72
29	83	87	86	87	86	87	86	90	94	91	91	89	89
30	85	86	89	89	89	89	89	92	90	96	94	94	87
31	83	86	86	86	86	86	86	91	89	97	87	93	94
32	-	89	86	86	86	86	86	93	88	90	91	90	85
33	49	58	58	58	58	55	55	50	51	54	50	52	53
34	49	64	64	64	64	61	61	51	54	51	55	53	56
35	-	58	58	58	58	55	55	52	50	50	52	54	50
36	57	60	60	60	60	64	67	60	58	58	60	61	59
37	57	76	76	76	72	72	72	67	64	68	65	71	65
38	-	66	66	66	75	75	75	60	61	60	59	61	62

MI: maximum number of iterations used for stopping the improvement metaheuristics.

APPENDIX 4 – SOLUTIONS OF SMALL SCALE PROBLEMS BY UTILIZING
HEURISTICS (CONTINUED)

Comparison of Meta-heuristics When Construction Rule = SPTcomp

Problem #	Mathematical Model	Value of C_{max}											
		Simulated Annealing						Tabu Search					
		$\alpha=0.80$		$\alpha=0.90$		$\alpha=0.99$		Tabulist size=1		Tabulist size=2		Tabulist size=3	
		MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100
1	47	60	56	56	56	56	56	47	47	49	47	49	49
2	47	61	61	50	50	50	50	50	49	49	49	49	47
3	47	60	60	56	56	56	56	49	47	49	49	47	47
4	47	60	56	56	56	56	56	49	47	51	49	47	49
5	47	48	48	48	48	48	48	48	48	47	48	47	47
6	47	51	51	51	51	51	51	48	47	48	48	48	48
7	47	48	48	48	48	48	48	48	48	47	47	48	48
8	47	48	48	48	48	48	48	48	47	47	48	51	48
9	55	61	61	61	61	61	61	59	55	55	55	59	55
10	55	61	61	61	61	61	61	56	55	56	55	55	55
11	55	61	61	61	61	61	61	55	55	57	55	55	55
12	55	61	61	61	61	61	61	55	55	56	55	55	55
13	69	80	80	80	80	80	80	71	72	70	72	70	72
14	69	91	91	91	91	91	91	72	72	71	72	72	71
15	69	80	80	80	80	80	80	73	71	72	72	75	72
16	69	80	80	80	80	80	80	76	71	72	72	72	72
17	53	68	68	68	68	68	68	58	56	59	56	56	55
18	53	68	68	68	68	68	68	53	58	58	56	57	57
19	53	68	68	68	68	68	68	59	56	61	54	58	56
20	53	68	68	68	68	68	68	55	54	55	55	58	60
21	58	69	69	69	69	69	69	66	63	58	64	60	64
22	58	73	73	73	73	73	73	67	66	66	66	67	62
23	58	69	69	69	69	69	69	66	66	66	66	66	68
24	58	69	69	69	69	69	69	66	66	64	63	67	61
25	69	88	88	88	88	88	88	69	69	78	69	71	69
26	69	101	101	101	101	101	101	76	74	73	76	78	78
27	69	89	89	89	89	89	89	74	69	70	73	77	71
28	69	88	88	88	88	88	88	74	69	73	69	79	71
29	83	92	92	92	92	92	92	91	90	88	89	84	88
30	85	100	100	100	100	100	100	99	88	97	88	91	97
31	83	91	91	91	91	91	91	95	85	89	89	95	90
32	-	92	92	92	92	92	92	97	90	91	91	91	84
33	49	57	57	57	57	57	57	50	52	53	50	50	52
34	49	62	62	62	62	62	62	54	55	54	53	52	54
35	-	57	57	57	57	57	57	55	52	53	52	53	52
36	57	75	75	75	75	75	75	60	60	60	58	65	60
37	57	65	65	65	65	65	65	65	65	68	69	67	69
38	-	67	67	67	67	67	67	64	62	59	61	59	62

APPENDIX 4 – SOLUTIONS OF SMALL SCALE PROBLEMS BY UTILIZING
HEURISTICS (CONTINUED)

Comparison of Meta-Heuristics When Construction Rule = LPT1

Problem #	Mathematical Model	Value of C_{max}											
		Simulated Annealing						Tabu Search					
		$\alpha=0.80$		$\alpha=0.90$		$\alpha=0.99$		Tabulist size=1		Tabulist size=2		Tabulist size=3	
MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100
1	47	64	64	64	64	64	64	49	49	52	47	47	47
2	47	64	64	64	64	64	64	49	49	49	49	47	49
3	47	64	64	64	64	64	64	49	49	49	49	49	49
4	47	64	64	64	64	64	64	49	47	49	50	49	49
5	47	53	53	53	53	53	53	47	47	48	48	48	48
6	47	53	53	53	53	53	53	48	47	48	47	48	48
7	47	53	53	53	53	53	53	48	48	48	48	47	47
8	47	53	53	53	53	53	53	48	48	47	48	47	48
9	55	55	55	55	55	55	55	55	55	55	55	55	55
10	55	55	55	55	55	55	55	55	55	55	55	56	55
11	55	55	55	55	55	55	55	55	55	55	55	55	55
12	55	55	55	55	55	55	55	55	55	55	55	55	55
13	69	91	91	91	91	91	91	72	70	72	72	72	72
14	69	97	97	97	97	97	97	72	69	74	73	79	76
15	69	91	91	91	91	91	91	72	72	76	71	72	72
16	69	91	91	91	91	91	91	72	72	72	69	75	71
17	53	75	75	75	75	75	75	59	54	59	56	60	57
18	53	75	75	75	75	75	75	59	55	63	56	56	56
19	53	75	75	75	75	75	75	55	54	56	56	58	56
20	53	75	75	75	75	75	75	60	56	57	58	65	54
21	58	69	69	69	69	69	69	62	67	64	60	66	65
22	58	71	71	71	71	71	71	64	61	73	64	65	68
23	58	69	69	69	69	69	69	62	65	66	65	66	66
24	58	69	69	69	69	69	69	66	60	68	64	68	65
25	69	95	95	95	95	95	95	71	69	76	71	73	73
26	69	91	91	91	91	91	91	74	74	79	75	83	75
27	69	97	97	97	97	97	97	73	73	73	69	74	77
28	69	95	95	95	95	95	95	72	72	69	73	72	69
29	83	102	102	102	102	102	102	86	87	88	86	91	88
30	85	102	102	102	103	103	103	92	92	96	88	97	90
31	83	102	102	102	102	102	102	98	86	89	88	95	88
32	-	101	101	101	102	102	102	88	85	91	85	92	89
33	49	59	59	59	59	59	59	55	53	55	50	51	50
34	49	63	63	63	63	63	63	55	52	50	54	56	54
35	-	59	59	59	59	59	59	50	53	51	50	52	54
36	57	79	79	79	79	79	79	59	60	61	60	60	60
37	57	79	79	79	79	79	79	69	64	66	66	65	67
38	-	79	79	79	79	79	79	63	62	65	61	62	60

APPENDIX 4 – SOLUTIONS OF SMALL SCALE PROBLEMS BY UTILIZING
HEURISTICS (CONTINUED)

Comparison of Meta-Heuristics When Construction Rule = LPTcomp

Problem #	Mathematical Model	Value of C_{max}											
		Simulated Annealing						Tabu Search					
		$\alpha=0.80$		$\alpha=0.90$		$\alpha=0.99$		Tabulist size=1		Tabulist size=2		Tabulist size=3	
		MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100	MI 50	MI 100
1	47	51	51	51	51	51	51	49	49	50	49	47	47
2	47	51	51	51	51	51	51	49	49	47	47	47	47
3	47	51	51	51	51	51	51	49	49	49	49	47	47
4	47	51	51	51	51	51	51	49	49	47	47	49	49
5	47	51	51	51	51	51	51	48	48	48	48	48	48
6	47	51	51	51	51	51	51	48	48	49	47	49	48
7	47	51	51	51	51	51	51	49	48	47	47	48	47
8	47	51	51	51	51	51	51	48	48	47	47	48	48
9	55	55	55	55	55	55	55	55	55	55	55	55	55
10	55	55	55	55	55	55	55	55	55	55	55	55	55
11	55	55	55	55	55	55	55	55	55	55	55	55	55
12	55	55	55	55	55	55	55	55	55	55	55	55	55
13	69	76	76	76	76	76	76	71	73	76	71	73	70
14	69	79	79	79	79	79	79	79	71	79	74	72	71
15	69	76	76	76	76	76	76	75	70	73	72	72	71
16	69	76	76	76	76	76	76	71	71	71	72	72	71
17	53	62	62	62	62	62	62	56	56	59	59	57	59
18	53	62	62	62	62	62	62	57	55	62	54	57	56
19	53	62	62	62	62	62	62	58	58	60	59	58	57
20	53	62	62	62	62	62	62	56	54	55	54	59	56
21	58	71	71	71	71	71	71	65	65	63	67	69	63
22	58	74	74	74	74	74	74	68	66	69	66	73	62
23	58	71	71	71	71	71	71	68	63	60	65	63	65
24	58	71	71	71	71	71	71	65	66	63	63	64	62
25	69	86	82	82	82	82	82	69	69	75	69	73	76
26	69	82	82	87	87	87	87	77	74	77	80	75	71
27	69	86	87	87	87	87	87	74	73	76	70	73	73
28	69	86	82	82	82	82	82	69	73	72	71	74	70
29	83	102	102	102	102	102	102	96	90	91	89	90	89
30	85	101	101	101	101	101	101	92	88	99	92	93	90
31	83	102	102	102	102	102	102	88	86	86	89	90	88
32	-	102	102	102	102	102	102	87	91	91	88	91	86
33	49	58	58	58	58	58	58	53	52	55	51	53	51
34	49	61	61	61	61	61	61	54	53	53	53	56	53
35	-	58	58	58	58	58	58	53	51	51	52	50	51
36	57	79	79	79	79	79	79	60	60	61	61	61	60
37	57	77	77	77	77	77	77	64	67	68	64	64	65
38	-	76	76	76	76	76	76	61	60	60	59	59	64

APPENDIX 5 – SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS

Number of Jobs = 20,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	20_SPT1_SA_									20_SPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	125	125	125	125	125	125	125	125	125	134	134	134	134	134	134	134	134	134
2	121	121	121	121	121	121	121	121	121	127	120	120	127	120	120	127	120	120
3	129	129	129	129	129	129	129	129	129	133	132	132	133	132	132	133	132	132
4	124	118	117	124	118	117	124	118	117	126	126	126	121	121	121	121	121	121
5	134	134	134	134	134	134	134	134	134	135	135	135	135	135	135	135	135	130
6	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
7	105	103	103	105	103	103	105	103	103	115	109	109	115	109	109	115	109	109
8	133	133	133	133	133	133	133	133	133	129	129	129	129	129	129	129	129	129
9	137	137	137	134	132	128	134	132	128	134	133	133	134	133	133	134	133	133
10	137	137	137	137	137	137	137	137	137	145	145	145	145	145	145	145	145	145
11	128	128	128	128	128	128	128	128	128	143	143	143	143	143	143	143	143	143
12	126	126	126	126	126	126	126	126	126	132	132	132	132	132	132	132	132	132
13	136	136	135	136	136	135	136	136	135	137	136	136	137	136	136	137	136	136
14	116	113	113	116	113	113	116	113	113	115	115	115	130	130	130	130	130	130
15	140	140	138	138	138	138	138	138	138	136	136	136	136	136	136	136	136	136
16	139	139	139	139	139	139	139	139	139	142	140	140	142	140	140	142	140	140
17	113	113	113	113	113	113	113	113	113	120	120	120	120	120	120	120	120	120
18	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
19	127	127	124	127	127	124	127	127	124	135	133	133	135	133	133	135	133	133
20	142	142	142	142	142	142	142	142	142	149	147	147	149	147	147	149	147	147

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	20_LPT1_SA_									20_LPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	150	150	150	150	150	150	150	150	150	149	151	151	151	151	151	151	151	151
2	141	134	134	141	134	134	141	134	134	132	132	132	132	132	132	132	132	132
3	140	140	139	140	140	139	140	140	139	138	138	138	138	138	138	138	138	138
4	137	133	130	137	133	130	137	133	130	130	129	129	130	129	129	130	129	129
5	142	142	140	142	142	140	142	142	140	136	136	135	136	136	135	136	136	135
6	154	154	154	154	154	154	154	154	154	139	139	139	139	139	139	139	139	139
7	119	116	116	119	116	116	119	116	116	111	111	111	111	111	111	111	111	111
8	144	140	140	144	140	140	144	140	140	139	139	139	139	139	139	139	139	139
9	143	143	143	143	143	143	143	143	143	137	136	136	137	136	136	137	136	136
10	161	161	161	161	161	161	161	161	161	151	151	151	151	151	151	151	151	151
11	159	159	159	159	159	159	159	159	159	142	142	142	142	142	142	142	142	142
12	137	136	136	137	136	136	137	136	136	137	137	135	149	149	149	149	149	149
13	153	151	149	153	151	149	153	151	149	142	142	142	142	142	142	142	142	140
14	139	139	139	139	139	139	139	139	139	129	129	129	129	129	129	129	129	129
15	166	166	166	166	166	166	166	166	166	157	157	157	157	157	157	157	157	157
16	144	143	143	144	143	143	144	143	143	142	141	141	142	141	141	142	141	141
17	130	130	130	130	130	130	130	130	130	131	131	131	131	131	131	131	131	131
18	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163
19	150	150	150	150	155	155	155	155	155	150	150	150	150	150	150	150	150	150
20	156	156	155	161	161	161	161	161	161	154	154	154	154	154	154	154	154	154

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	50_SPT1_SA_									50_SPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	287	286	286	287	286	286	287	286	286	289	288	288	289	287	287	289	287	287
2	289	289	283	289	289	283	289	289	283	291	291	288	291	291	288	291	291	288
3	297	297	297	297	297	297	297	297	297	302	302	303	303	303	303	303	303	303
4	283	283	283	283	283	283	283	283	283	289	286	286	289	286	286	289	286	286
5	303	303	303	303	303	303	303	303	301	307	306	306	307	306	306	307	306	306
6	277	277	277	277	277	277	277	277	277	291	291	291	291	291	291	291	291	291
7	274	274	274	274	274	274	274	274	274	276	276	274	280	277	275	280	277	275
8	297	297	297	297	297	297	297	297	297	307	307	307	307	307	306	306	306	306
9	282	279	279	282	279	279	282	271	271	285	285	278	285	285	278	285	285	278
10	286	286	286	286	286	286	292	288	286	267	267	267	267	267	267	267	267	267
11	323	321	321	323	321	321	323	321	321	322	322	320	322	322	320	322	322	320
12	273	273	273	273	273	273	273	273	273	264	264	264	264	264	264	264	264	264
13	288	287	284	286	284	284	286	284	284	295	295	295	295	295	295	295	295	295
14	263	263	263	263	263	263	263	263	263	276	276	276	276	276	276	276	276	276
15	272	272	272	272	272	272	272	272	272	276	276	277	277	277	277	277	277	277
16	284	280	280	284	280	280	284	280	280	292	292	289	292	292	289	292	292	289
17	272	272	272	272	272	272	272	272	272	270	270	270	270	270	270	270	270	270
18	274	274	274	274	274	274	274	274	274	277	277	277	277	277	277	277	277	285
19	282	282	282	282	282	282	282	282	282	278	278	278	278	278	278	278	278	278
20	283	283	282	283	283	282	283	283	282	286	286	286	286	286	286	286	286	286

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	50_LPT1_SA_									50_LPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	319	319	315	319	319	315	319	319	315	316	316	313	316	316	313	316	316	313
2	306	3002	297	306	302	297	306	302	297	296	296	296	296	321	321	321	321	321
3	337	337	337	337	337	337	337	337	337	312	312	312	312	312	312	312	312	312
4	312	312	312	312	312	312	312	312	312	303	295	295	303	295	295	303	295	295
5	336	336	336	336	336	336	336	336	336	326	326	326	326	326	326	326	326	326
6	303	303	303	276	276	276	276	276	276	279	277	277	279	277	277	279	277	277
7	308	306	306	308	306	306	308	306	306	301	301	301	301	301	301	301	301	301
8	334	334	334	334	334	334	334	334	334	323	323	323	323	323	323	323	323	323
9	310	308	308	310	308	308	310	308	308	304	304	304	304	304	304	304	304	304
10	311	307	307	311	307	307	311	307	307	285	284	283	285	284	283	285	284	283
11	333	333	333	333	333	333	333	333	333	325	325	325	325	344	344	344	344	344
12	309	309	309	309	309	309	309	309	309	292	291	290	292	291	290	292	291	290
13	343	337	335	343	337	335	343	337	335	307	305	305	307	305	305	307	305	307
14	298	298	296	298	298	296	298	298	296	294	294	294	294	294	294	294	294	294
15	331	331	331	331	331	331	331	331	331	305	305	305	305	305	305	305	305	305
16	309	305	303	309	309	319	323	323	319	308	305	305	308	305	305	308	305	305
17	325	325	325	325	325	325	325	325	325	317	317	317	317	317	317	317	317	317
18	311	311	311	311	311	311	311	311	311	293	293	293	293	293	293	293	293	293
19	321	320	319	321	320	325	325	325	325	302	299	299	302	299	299	302	299	299
20	312	311	311	311	311	311	311	311	311	308	308	308	308	308	308	308	308	308

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	100_SPT1_SA_									100_SPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	588	588	588	588	588	588	588	588	588	595	594	594	595	594	594	595	594	594
2	546	544	544	551	551	551	551	551	551	556	556	556	556	556	556	556	556	556
3	528	527	527	528	527	527	528	527	527	533	533	532	533	532	532	533	532	532
4	562	562	562	562	562	562	566	565	565	570	565	565	570	565	565	570	565	565
5	515	515	515	515	515	515	515	515	515	517	517	515	517	517	515	517	517	515
6	598	598	598	598	598	598	598	598	598	596	596	596	596	596	596	596	596	586
7	540	540	540	540	540	540	540	540	540	547	545	545	547	545	545	547	545	547
8	557	557	557	557	557	557	557	552	549	553	552	552	553	552	552	553	552	552
9	553	551	550	553	551	550	553	551	550	551	551	550	557	550	550	557	550	550
10	500	496	493	496	494	493	496	494	493	504	504	504	504	504	504	504	504	504
11	568	568	568	568	568	568	568	568	568	575	575	575	575	575	575	575	575	575
12	543	543	542	542	540	539	542	540	539	545	545	545	545	545	545	545	545	545
13	558	558	558	558	558	558	558	558	558	560	560	560	560	560	560	560	560	560
14	491	491	491	491	491	491	491	507	490	501	494	494	501	494	494	501	494	494
15	508	508	508	508	508	508	508	508	508	503	503	503	503	503	498	501	501	500
16	547	547	547	547	547	547	547	547	547	552	552	552	552	552	542	545	545	542
17	518	518	517	518	518	517	518	518	517	538	532	532	538	532	539	539	539	539
18	509	507	507	509	507	507	509	507	507	514	514	513	514	514	523	523	523	523
19	524	524	524	524	524	524	524	524	522	523	522	522	523	522	522	523	522	522
20	524	524	524	524	524	524	524	524	523	526	526	526	526	526	526	526	526	526

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	100_SPT1_SA_									100_SPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	620	621	621	625	621	621	625	621	621	609	609	608	609	609	608	609	609	608
2	604	604	604	604	588	588	588	588	588	576	576	576	576	576	576	576	593	593
3	593	593	593	593	593	593	593	593	593	551	551	551	551	576	576	578	576	576
4	607	603	602	607	603	602	607	635	635	617	615	615	617	615	615	617	615	615
5	574	574	572	574	574	572	574	574	572	542	574	572	577	574	572	577	574	572
6	627	627	622	627	627	622	627	627	622	606	605	605	606	605	605	606	605	605
7	561	561	561	561	561	561	561	561	561	555	555	555	555	555	555	555	555	555
8	601	601	601	601	601	601	601	601	601	572	572	572	572	572	572	572	572	572
9	574	574	574	574	574	574	574	574	574	573	571	571	573	574	574	577	574	574
10	580	580	580	561	561	561	561	561	561	554	552	552	554	552	552	554	552	552
11	627	627	627	627	627	627	627	627	619	600	599	599	600	599	599	600	599	599
12	592	592	588	592	615	615	615	615	615	579	579	579	579	579	579	579	579	579
13	603	603	603	603	603	603	603	603	603	588	588	587	588	588	587	588	588	587
14	549	548	548	549	548	548	549	548	548	562	560	558	562	560	558	562	560	558
15	605	589	589	605	589	589	605	589	589	537	537	535	537	537	535	537	537	554
16	602	585	585	602	585	585	602	585	585	602	580	578	580	580	578	580	584	584
17	614	612	612	614	612	612	614	612	612	565	565	565	565	565	565	565	551	549
18	597	597	597	597	597	597	597	597	597	554	554	554	554	554	554	554	548	541
19	587	586	580	587	586	580	587	586	580	553	551	550	551	551	550	551	551	550
20	572	572	565	572	572	565	572	572	565	542	549	549	549	549	549	549	549	549

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Tabu Search

Problem #	20_SPT1_TS									20_SPTcomp_TS								
	Tabulist size = 2			Tabulist size = 4			Tabulist size = 6			Tabulist size = 2			Tabulist size = 4			Tabulist size = 6		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	126	126	126	126	126	126	126	126	126	134	132	132	134	132	132	134	134	134
2	127	124	124	127	124	124	127	127	127	127	127	127	127	127	127	127	127	127
3	131	131	131	131	131	131	131	129	129	135	135	134	135	133	133	135	133	133
4	127	123	120	127	123	123	126	126	126	126	121	121	126	121	121	125	117	117
5	129	129	129	129	129	129	132	130	130	131	131	131	131	131	131	129	129	129
6	124	124	124	124	124	124	124	124	124	126	126	126	126	126	124	126	126	123
7	104	104	104	104	104	104	104	104	104	107	102	102	107	102	102	106	104	104
8	137	135	135	137	135	135	130	130	130	138	138	135	138	137	134	137	136	134
9	143	127	127	143	127	127	140	133	133	134	134	134	134	134	134	133	131	131
10	138	134	134	138	134	134	138	138	138	137	137	137	137	137	137	139	137	136
11	131	131	131	131	131	131	131	131	131	142	135	135	142	138	138	140	134	134
12	133	130	130	133	130	129	133	131	131	133	130	130	133	130	130	132	132	132
13	136	133	133	136	133	133	136	135	135	139	137	137	139	137	135	138	138	136
14	111	99	99	111	99	99	107	105	105	114	111	108	114	111	111	114	108	108
15	140	140	140	140	140	140	140	140	140	139	139	139	139	139	139	139	139	139
16	143	138	138	143	138	138	143	139	139	141	141	141	141	141	141	141	141	141
17	110	110	110	110	110	110	110	110	110	113	111	111	113	111	111	114	114	112
18	146	141	141	146	141	141	147	141	141	144	144	144	144	144	144	142	142	142
19	135	135	135	135	135	135	135	132	132	136	134	134	136	134	134	133	133	133
20	151	147	147	151	147	147	148	148	148	149	148	146	149	148	145	150	146	146

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Tabu Search

Problem #	20_LPT1_TS									20_LPTcomp_TS								
	Tabulist size = 2			Tabulist size = 4			Tabulist size = 6			Tabulist size = 2			Tabulist size = 4			Tabulist size = 6		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	138	136	136	138	138	138	139	135	135	140	140	140	140	140	140	141	141	140
2	125	125	125	125	125	125	129	129	129	127	127	127	127	127	127	126	126	126
3	133	133	133	133	133	132	136	134	133	137	136	134	137	133	133	135	135	135
4	125	125	125	125	125	125	132	123	123	118	118	118	118	118	118	121	121	120
5	135	132	132	135	132	130	133	133	133	135	133	130	135	126	126	137	132	132
6	129	126	126	129	128	128	132	123	123	131	128	128	131	131	130	130	130	130
7	111	107	107	111	107	105	108	108	108	106	106	106	106	106	105	106	106	106
8	135	129	129	135	131	131	136	135	135	145	136	136	145	138	133	141	141	135
9	136	136	136	136	136	136	138	138	133	134	134	134	134	134	134	138	135	135
10	138	137	137	138	138	138	141	140	140	137	137	134	137	137	133	136	136	136
11	146	130	130	146	133	133	145	137	137	133	133	133	133	133	133	134	134	134
12	134	132	131	134	129	129	132	128	128	141	133	132	141	134	134	135	134	127
13	139	139	138	139	138	138	137	137	137	135	135	135	135	135	135	134	134	134
14	113	107	107	113	107	107	107	107	107	116	111	108	116	111	107	117	114	107
15	142	142	138	142	142	142	140	140	140	143	142	140	143	143	141	144	144	141
16	141	138	138	141	140	140	145	138	138	140	140	140	140	140	139	142	142	138
17	114	114	113	114	114	112	115	115	113	115	113	113	115	114	114	113	113	113
18	145	141	141	145	144	144	145	141	141	151	145	141	151	143	141	151	148	144
19	135	135	135	135	135	135	139	136	133	138	137	135	138	138	134	138	134	133
20	149	149	146	149	149	146	148	148	145	147	147	147	147	147	147	146	146	146

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Tabu Search

Problem #	50_SPT1_TS									50_SPTcomp_TS								
	Tabulist size = 5			Tabulist size = 10			Tabulist size = 15			Tabulist size = 5			Tabulist size = 10			Tabulist size = 15		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	297	295	295	297	295	295	297	295	295	293	293	293	293	293	293	293	293	293
2	287	287	287	287	287	287	287	287	287	292	292	292	292	292	292	292	292	292
3	300	300	300	300	300	300	300	300	300	296	296	296	296	296	296	296	296	296
4	285	285	285	285	285	285	285	285	285	290	286	286	290	286	286	290	286	286
5	306	306	306	306	306	306	306	306	306	313	313	313	313	313	313	313	313	313
6	259	259	259	259	259	259	259	259	259	258	258	258	258	258	258	258	258	258
7	284	284	284	284	284	284	284	284	284	280	280	280	280	280	280	280	280	280
8	299	299	299	299	299	299	299	299	299	306	305	305	306	305	305	306	305	305
9	285	285	285	285	285	285	285	285	285	291	291	291	291	291	291	291	291	291
10	281	274	274	281	274	274	281	274	274	269	269	269	269	269	269	269	269	269
11	326	324	324	326	324	324	326	324	324	327	322	322	327	322	322	327	322	322
12	265	265	265	265	265	265	265	265	265	272	272	269	272	272	269	272	272	269
13	291	289	289	291	289	289	291	289	289	294	294	294	294	294	294	294	294	294
14	267	267	267	267	267	267	267	267	267	276	276	273	276	276	273	276	276	273
15	272	272	272	272	272	272	272	272	272	278	278	278	278	278	278	278	278	278
16	280	280	280	280	280	280	280	280	280	292	292	291	292	292	291	292	292	291
17	273	273	273	273	273	273	273	273	273	270	270	270	270	270	270	270	270	270
18	275	275	275	275	275	275	275	275	275	280	280	280	280	280	280	280	280	280
19	282	282	282	282	282	282	282	282	282	287	287	286	287	287	286	287	287	286
20	282	282	282	282	282	282	282	282	282	291	291	291	291	291	291	291	291	291

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Tabu Search

Problem #	50_LPT1_TS									50_LPTcomp_TS								
	Tabulist size = 5			Tabulist size = 10			Tabulist size = 15			Tabulist size = 5			Tabulist size = 10			Tabulist size = 15		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	310	302	296	310	302	296	310	302	296	310	302	301	310	302	301	310	302	301
2	308	298	293	308	298	293	308	298	293	297	297	294	297	297	294	297	297	294
3	315	313	309	315	313	309	315	313	309	312	312	305	312	312	305	312	312	305
4	302	293	289	302	293	289	302	293	289	290	290	287	290	290	287	290	290	287
5	329	316	316	329	316	316	329	316	316	318	314	314	318	314	314	318	314	314
6	285	274	264	285	274	264	285	274	264	274	266	266	274	266	266	274	266	266
7	291	291	287	291	291	287	291	291	287	286	285	285	286	285	285	286	285	285
8	311	305	305	311	305	305	311	305	305	312	305	304	312	305	304	312	305	304
9	296	293	293	296	293	293	296	293	293	295	295	295	295	295	295	295	295	295
10	284	272	271	284	272	271	284	272	271	280	267	267	280	267	267	280	267	267
11	328	328	326	328	328	326	328	328	326	330	327	327	330	327	327	330	327	327
12	279	271	271	279	271	271	279	271	271	276	276	275	276	276	275	276	276	275
13	307	301	300	307	301	300	307	301	300	298	292	292	298	292	292	298	292	292
14	281	278	278	281	278	278	281	278	278	277	273	273	277	273	273	277	273	273
15	282	282	282	282	282	282	282	282	282	288	281	281	288	281	281	288	281	281
16	294	293	291	294	293	291	294	293	291	300	290	290	300	290	290	300	290	290
17	289	283	283	289	283	283	289	283	283	286	279	279	286	279	279	286	279	279
18	282	282	282	282	282	282	282	282	282	281	281	281	281	281	281	281	281	281
19	290	290	290	290	290	290	290	290	290	297	294	289	297	294	289	297	294	289
20	299	299	294	299	299	294	299	299	294	303	291	291	303	291	291	303	291	291

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Tabu Search

Problem #	100_SPT1_TS									50_SPTcomp_TS								
	Tabulist size = 10			Tabulist size = 20			Tabulist size = 30			Tabulist size = 10			Tabulist size = 20			Tabulist size = 30		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	599	596	596	599	596	596	599	596	596	592	592	592	592	592	592	592	592	592
2	551	551	551	551	551	551	551	551	551	557	557	557	557	557	557	557	557	557
3	533	533	533	533	533	533	533	533	533	539	538	538	539	538	538	539	536	536
4	571	571	571	571	571	571	571	571	571	575	575	575	575	575	575	575	575	575
5	521	521	521	521	521	521	521	521	521	524	524	518	524	524	518	524	524	520
6	590	590	590	590	590	590	590	590	590	596	596	596	596	596	596	596	596	596
7	548	548	547	548	548	547	548	548	547	552	552	552	552	552	552	552	552	552
8	556	556	556	556	556	556	556	556	556	557	557	557	557	557	557	557	557	557
9	556	556	556	556	556	556	556	556	556	556	556	556	556	556	556	556	556	556
10	495	495	495	495	495	495	495	495	495	505	505	505	505	505	505	505	505	505
11	570	570	570	570	570	570	570	570	570	582	582	582	582	582	582	582	582	581
12	545	545	545	545	545	545	545	545	545	549	549	549	549	549	549	549	549	549
13	558	558	558	558	558	558	558	558	558	562	562	562	562	562	562	562	562	562
14	486	486	486	486	486	486	486	486	486	492	492	492	492	492	492	492	492	492
15	532	523	520	523	523	520	523	523	520	506	506	506	506	506	506	506	506	506
16	548	548	548	548	548	548	548	548	548	545	545	545	545	545	545	545	545	545
17	524	524	524	524	524	524	524	524	524	539	539	537	539	539	537	539	539	536
18	513	513	513	513	513	513	513	513	513	520	519	519	520	519	519	520	519	513
19	533	533	533	533	533	533	533	533	532	530	530	530	530	530	530	530	530	530
20	527	527	527	527	527	527	527	527	527	530	530	530	530	530	530	530	530	530

APPENDIX 5 - SOLUTIONS OF LARGE SCALE PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Tabu Search

Problem #	100_LPT1_TS									50_LPTcomp_TS								
	Tabulist size = 10			Tabulist size = 20			Tabulist size = 30			Tabulist size = 10			Tabulist size = 20			Tabulist size = 30		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	619	608	598	619	608	598	619	608	594	611	601	596	611	601	596	611	601	597
2	571	565	558	571	565	558	571	560	560	581	561	549	581	561	549	581	561	555
3	566	565	539	566	565	539	566	565	540	565	559	547	565	559	547	565	565	543
4	611	585	573	611	585	573	611	585	575	605	593	575	605	593	575	605	590	571
5	553	541	520	553	541	520	553	541	522	549	529	528	549	529	528	549	529	528
6	614	600	592	614	600	592	614	600	598	597	597	597	597	597	597	597	597	597
7	577	554	549	577	554	549	577	554	552	569	564	548	569	564	548	569	564	548
8	594	565	555	594	565	555	594	564	554	579	568	554	579	568	554	579	568	555
9	572	568	555	572	568	555	572	568	555	587	571	558	587	571	558	587	571	558
10	533	520	511	533	520	511	533	520	507	522	522	512	522	522	512	522	522	515
11	589	586	579	589	586	579	589	586	575	587	581	577	587	581	577	587	582	577
12	577	561	559	577	561	559	577	561	561	572	549	549	572	549	549	572	549	549
13	588	587	572	588	587	572	588	587	572	573	570	567	573	570	567	573	570	565
14	536	513	513	536	513	513	536	513	513	540	504	502	540	504	502	540	507	503
15	565	530	510	565	530	510	565	530	507	537	529	506	537	529	506	537	527	506
16	583	567	552	583	567	552	583	567	558	567	548	546	567	548	546	567	548	546
17	579	538	528	579	538	528	579	539	534	534	534	534	534	534	534	534	534	534
18	529	524	518	529	524	518	529	524	523	542	526	526	542	526	526	542	526	522
19	555	540	531	555	540	531	555	540	536	557	539	531	557	539	531	557	538	530
20	550	541	533	550	541	533	550	543	531	549	546	531	549	546	531	549	546	533

APPENDIX 6 – SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS

Number of Jobs = 50,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	50_SPT1_SA_									50_SPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	4606.3	4606.3	4606.3	4606.3	4606.3	4606.3	4606.3	4606.3	4606.3	4183.1	4183.1	4183.1	4183.1	4183.1	4183.1	4183.1	4183.1	4183.1
2	8014.6	8014.6	8014.6	7980.4	7980.4	7980.4	7980.4	7980.4	7980.4	7995.5	7995.5	7995.5	7995.5	7995.5	7995.5	7995.5	7995.5	7995.5
3	15583.1	15583.1	15583.1	15583.1	15583.1	15583.1	15583.1	15583.1	15583.1	15571.2	15571.2	15571.2	15571.2	15571.2	15571.2	15571.2	15571.2	15571.2
4	8414.6	8414.6	8414.6	8414.6	8414.6	8414.6	8414.6	8414.6	8414.6	8228.6	8228.6	8228.6	8228.6	8228.6	8228.6	8228.6	8228.6	8228.6
5	5636.9	5636.9	5636.9	5636.9	5636.9	6187.4	6187.4	6187.4	6187.4	6260.9	6260.9	6260.9	6260.9	6260.9	6260.9	6260.9	6260.9	6260.9
6	4998.1	4998.1	4998.1	4998.1	4998.1	4998.1	4998.1	4998.1	4998.1	5154.4	5154.4	5154.4	5154.4	5154.4	5154.4	5154.4	5154.4	5154.4
7	4503.3	4503.3	4456.3	4456.3	4456.3	4456.3	4456.3	4456.3	4456.3	4252.3	4252.3	4252.3	4252.3	4252.3	4252.3	4252.3	4166.1	4151.3
8	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	3848.2	3848.2	3848.2	3848.2	3848.2	3848.2	3848.2	3848.2	3848.2
9	5938.1	5938.1	5938.1	5938.1	5938.1	5938.1	5938.1	5938.1	5938.1	5866.3	5866.3	5901.6	5901.6	5901.6	5901.6	5901.6	5901.6	5901.6
10	5209.8	5209.8	5209.8	5209.8	5209.8	5209.8	5209.8	5209.8	5209.8	5269.7	5269.7	5269.7	5269.7	6001.3	6001.3	6001.3	6001.3	6001.3
11	6364.5	6364.5	6364.5	6364.5	6364.5	6364.5	6457.3	6457.3	6457.3	6502.2	6502.2	6502.2	6502.2	6502.2	6502.2	6502.2	6502.2	6502.2
12	5941.8	5941.8	6293.9	6293.9	6293.9	6293.9	6293.9	6293.9	6293.9	6809.9	6809.9	6809.9	6809.9	6809.9	6809.9	6809.9	5509.1	5509.1
13	4520.8	4520.8	4520.8	4520.8	4520.8	4520.8	4520.8	4520.8	4520.8	6271.0	6887.7	6887.7	6887.7	6887.7	6887.7	6887.7	6887.7	6887.7
14	7208.1	7208.1	7208.1	7208.1	7208.1	7214.9	7214.9	7214.9	7214.9	7804.6	7804.6	7804.6	7804.6	7804.6	7804.6	7804.6	7804.6	7804.6
15	4925.4	4925.4	4925.4	4925.4	4425.6	4425.6	4425.6	4425.6	4425.6	4018.5	4018.5	4018.5	4018.5	4018.5	4018.5	4018.5	3991.1	3991.1
16	3765.6	3765.6	3765.6	3765.6	3765.6	3765.6	3765.6	3765.6	3765.6	5581.3	5581.3	5581.3	5581.3	5581.3	5581.3	5187.5	5187.5	5187.5
17	7058.1	7058.1	7058.1	7058.1	7058.1	7058.1	7058.1	7058.1	7058.1	6725.1	6725.1	6725.1	6725.1	6725.1	6725.1	6725.1	6725.1	6725.1
18	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	4754.5	3814.8	3814.8	3814.8	3814.8	3814.8	3814.8	3814.8	3814.8	3814.8
19	5078.8	5078.8	5078.8	5078.8	5078.8	5078.8	5078.8	5078.8	5078.8	5829.4	5829.4	5829.4	5829.4	5829.4	5829.4	5829.4	5829.4	5829.4
20	5070.8	5070.8	5070.8	5070.8	4633.6	4633.6	4633.6	4633.6	4633.6	5423.1	5423.1	5423.1	5423.1	5423.1	5423.1	5423.1	5423.1	4633.6

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	50_LPT1_SA_									50_LPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	4726.0	4726.0	4726.0	4726.0	4726.0	4726.0	4726.0	4726.0	4726.0	5326.0	5326.0	5326.0	5326.0	5326.0	5326.0	5326.0	5097.3	5097.3
2	8141.6	8141.6	8141.6	8141.6	8141.6	8141.6	8141.6	8141.6	8141.6	8415.7	8415.7	8415.7	8415.7	8415.7	8415.7	8415.7	8415.7	8415.7
3	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	15733.9	15733.9	15733.9	15733.9	15733.9	15733.9	15733.9	15733.9	15733.9
4	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9	13328.9
5	5758.2	5758.2	5758.2	5758.2	5758.2	5758.2	5758.2	5758.2	5758.2	6151.4	6151.4	6151.4	6151.4	6151.4	6228.7	6260.9	6228.7	6228.7
6	5008.6	5008.6	5008.6	5008.6	5008.6	5008.6	5008.6	5008.6	5008.6	5566.8	5566.8	5566.8	5566.8	4987.4	4987.4	4987.4	4987.4	4987.4
7	5099.2	5099.2	5099.2	5099.2	5099.2	5099.2	5099.2	5099.2	5099.2	5047.9	5047.9	5012.2	5012.2	5012.2	5012.2	5012.2	5012.2	5012.2
8	4984.7	4984.7	4984.7	4984.7	4913.9	4913.9	4913.9	4913.9	4913.9	4899.2	4899.2	4899.2	4899.2	4899.2	4899.2	4899.2	4899.2	4899.2
9	5879.3	5879.3	5879.3	5879.3	5879.3	5879.3	5894.7	5894.7	5894.7	6987.0	6987.0	6987.0	6987.0	6987.0	6987.0	6987.0	6987.0	6987.0
10	4510.6	4510.6	4510.6	4510.6	4510.6	4510.6	4510.6	4510.6	4510.6	8213.4	8213.4	8213.4	8213.4	8213.4	8213.4	8213.4	8213.4	8213.4
11	6243.2	6226.8	6211.4	6226.8	6226.8	6211.4	6226.8	6226.8	6211.4	6613.2	5934.3	5934.3	6613.2	5934.3	5934.3	6745.7	6745.7	6459.3
12	5879.0	5879.0	5879.0	5879.0	5879.0	5879.0	5879.0	5879.0	5879.0	5487.7	5188.4	6369.0	6428.7	6388.9	6369.0	6428.7	6388.9	6369.0
13	6067.5	6067.5	6067.5	6067.5	6067.5	6067.5	6067.5	6067.5	6067.5	8058.9	8058.9	8058.9	8058.9	8058.9	8058.9	8058.9	8058.9	4968.6
14	6920.3	6920.3	6920.3	6920.3	6920.3	6920.3	6920.3	6920.3	6920.3	8281.2	8281.2	8281.2	8281.2	8281.2	6960.4	6993.6	6993.6	6993.6
15	2841.0	3859.7	3859.7	2841.8	3859.7	3859.7	2841.8	3859.7	3859.7	2841.8	2787.4	3859.7	3859.7	2931.9	3853.6	3859.7	2931.9	3853.6
16	4658.7	4658.7	4658.7	4658.7	4658.7	4658.7	4658.7	4658.7	4658.7	5060.3	5286.2	5286.2	5286.2	5286.2	5286.2	5286.2	5286.2	5286.2
17	6505.8	6505.8	6505.8	6505.8	6505.8	6505.8	6505.8	6505.8	6505.8	6842.6	6842.6	6842.6	6842.6	6842.6	6842.6	6842.6	6842.6	6842.6
18	4456.3	5202.5	5202.5	5202.5	5202.5	5202.5	5202.5	5202.5	5202.5	4590.7	4590.7	4590.7	4590.7	4590.7	4590.7	4590.7	4590.7	4590.7
19	5703.3	5703.3	5703.3	5703.3	5703.3	5703.3	5703.3	5703.3	5703.3	6044.9	6044.9	6044.9	4942.3	4942.3	4942.3	4942.3	4942.3	4942.3
20	4506.8	4506.8	4506.8	4506.8	4506.8	4506.8	4506.8	4506.8	4506.8	4970.1	4970.1	4970.1	5640.6	5640.6	5640.6	5640.6	5640.6	5640.6

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Simulated Annealing

120

Problem #	50_LPT1_SA_									50_LPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	7953.3	7953.3	7953.3	7953.3	7953.3	7953.3	7953.3	7953.3	7953.3	8489.6	9683.5	9683.5	9683.5	9683.5	9683.5	9683.5	9683.5	9683.5
2	9100.6	9100.6	9100.6	9100.6	9100.6	9100.6	9100.6	9100.6	9100.6	9695.2	9695.2	9695.2	9695.2	9695.2	9695.2	9695.2	9695.2	9695.2
3	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	15639.6	16197.3	16197.3	16197.3	16197.3	16197.3	16197.3	16197.3	16211.6	16211.6
4	13878.2	13878.2	13878.2	13878.2	13878.2	13878.2	13284.4	13284.4	13284.4	13271.8	13271.8	13271.8	13271.8	13271.8	13271.8	13271.8	13314.9	13314.9
5	6104.9	6104.9	6104.9	6571.4	6571.4	6571.4	6571.4	6571.4	6571.4	8296.4	8296.4	8296.4	8296.4	7473.3	7473.3	7473.3	7473.3	7473.3
6	8025.0	8025.0	8025.0	8025.0	8025.0	8025.0	8025.0	8025.0	8025.0	8731.8	8537.9	8537.9	9146.1	8537.9	8537.9	9146.1	8537.9	8537.9
7	9079.2	9079.2	9056.7	9056.7	9056.7	9056.7	9056.7	9056.7	9056.7	12530.4	12530.4	10105.3	10105.3	10105.3	10105.3	10105.3	10105.3	10105.3
8	7701.7	7701.7	7701.7	7701.7	7701.7	7701.7	7701.7	7701.7	7701.7	7581.6	7581.6	7581.6	7581.6	7581.6	7581.6	7581.6	7581.6	7581.6
9	9056.3	9056.3	9056.3	9056.3	9056.3	9056.3	9039.9	9039.9	9039.9	10369.4	10369.4	10369.4	10369.4	10369.4	10369.4	10369.4	10369.4	10250.6
10	7670.8	7670.8	7670.8	7670.8	7670.8	7670.8	7670.8	7670.8	7863.7	10187.3	10016.5	9635.6	10187.3	10016.5	9635.6	10187.3	10016.5	10187.3
11	9016.5	9016.5	8984.7	8984.7	8984.7	8984.7	8984.7	8984.7	8984.7	12602.1	12602.1	12602.1	9712.9	9712.9	9712.9	9712.9	9712.9	9712.9
12	8725.9	8725.9	8725.9	8725.9	8725.9	8725.9	8725.9	8725.9	8342.9	9460.8	9457.9	9457.9	9460.8	9457.9	9457.9	9460.8	9457.9	9460.8
13	9651.6	7725.5	7725.5	7725.5	7725.5	7725.5	7725.5	7725.5	7725.5	10797.7	10797.7	14757.6	14757.6	14757.6	14757.6	14757.6	14757.6	14757.6
14	11273.2	11273.2	11255.7	11255.7	11255.7	11255.7	11255.7	11255.7	11255.7	14422.3	14422.3	14422.3	14422.3	14446.9	14446.9	14446.9	14446.9	14446.9
15	8380.9	8380.9	8380.9	8380.9	8380.9	8380.9	8380.9	8380.9	8380.9	11821.1	11821.1	11821.1	11821.1	9085.6	9085.6	9085.6	9085.6	9085.6
16	6793.7	6793.7	6793.7	6793.7	6793.7	6793.7	7726.1	7726.1	7726.1	7972.4	7972.4	7972.4	7972.4	7972.4	7972.4	7972.4	8620.1	8620.1
17	8448.0	8448.0	8448.0	8448.0	8448.0	8448.0	8448.0	8448.0	8448.0	9902.9	9187.2	9187.2	9776.9	9187.2	9187.2	9776.9	9187.2	9187.2
18	5455.5	5455.5	5455.5	5455.5	5455.5	5455.5	5455.5	5525.2	5525.2	6412.8	6412.8	6412.8	6412.8	6412.8	6412.8	6412.8	6412.8	7908.1
19	6377.8	6377.8	6377.8	6377.8	7342.1	7342.1	7342.1	7342.1	7342.1	7580.4	7580.4	7580.4	7580.4	7580.4	7580.4	7580.4	7580.4	7580.4
20	8437.7	8437.7	8437.7	8437.7	8437.7	8437.7	8437.7	8437.7	8437.7	10211.0	10211.0	10211.0	10211.0	10211.0	10211.0	10211.0	8202.3	8202.3

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	50_SPT1_SA_									50_SPTcomp_SA_									
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	
1	7819.2	7819.2	7800.4	7819.2	7819.2	7800.4	8037.3	8037.3	8037.3	9617.3	9617.3	9617.3	9617.3	9617.3	8507.1	8701.8	8507.1	8507.1	
2	11724.6	11724.6	11724.6	11724.6	11724.6	11724.6	11724.6	11724.6	11724.6	11451.7	11451.7	11451.7	11451.7	11451.7	11451.7	11451.7	11451.7	11451.7	11460.1
3	16279.7	16279.7	16279.7	16279.7	16279.7	16279.7	16279.7	16279.7	16279.7	16121.2	16121.2	16121.2	16121.2	16121.2	15605.4	15605.4	15605.4	15605.4	
4	14324.1	11555.8	11555.8	11555.8	11555.8	11555.8	11555.8	11555.8	11555.8	8731.9	8731.9	8731.9	8731.9	8731.9	8731.9	8731.9	8094.9	8094.9	
5	9850.6	9850.6	9850.6	9850.6	9850.6	9850.6	10040.9	10040.9	10040.9	7571.4	7571.4	7571.4	7571.4	7571.4	7923.0	7923.0	7923.0	7923.0	
6	10912.9	10912.9	10912.9	10912.9	9753.7	9753.7	9753.7	9753.7	9753.7	10975.6	10975.6	11704.6	11704.6	11704.6	11704.6	11704.6	11704.6	11704.6	
7	12593.8	12593.8	12593.8	12593.8	12593.8	12593.8	12593.8	10761.5	10761.5	12428.9	11350.2	11350.2	12428.9	11350.2	11350.2	13343.3	13343.3	13343.3	
8	10113.3	10113.3	10113.3	10113.3	10113.3	10113.3	11210.6	11210.6	11210.6	9096.7	9096.7	9096.7	9096.7	9096.7	6781.3	7035.8	6781.3	6781.3	
9	11542.6	11542.6	11533.0	11533.0	11533.0	11533.0	11533.0	11533.0	11533.0	12733.3	12733.3	12733.3	12733.3	12733.3	12733.3	12733.3	12733.3	11520.4	
10	12179.1	12179.1	12179.1	12179.1	12179.1	12179.1	13197.3	13197.3	13197.3	12385.9	12385.9	12385.9	12385.9	9994.3	9994.3	10418.4	9994.3	9994.3	
11	12396.0	12396.0	12396.0	12396.0	12396.0	12396.0	12396.0	12396.0	12396.0	12287.5	12287.5	12276.8	12287.5	12287.5	12276.8	12287.5	12287.5	13640.3	
12	12546.2	12546.2	12546.2	12546.2	12546.2	12546.2	12935.4	12935.4	12935.4	14678.1	14678.1	14678.1	14678.1	14678.1	14641.6	14641.6	14641.6	14641.6	
13	13075.5	13075.5	13075.5	13075.5	13075.5	13075.5	13075.5	13075.5	10099.4	14198.6	11379.6	11379.6	14198.6	11379.6	11379.6	14198.6	17085.4	17085.4	
14	14609.1	14609.1	14609.1	14609.1	14426.0	14426.0	14426.0	14426.0	14426.0	17233.7	17233.7	17233.7	17272.3	17272.3	17272.3	17272.3	17272.3	17272.3	
15	12346.3	12346.3	12346.3	12346.3	12346.3	12346.3	12346.3	12346.3	10457.7	11863.7	11863.7	11863.7	11863.7	11863.7	11863.7	11863.7	13087.7	13087.7	
16	12205.0	12205.0	12205.0	10929.7	10929.7	10929.7	10929.7	10929.7	10929.7	11455.1	13201.0	13201.0	13201.0	13201.0	13201.0	13201.0	13201.0	13201.0	
17	10396.9	10396.9	10396.9	10396.9	10396.9	10396.9	12164.9	12164.9	12164.9	9973.7	9973.7	9973.7	9973.7	9973.7	10832.8	10832.8	10832.8	10832.8	
18	10893.9	10893.9	10893.9	10893.9	10893.9	10893.9	10893.9	10893.9	10893.9	10666.4	10666.4	10666.4	11167.7	11167.7	11167.7	11167.7	11167.7	11167.7	
19	8444.7	6823.6	8444.7	8444.7	8444.7	8444.7	8444.7	8444.7	8444.7	9162.2	8883.4	8883.4	9162.2	8883.4	8883.4	9162.2	8883.4	9869.5	
20	11184.4	11184.4	11184.4	11184.4	11184.4	11184.4	11184.4	11184.4	11184.4	13595.9	13595.9	13595.9	13595.9	13595.9	11296.9	11296.9	11296.9	11296.9	

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Simulated Annealing

Problem #	50_LPT1_SA_									50_LPTcomp_SA_								
	$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$			$\alpha=0.80$			$\alpha=0.90$			$\alpha=0.99$		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	8031.2	8031.2	8031.2	8031.2	8031.2	8031.2	8031.2	8031.2	8031.2	11707.8	11707.8	8572.5	10488.8	8572.5	8572.5	10488.8	8572.5	8572.5
2	11450.6	11450.6	11450.6	11450.6	11450.6	11450.6	11450.6	11527.9	11527.9	12146.2	12146.2	12146.2	12146.2	12146.2	12146.2	12550.8	12550.8	12550.8
3	15604.3	15604.3	15604.3	15604.3	15604.3	15604.3	15604.3	15604.3	15604.3	17180.4	17180.4	16588.0	16588.0	16588.0	16588.0	16588.0	16588.0	16588.0
4	9270.1	8698.9	8698.9	9270.1	8698.9	8698.9	9270.1	9270.1	9270.1	13530.5	13530.5	12227.3	13801.4	12227.3	12227.3	13801.4	12227.3	12227.3
5	8217.5	8217.5	8217.5	7433.5	7433.5	7433.5	7433.5	7433.5	7433.5	8664.1	8664.1	10675.9	10675.9	10675.9	10675.9	10675.9	10675.9	10675.9
6	10637.4	9764.2	9764.2	10618.8	9764.2	9764.2	10618.8	9764.2	9764.2	12374.5	12374.5	12081.9	12374.5	12374.5	12081.9	12374.5	13738.4	13738.4
7	13230.9	13230.9	13230.9	13230.9	13230.9	12645.6	12680.9	12645.6	12645.6	12830.7	12830.7	12830.7	12830.7	15712.3	15712.3	15712.3	15712.3	15712.3
8	10195.9	10195.9	10195.9	10631.1	10631.1	10631.1	10631.1	10631.1	10631.1	12281.5	12281.5	10611.2	10611.2	10611.2	10611.2	10611.2	10611.2	10611.2
9	11332.3	11332.3	11332.3	11332.3	11332.3	11332.3	11332.3	10533.8	10533.8	13033.5	11762.2	11762.2	13033.5	11762.2	16102.7	16102.7	16102.7	16102.7
10	11147.5	11147.5	9656.9	9656.9	9656.9	9656.9	9656.9	9656.9	9656.9	12150.5	17115.7	17115.7	17115.7	17115.7	17115.7	17115.7	17115.7	17115.7
11	11998.8	11998.8	11998.8	11998.8	11998.8	11998.8	11998.8	11998.8	11998.8	15009.8	15009.8	15009.8	15009.8	15009.8	15009.8	17329.8	17329.8	17329.8
12	12374.4	12374.4	12374.4	12374.4	12374.4	12374.4	12374.4	12374.4	12374.4	11733.2	11631.9	14986.4	15115.9	14986.4	14986.4	15115.9	14986.4	14986.4
13	13719.3	13719.3	13719.3	13719.3	13719.3	13719.3	12542.9	12189.0	12079.3	15437.5	15081.5	15081.5	15437.5	15081.5	15790.4	17618.4	15790.4	15790.4
14	14229.8	14229.8	14229.8	14229.8	14229.8	14229.8	14229.8	14229.8	14229.8	19019.4	19019.4	19019.4	19019.4	19019.4	19019.4	19019.4	19019.4	19000.2
15	12653.5	12653.5	12653.5	12653.5	12653.5	12653.5	9878.9	9878.9	9878.9	12019.3	12019.3	12019.3	12019.3	12019.3	12019.3	16114.2	16114.2	16114.2
16	10155.6	10155.6	10155.6	10155.6	10155.6	10155.6	10155.6	10155.6	11892.7	13107.5	13107.5	13107.5	13107.5	13107.5	13107.5	16552.9	16552.9	16552.9
17	10675.0	9755.8	9755.8	10659.9	10646.5	10646.5	10659.9	10646.5	10646.5	14518.7	13333.9	15495.6	15495.6	15495.6	15495.6	15495.6	15495.6	15495.6
18	9465.9	9465.9	8634.4	8728.1	8634.4	8634.4	8728.1	8634.4	8634.4	12034.6	12034.6	12034.6	12034.6	12034.6	12034.6	12034.6	12034.6	12034.6
19	9988.2	9988.2	9988.2	9988.2	9988.2	9988.2	8294.3	8294.3	8294.3	9467.3	9463.7	9463.7	9467.3	9463.7	12051.1	12051.1	12051.1	12051.1
20	9159.2	9159.2	9159.2	9159.2	9159.2	9159.2	9159.2	9159.2	9159.2	17066.7	17066.7	16932.9	16932.9	16932.9	16932.9	16932.9	16932.9	16932.9

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Tabu Search

Problem #	50_SPT1_TS_									50_SPTcomp_TS_								
	Tabulist=5			Tabulist=10			Tabulist=15			Tabulist=5			Tabulist=10			Tabulist=15		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	4040.9	4034.4	4034.4	4384.8	4065.5	4034.4	4384.8	4065.5	4048.7	4035.7	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4
2	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7984.8	7979.3	7979.3	7984.8	7980.4	7980.4	7984.8	7980.4	7980.4
3	15582.1	15565.7	15552.0	15583.1	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3
4	8414.6	8325.6	8325.6	8325.6	8325.6	8325.6	8325.6	8325.6	8325.6	8325.6	8228.6	8228.6	8228.6	8228.6	8228.6	8228.6	8228.6	8228.6
5	5730.9	5628.0	5628.0	5664.3	5628.0	5628.0	5664.3	5628.0	5628.0	5687.8	5670.1	5606.4	5683.9	5640.3	5610.6	5746.6	5653.4	5610.6
6	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4998.1	4973.1	4973.1	4974.4	4974.4	4974.4	4974.4	4973.1	4974.4	4974.4	4974.4	4973.1
7	4262.8	4059.7	4193.5	4089.8	4279.9	4059.7	4279.9	4176.3	4010.3	4279.9	4279.9	4279.9	4279.9	4279.9	4279.9	4279.9	4279.9	4279.9
8	3500.9	3500.5	3500.9	3500.9	3500.5	3500.9	3500.9	3500.5	3500.9	3593.3	3593.3	3500.9	3593.3	3593.3	3500.9	3593.3	3593.3	3500.9
9	5882.3	5853.3	5853.3	5853.3	5853.3	5847.8	5872.8	5847.8	5847.8	5852.0	5852.0	5849.1	5852.0	5852.0	5849.1	5852.0	5852.0	5849.1
10	4924.4	4832.0	4832.0	5103.4	4862.0	4832.0	5103.4	4862.0	4832.0	4841.6	4832.0	4832.0	4841.6	4832.0	4832.0	4841.6	4832.0	4832.0
11	6190.2	6173.4	6173.4	6253.4	6173.0	6173.0	6173.4	6173.4	6173.4	6191.3	6173.0	6173.4	6173.4	6173.0	6177.2	6177.2	6177.2	6177.2
12	5840.6	5843.5	5840.6	5856.4	5843.5	5840.6	5875.3	5840.6	5840.6	5843.5	5843.5	5843.5	5843.5	5843.5	5840.6	5840.6	5840.6	5840.6
13	4637.2	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	6857.7	6845.3	6846.6	6863.8	6847.0	6846.6	6863.8	6847.0	6846.6	6882.3	6847.0	6847.0	6882.3	6847.0	6847.0	6856.0	6845.3	6845.3
15	2872.6	2803.2	2803.2	2773.3	2803.2	2803.2	2773.3	2834.9	2769.9	3143.4	3532.1	3143.4	3532.1	3532.1	3143.4	3532.1	3532.1	3143.4
16	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2
17	6283.4	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6283.4	6258.8	6271.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	3590.8	3552.1	3560.1	4625.6	3580.4	3560.1	4625.6	3580.4	3560.1	3738.0	3631.4	3631.4	3738.0	3631.4	3631.4	3738.0	3631.4	3631.4
19	4593.6	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4578.2	4576.9	4576.9	4576.9	4576.9	4576.9
20	4598.3	4598.3	4598.3	4598.3	4598.3	4598.3	4615.8	4615.8	4598.3	4598.3	4598.3	4598.3	4598.3	4598.3	4598.3	4598.3	4598.3	4598.3

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Tabu Search

Problem #	50_LPT1_TS_									50_LPTcomp_TS_								
	Tabulist=5			Tabulist=10			Tabulist=15			Tabulist=5			Tabulist=10			Tabulist=15		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	4034.4	4034.4	4015.9	4034.4	4034.4	4030.2	4069.9	4035.7	4035.7	4543.5	4035.5	4035.5	4543.5	4035.5	4035.5	4543.5	4035.5	4035.5
2	7997.8	7984.8	7984.8	7997.8	7984.8	7984.8	7997.8	7984.8	7984.8	7984.8	7979.3	7979.3	7984.8	7979.3	7979.3	7984.8	7979.3	7979.3
3	15568.8	15550.3	15550.3	15568.8	15550.3	15550.3	15568.8	15550.3	15550.3	15552.0	15552.0	15552.0	15550.3	15552.0	15550.3	15550.3	15550.3	15550.3
4	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	10382.6	8323.1	8323.1	10382.6	8323.1	8323.1
5	5696.5	5624.7	5624.7	5633.8	5670.1	5670.1	5633.8	5668.8	5636.4	5639.5	5639.5	5639.5	5639.5	5639.5	5639.5	5639.5	5639.5	5639.5
6	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4989.8	4989.8	4989.8
7	4179.0	4020.4	4000.9	4179.0	4490.9	4282.3	4490.9	4318.6	4163.4	4563.9	4540.6	4163.4	5086.4	4540.6	4163.4	5086.4	4540.6	4163.4
8	3746.0	3500.9	3799.2	3799.2	3799.2	3799.2	3799.2	3799.2	3799.2	3801.2	3801.2	3801.2	3801.2	3801.2	3801.2	3801.2	3500.9	3500.9
9	5849.1	5857.8	5853.3	5879.3	5857.8	5853.3	5879.3	5857.8	5853.3	5866.3	5887.5	5853.3	5887.5	5866.3	5862.1	6121.7	5862.1	5862.1
10	4438.7	4385.2	4438.7	4438.7	4385.2	4557.6	4557.6	4557.6	4557.6	4679.6	4827.8	4679.6	4679.6	4827.8	4679.6	4679.6	4827.8	4679.6
11	6188.4	6173.0	6173.0	6188.4	6173.0	6173.0	6188.4	6173.0	6173.0	5723.6	5723.6	6173.4	6265.8	6173.4	6167.7	6167.7	6173.4	6167.7
12	5841.0	5841.0	5841.0	5841.0	5841.0	5841.0	5841.0	5841.0	5841.0	5644.9	5840.6	5644.9	5644.9	5840.6	5822.6	5840.6	5822.6	5840.6
13	4592.0	4592.0	4592.0	4682.3	4592.0	4592.0	4682.3	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	6856.0	6847.0	6856.0	6856.0	6847.0	6856.0	6856.0	6847.0	6847.0	6882.3	6847.0	6863.8	6882.3	6882.3	6813.8	6856.0	6882.3	6813.8
15	2776.0	2738.3	2834.9	3859.7	2910.8	2776.0	3859.7	2910.8	2776.0	2841.0	2841.0	2834.9	3950.2	2841.0	2834.9	2937.6	4274.6	2937.2
16	3378.7	3356.2	3356.2	3378.7	3356.2	3200.9	3356.2	3356.2	3200.9	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3330.2	3987.4
17	6258.8	6258.8	6258.8	6280.0	6271.8	6258.8	6280.0	6271.8	6258.8	6271.8	6271.8	6258.8	6271.8	6271.8	6258.8	6258.8	6258.8	6258.8
18	3597.9	3679.5	3631.1	4355.5	3593.7	4219.4	4400.6	4426.3	4219.4	4590.7	4474.4	4316.0	4590.7	4474.4	4316.0	4590.7	4474.4	4316.0
19	4578.2	4578.2	4576.9	4578.2	4578.2	4576.9	4578.2	4578.2	4576.9	4669.7	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4506.8	4187.4	4506.8	4187.4	4506.8	4187.4	4187.4	4506.8	4187.4	4617.5	4600.0	4600.0	4617.5	4600.0	4616.8	4600.0	4616.8	4616.8

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Tabu Search

Problem#	75_SPT1_TS_									75_SPTcomp_TS_								
	Tabulist=8			Tabulist=15			Tabulist=22			Tabulist=8			Tabulist=15			Tabulist=22		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	7642.6	7883.5	7883.5	7883.5	7883.5	7883.5	7973.4	7883.1	7886.0	7881.8	7881.8	7881.8	7881.8	7881.8	7881.8	7881.8	7887.3	7887.3
2	9113.0	9015.0	8995.2	9034.9	8995.2	8995.2	9063.3	8995.2	8995.2	9015.0	9015.0	9015.0	9015.0	9015.0	9010.8	9015.0	9010.8	9010.8
3	15568.8	15555.8	15596.1	15737.8	15681.8	15596.1	15737.8	15681.8	15596.1	15570.1	15570.1	15570.1	15555.8	15551.6	15555.8	15555.8	15551.6	15555.8
4	8683.4	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	8323.1	6311.2	5856.8	5856.8	5856.8	5856.8	5856.8	5856.8	5856.8	5856.8
5	7034.9	5735.6	6585.7	5735.6	5735.6	6585.7	5735.6	5735.6	6585.7	5697.7	6051.6	5836.4	6051.6	6051.6	5836.4	6051.6	6051.6	5836.4
6	7974.1	7999.1	7988.4	7989.5	7989.5	7988.4	7989.5	7989.5	7988.4	8025.0	7975.4	7975.4	8025.0	7975.4	7975.4	8025.0	7975.4	7975.4
7	7816.2	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4	7034.4
8	7405.1	5452.4	5452.4	5452.4	5452.4	5464.1	5776.1	5544.1	5464.1	5690.2	5464.1	5464.1	5690.2	5464.1	5464.1	5452.0	5467.5	5467.5
9	9038.6	8986.1	8986.1	9011.1	8986.1	8984.8	9034.4	8984.8	8984.8	9000.8	9001.5	8986.1	9005.7	8986.1	8986.1	8986.1	8986.5	8986.5
10	7697.5	7594.7	7594.7	7683.7	7594.7	7594.7	7683.7	7594.7	7604.3	7611.1	7600.5	7590.9	7611.1	7600.5	7590.9	7611.1	7600.5	8289.0
11	9050.4	8946.3	8946.3	8961.7	8946.3	8946.3	8961.7	8961.7	8946.3	8950.5	8949.2	8949.2	8950.5	8949.2	8949.2	8950.5	8949.2	8949.2
12	8694.5	8694.5	8694.1	8694.5	8694.1	8694.1	8694.5	8694.1	8694.1	8698.3	8698.3	8697.0	8698.3	8698.3	8697.0	8698.3	8698.3	8697.0
13	7290.3	7214.1	7214.1	7214.1	7214.1	7137.9	7214.1	7137.9	7137.9	7137.9	7137.9	7137.9	7137.9	7137.9	7137.9	7137.9	7143.6	7137.9
14	11217.7	11217.3	11217.3	11217.7	11217.3	11217.7	11293.9	11217.7	11217.7	11308.8	11217.3	11216.0	11308.8	11217.3	11216.0	11217.7	11217.7	11226.7
15	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	6079.1	6079.1	6079.1	6079.1	6079.1	6079.1	6079.1	4830.8	4927.8
16	5445.9	4904.2	4483.6	5369.2	4904.2	4483.6	5369.2	4904.2	4483.6	5933.5	4927.7	4904.2	5755.3	5075.8	4904.2	5755.3	5075.8	4904.2
17	6872.0	7404.9	6605.3	7655.9	7404.9	6605.3	7655.9	7404.9	6605.3	6805.4	6605.3	6605.3	6605.3	6605.3	6605.3	6605.3	6605.3	6605.3
18	5349.8	4825.9	4896.8	5304.0	5065.8	5010.9	5406.6	5406.6	5010.9	5530.7	4886.3	4886.3	5431.1	4886.3	4886.3	5181.1	4886.3	4886.3
19	5832.2	5427.1	5427.1	5551.2	5427.1	5427.1	5551.2	5427.1	5427.1	5428.4	5442.5	5428.4	5443.8	5442.5	5428.4	5443.8	5442.5	5428.4
20	7228.4	7124.9	7205.7	7154.1	6375.0	6375.0	7138.4	6375.0	6375.0	5811.9	5513.5	5513.5	5811.9	5513.5	5513.5	7283.9	7062.6	5912.4

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Tabu Search

Problem #	75_LPT1_TS_									75_LPTcomp_TS_								
	Tabulist=8			Tabulist=15			Tabulist=22			Tabulist=8			Tabulist=15			Tabulist=22		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	7915.7	7883.1	7883.1	7927.6	7883.1	7883.1	7927.6	7883.1	7881.8	8185.3	7883.5	7881.8	8185.3	7883.5	7881.8	8185.3	7883.5	7881.8
2	9015.0	9015.0	9010.6	9015.0	9015.0	9010.6	9009.5	8995.2	8995.2	9049.2	9049.2	9024.4	9049.2	9049.2	9024.4	9049.2	9009.5	9000.7
3	15621.8	15583.1	15550.3	15621.8	15583.1	15555.8	15604.1	15555.8	15555.8	15567.4	15566.3	15552.0	15567.4	15566.3	15552.0	15552.0	15552.0	15552.0
4	8319.3	8319.3	10317.9	13328.9	13328.9	10317.9	13328.9	13328.9	10317.9	13271.8	13271.8	8416.3	9877.0	8414.2	8329.6	9877.0	8414.2	8329.6
5	6022.1	5777.8	5706.6	5782.9	5777.8	5706.6	5782.9	5777.8	5706.6	7493.3	7493.3	6615.1	6615.1	6615.1	6615.1	6615.1	6615.1	6615.1
6	8009.6	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7975.4	8001.4	8026.4	8009.6	8001.4	8026.4	8009.6	8001.4
7	7416.6	7040.5	7040.5	7416.6	7040.5	7040.5	7416.6	7040.5	7507.5	7040.5	7040.5	7040.5	7040.5	7040.5	7040.5	7040.5	7040.5	7040.5
8	7029.5	5693.7	5556.9	7029.5	5693.7	5556.9	7029.5	5677.0	5677.0	6561.7	5544.1	5544.1	6561.7	5544.1	5544.1	6561.7	5544.1	5412.2
9	8984.8	8984.8	8984.8	9000.2	8984.8	8984.8	9016.6	9003.3	9003.3	8649.0	9001.5	8649.0	9031.7	8649.0	8986.1	8649.0	9001.5	8649.0
10	7628.9	7628.9	7606.9	7628.9	7628.9	7606.9	7628.9	7628.9	7606.9	7620.7	7590.5	7594.7	7843.7	7667.1	7590.5	7620.7	7590.5	7594.7
11	8963.5	8946.7	8946.7	8946.3	8946.7	8946.7	8946.3	8946.7	8946.7	8946.7	8982.3	8982.3	8982.3	8982.3	8982.3	8982.3	8982.3	8982.3
12	8694.5	8694.5	8694.5	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	7963.2	7963.2	7963.2	7963.2	7963.2
13	6900.6	6900.6	6900.6	6900.6	6900.6	6900.6	6900.6	6900.6	6900.6	7137.9	7304.4	7137.9	7137.9	7304.4	7137.9	7137.9	7304.4	7137.9
14	11217.7	11217.7	11217.7	11217.7	11217.7	11217.7	11217.7	11217.7	11216.0	11216.0	11234.8	11216.0	11228.4	11234.8	11216.0	11228.4	11234.8	11216.0
15	7494.9	7494.9	7488.8	7494.9	7494.9	7488.8	7494.9	7494.9	4830.8	8389.7	7585.4	7585.4	8389.7	7585.4	7585.4	8389.7	7585.4	7585.4
16	5290.4	5655.6	5655.6	5655.6	5655.6	5655.6	5655.6	5655.6	5655.6	6109.0	5319.4	4878.6	4904.2	4878.6	4878.6	4904.2	4878.6	4878.6
17	7500.9	6605.3	6605.3	6989.2	6605.3	6605.3	6989.2	6605.3	6605.3	6787.0	6787.0	6605.3	6755.9	6732.6	6732.6	6755.9	6732.6	6732.6
18	4898.8	4885.0	4882.1	5010.9	4885.0	4882.1	4919.1	4919.1	4882.1	5081.3	5052.6	4201.0	5081.3	5052.6	4201.0	5081.3	4886.3	4885.0
19	5454.4	5454.4	5428.4	5428.4	5428.4	5428.4	5428.4	5428.4	5428.4	5427.1	5427.1	5427.1	5575.0	5454.4	5112.9	5575.0	5454.4	5112.9
20	7019.3	7019.3	6321.0	7019.3	7019.3	6321.0	7019.3	6157.7	5584.9	7106.2	5615.0	5615.0	7106.2	5615.0	5615.0	7106.2	5615.0	6266.0

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= SPT1 & SPTcomp,

Improvement Heuristic: Tabu Search

Problem #	100_SPT1_TS_									100_SPTcomp_TS_								
	Tabulist=10			Tabulist=20			Tabulist=30			Tabulist=10			Tabulist=20			Tabulist=30		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	7774.4	7822.5	7822.5	7742.0	7822.5	7900.3	7925.3	7900.3	7900.3	8388.7	7900.3	7900.3	7913.0	7913.0	7913.0	7897.8	7913.0	7913.0
2	11398.3	11396.6	11396.6	11539.4	11396.6	11396.6	11539.4	11396.6	11396.6	11416.4	11416.4	11412.2	11416.4	11416.4	11412.2	11416.4	11416.4	11412.6
3	15570.1	15554.5	15551.6	15583.1	15568.8	15551.6	15583.1	15568.8	15555.8	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15552.0	15555.8
4	11560.8	6173.0	8639.1	8512.9	6152.3	6152.3	8512.9	10215.2	10221.3	7991.9	7991.9	7991.9	7592.6	7991.9	7991.9	7729.3	7729.3	7729.3
5	7104.0	7051.1	5818.1	6058.1	5847.2	6058.1	6086.1	6058.1	5818.1	6912.9	5729.7	5736.6	5835.3	5736.6	5736.6	5835.3	5736.6	5736.6
6	9728.7	9728.7	9728.7	9728.7	9728.7	9728.7	9728.7	9745.4	9730.0	9779.6	9755.0	9755.0	9779.6	9755.0	9728.7	9730.0	9730.0	9728.7
7	9305.0	8403.5	8403.5	9664.2	8403.5	8403.5	9664.2	8403.5	7690.6	10330.3	8397.6	8361.9	10330.3	8397.6	8361.9	10330.3	7358.1	7358.1
8	6744.6	8439.9	6540.6	8932.2	8439.9	6540.6	8932.2	8439.9	6540.6	6595.7	6559.0	6595.7	6595.7	6559.0	6595.7	6595.7	6559.0	6651.8
9	11276.8	11300.5	10907.5	10698.3	10698.3	10907.5	10698.3	11353.0	10661.0	11266.3	11260.8	11266.3	11266.3	11260.8	10694.4	11280.6	11266.3	10694.4
10	9811.9	9953.5	9776.3	10913.9	10885.2	9776.3	10961.3	10757.9	10757.9	9978.0	9772.1	9776.3	9793.7	9772.1	9776.3	9793.7	9772.1	9818.7
11	12008.4	11928.6	11928.6	12004.8	12022.0	11929.0	12088.2	12022.0	11929.0	13010.6	11944.4	11929.0	11944.4	11929.0	11944.4	11944.4	11929.0	11929.0
12	11549.7	11353.1	11353.1	11353.1	11353.1	11353.1	11353.1	11353.1	11353.1	11569.3	11549.7	11549.7	11553.3	11550.1	11550.1	11553.3	11550.1	11553.9
13	9320.1	9320.1	9320.1	9931.0	9320.1	9320.1	9551.7	9320.1	9320.1	9866.9	9320.1	9320.1	9401.0	9320.1	9320.1	9401.0	9320.1	9320.1
14	14251.4	14201.8	14172.6	14289.5	14201.8	14172.6	14185.0	14183.3	14174.3	15019.3	14191.4	14172.6	15019.3	14191.4	14184.6	14191.4	14184.6	14184.6
15	6151.8	9857.4	6145.7	10430.9	6145.7	6145.7	10430.9	6145.7	6145.7	6638.0	6242.3	6242.3	6638.0	6242.3	6242.3	6638.0	6242.3	6242.3
16	7235.9	7066.4	7066.4	9523.1	7120.1	7066.4	9523.1	7120.1	6321.3	10089.0	9316.7	6775.3	10089.0	9316.7	6775.3	7739.7	6426.2	6426.2
17	9241.1	8447.5	8041.6	8275.0	7537.8	7537.8	7562.4	7537.8	7537.8	7815.2	7647.6	7647.6	8222.1	7575.4	7575.4	8222.1	7575.4	7575.4
18	7656.2	7633.9	7633.9	7633.9	7633.9	7633.9	7430.3	7430.3	7795.4	8098.1	7976.0	7793.7	8098.1	7976.0	7797.9	8654.3	7799.2	7799.2
19	6993.4	6541.5	6541.5	6910.2	6541.5	6541.5	6910.2	6541.5	6556.9	7129.6	6791.1	6791.1	7129.6	6791.1	6791.1	6931.5	6542.8	6542.8
20	9066.9	8970.7	8987.5	9130.3	8970.3	8970.3	9062.7	8970.3	8970.3	9667.0	8969.0	8969.0	9244.2	9006.0	9006.0	9244.2	9006.0	9006.0

APPENDIX 6 - SOLUTIONS OF REAL PROBLEMS BY UTILIZING HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics= LPT1 & LPTcomp,

Improvement Heuristic: Tabu Search

Problem #	100_LPT1_TS_									100_LPTcomp_TS_								
	Tabulist=10			Tabulist=20			Tabulist=30			Tabulist=10			Tabulist=20			Tabulist=30		
	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150	MI 50	MI 100	MI 150
1	7935.8	7913.3	7886.0	7921.5	7916.3	7886.0	7921.5	7916.3	7886.0	8438.5	7994.8	7887.3	8172.3	8172.3	7887.3	8172.3	8172.3	7887.3
2	11412.0	11402.1	11397.9	11412.0	11402.1	11397.9	11412.0	11396.6	11412.2	11513.6	11412.0	11451.7	11513.6	11412.0	11451.7	11536.9	11464.7	11415.1
3	15604.3	15554.5	15552.0	15604.3	15554.5	15552.0	15590.0	15590.0	15590.0	15681.8	15555.8	15555.8	15681.8	15555.8	15568.8	15679.7	15568.8	15568.8
4	9096.7	8490.9	8323.1	9096.7	8490.9	8218.9	8243.1	8218.9	8218.9	13041.0	13167.6	8329.6	10555.2	10221.3	8426.2	10555.2	10221.3	8426.2
5	6747.0	5793.7	5793.7	6089.3	5793.7	5793.7	6089.3	6737.9	6737.9	6352.7	5997.8	5997.8	6352.7	5997.8	5997.8	8289.9	5864.4	5733.0
6	9764.2	9743.0	9743.0	9743.0	9813.8	9792.6	9813.8	9813.8	9792.6	9906.6	9743.0	9743.0	9870.5	9730.0	9730.0	9768.0	9730.0	9730.0
7	10545.3	8541.7	8541.7	10545.3	8541.7	8541.7	9698.4	8403.7	9372.8	9783.3	8397.6	8397.6	9783.3	8858.3	9181.5	10131.3	9194.3	9181.5
8	7182.2	6571.6	6410.5	7182.2	6571.6	6410.5	8299.1	8299.1	6541.0	8655.2	8655.2	6555.2	8655.2	8655.2	8500.9	9127.7	8534.1	8500.9
9	11293.6	11293.6	11265.0	11293.6	11262.1	11260.8	11262.1	11262.1	11260.8	11262.5	11291.3	11260.8	11790.7	10379.3	10379.3	11790.7	10379.3	10379.3
10	9788.5	9788.5	9772.5	9788.5	9788.5	9772.5	9788.5	9788.5	9679.2	11647.3	10794.0	9772.1	11647.3	10794.0	9772.1	11857.6	10476.4	9802.3
11	11958.8	11967.0	11967.0	11967.0	11967.0	11967.0	11967.0	11967.0	11967.0	11596.5	11596.5	11596.5	11596.5	11596.5	11596.5	11596.5	11596.5	11928.6
12	11613.1	11569.3	11553.9	11613.1	11569.3	11553.9	11613.1	11552.6	11549.7	11840.0	11461.2	11424.8	11461.2	11461.2	11424.8	11363.1	11670.4	11363.1
13	9887.6	9320.1	9320.1	9412.9	9320.1	9320.1	9412.9	9320.1	9320.1	9781.9	9296.1	9253.4	10157.4	9296.1	9253.4	10157.4	9296.1	9253.4
14	14212.3	14172.6	14172.6	14212.3	14173.9	14173.9	14201.8	14173.9	14173.9	14261.2	14183.3	14172.6	15195.4	14160.0	14191.1	15195.4	14160.0	14191.1
15	6262.4	6151.8	6151.8	9766.9	6151.8	6151.8	9766.9	7231.1	7231.1	11019.4	10340.4	10340.4	11019.4	10340.4	10340.4	11054.4	10931.7	9766.9
16	6523.2	8025.9	6774.2	6523.2	8025.9	7072.3	7100.3	7247.7	6480.0	9660.7	6426.2	6289.6	9660.7	8034.6	6426.2	9530.6	8034.6	6426.2
17	8986.2	8986.2	8087.3	8986.2	8986.2	8087.3	8986.2	8986.2	8556.8	11883.7	9236.3	8029.1	11883.7	9236.3	8029.1	11883.7	8237.6	8206.4
18	8211.6	7831.0	7831.0	8105.8	7809.7	7795.4	7827.2	7795.0	7793.7	7793.7	7793.7	7812.2	8665.6	8011.0	7795.4	8665.6	8011.0	7795.4
19	7396.9	6618.4	6618.4	7396.9	6618.4	6541.5	6724.2	6541.5	6541.5	7387.4	6542.8	6542.8	7387.4	6541.5	6541.5	6798.3	7196.0	6541.5
20	7358.5	8809.6	8809.6	8809.6	8809.6	8809.6	8809.6	8809.6	8809.6	10239.7	9534.0	9251.7	10239.7	9534.0	9251.7	10239.7	9534.0	8668.0

APPENDIX 7 – SOLUTIONS OF LARGE SCALE GENERIC TEST PROBLEMS WITH COUPLING OF HEURISTICS

Number of Jobs = 20,

Construction Heuristics= SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	125	125	125	125	125	125	125	125	125	125	125	125
2	121	121	121	121	121	119	119	119	121	118	119	119
3	129	129	129	129	129	127	127	127	129	127	127	127
4	124	124	123	123	118	118	118	118	117	117	117	115
5	134	129	129	129	134	129	129	129	134	129	122	129
6	128	125	121	125	128	125	125	125	128	125	125	125
7	105	98	98	98	103	98	98	98	103	98	98	98
8	133	133	133	133	133	133	133	133	133	132	132	132
9	137	131	131	131	137	137	136	132	137	134	135	136
10	137	137	135	137	137	137	137	137	137	137	137	136
11	128	122	122	122	128	122	122	122	128	121	121	121
12	126	125	125	125	126	125	125	125	126	125	125	125
13	136	135	135	135	136	135	134	134	135	134	134	134
14	116	100	107	110	113	104	107	104	113	104	105	104
15	140	136	136	136	140	136	136	136	138	136	136	136
16	139	136	137	137	139	137	137	137	139	136	137	137
17	113	110	110	110	113	110	110	110	113	110	110	110
18	140	140	140	140	140	139	139	139	140	139	139	139
19	127	127	127	127	127	127	127	127	124	124	124	124
20	142	142	142	142	142	142	142	142	142	142	142	142

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	125	125	125	125	125	125	125	125	125	125	125	125
2	121	121	121	121	121	119	119	119	121	118	119	119
3	129	127	127	127	129	127	127	127	129	127	127	127
4	124	123	120	118	118	118	118	118	117	117	117	117
5	134	129	129	129	134	129	129	129	134	129	122	129
6	128	125	121	125	128	125	125	125	128	125	125	125
7	105	98	98	98	103	98	98	98	103	98	98	98
8	133	133	133	133	133	133	133	133	133	132	132	132
9	134	134	131	134	132	132	132	132	128	128	128	128
10	137	137	135	137	137	135	135	135	137	133	134	134
11	128	122	122	122	128	122	122	122	128	121	121	121
12	126	125	125	125	126	125	125	125	126	125	125	125
13	136	135	135	135	136	135	134	134	135	134	134	134
14	116	100	107	110	113	104	107	104	113	106	106	106
15	138	136	136	136	138	136	136	136	138	136	136	136
16	139	136	137	137	139	137	137	137	139	139	139	139
17	113	110	110	110	113	110	110	110	113	110	110	110
18	140	140	140	140	140	139	139	139	140	139	139	139
19	127	127	127	127	127	127	127	127	124	124	124	124
20	142	142	142	142	142	142	142	142	142	142	142	142

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	125	125	125	125	125	125	125	125	125	125	125	125
2	121	121	121	121	121	119	119	119	121	118	119	119
3	129	127	127	127	129	127	127	127	129	127	127	127
4	124	123	120	118	118	118	118	118	117	117	117	117
5	134	129	129	129	134	129	129	129	134	129	122	129
6	128	125	121	125	128	125	125	125	128	124	121	121
7	105	98	98	98	103	98	98	98	103	98	98	98
8	133	133	133	133	133	133	133	133	133	133	133	133
9	134	134	131	134	132	132	132	132	128	128	128	128
10	137	135	135	135	137	135	135	135	137	133	134	134
11	128	122	122	122	128	122	122	122	128	121	121	121
12	126	125	125	125	126	125	125	125	126	125	125	125
13	136	135	135	135	136	135	134	134	135	130	133	133
14	116	107	106	113	113	106	106	106	113	106	106	106
15	138	136	136	136	138	136	136	136	138	136	136	136
16	139	139	139	139	139	139	139	139	139	139	139	139
17	113	110	110	110	113	110	110	110	113	110	110	110
18	140	140	140	140	140	139	139	139	140	139	139	139
19	127	127	127	127	127	127	127	127	124	124	124	124
20	142	142	142	142	142	142	142	142	142	142	142	142

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics= SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	134	132	132	132	134	132	132	130	134	130	130	130
2	127	127	123	122	120	120	120	120	120	119	120	120
3	133	131	130	130	132	131	130	131	132	129	131	129
4	126	124	124	122	126	124	122	124	126	118	121	124
5	135	131	133	133	135	131	133	130	135	128	133	130
6	128	124	124	124	128	123	122	123	128	123	123	123
7	115	105	101	105	109	100	109	106	109	106	102	102
8	129	129	129	129	129	129	129	129	129	129	129	127
9	134	134	133	134	133	131	133	133	133	131	133	133
10	145	137	137	137	145	136	136	136	145	136	136	136
11	143	135	130	136	143	134	134	134	143	132	132	132
12	132	132	131	132	132	131	131	132	132	130	130	130
13	137	135	137	137	136	136	135	136	136	136	135	136
14	115	109	113	111	115	110	108	105	115	109	107	108
15	136	135	135	135	136	135	135	135	136	135	135	135
16	142	140	142	142	140	140	140	140	140	140	136	140
17	120	111	116	116	120	111	114	112	120	111	112	111
18	140	140	140	140	140	140	140	140	140	140	140	140
19	135	132	132	132	133	132	132	132	133	132	132	131
20	149	147	146	147	147	147	147	147	147	146	145	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics= SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	134	131	131	131	134	131	131	131	134	130	130	130
2	127	127	123	122	120	120	120	120	120	119	120	120
3	133	131	130	130	132	131	130	131	132	129	131	129
4	121	121	121	121	121	121	121	121	121	118	121	121
5	135	131	133	133	135	131	133	130	135	128	133	130
6	128	124	124	124	128	123	122	123	128	123	123	123
7	115	105	101	105	109	100	109	106	109	106	102	102
8	129	129	129	129	129	129	129	129	129	129	129	127
9	134	134	133	134	133	131	133	133	133	131	133	133
10	145	137	137	137	145	136	136	136	145	136	136	136
11	143	135	130	136	143	134	134	134	143	132	132	132
12	132	132	131	132	132	131	131	132	132	130	130	130
13	137	135	137	137	136	136	135	136	136	136	135	136
14	130	109	113	111	130	110	108	105	130	109	107	108
15	136	135	135	135	136	135	135	135	136	135	135	135
16	142	140	142	142	140	140	140	140	140	140	136	140
17	120	113	118	116	120	112	111	112	120	112	113	118
18	140	140	140	140	140	140	140	140	140	140	140	140
19	135	132	132	132	133	132	132	132	133	132	132	131
20	149	147	146	147	147	147	147	147	147	146	145	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics= SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50			MI=100				MI=150				
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	134	131	131	131	134	131	131	131	134	130	130	130
2	127	127	123	122	120	120	120	120	120	119	120	120
3	133	131	130	130	132	131	130	131	132	129	131	129
4	121	121	121	121	121	121	121	121	121	118	121	121
5	135	131	133	133	135	131	133	130	130	128	130	130
6	128	124	124	124	128	123	122	123	128	123	123	123
7	115	105	101	105	109	100	109	106	109	106	102	102
8	129	129	129	129	129	129	129	129	129	129	129	127
9	134	134	133	134	133	131	133	133	133	131	133	133
10	145	137	137	137	145	136	136	136	145	136	136	136
11	143	135	130	136	143	134	134	134	143	132	132	132
12	132	132	131	132	132	131	131	132	132	130	130	130
13	137	135	137	137	136	136	135	136	136	136	135	136
14	130	109	113	111	130	110	108	105	130	109	107	108
15	136	135	135	135	136	135	135	135	136	135	135	135
16	142	140	142	142	140	140	140	140	140	140	136	140
17	120	113	118	116	120	112	111	112	120	112	113	118
18	140	140	140	140	140	140	140	140	140	140	140	140
19	135	132	132	132	133	132	132	132	133	132	132	131
20	149	147	146	147	147	147	147	147	147	147	147	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	150	137	137	138	150	139	140	141	150	138	136	137
2	141	132	127	128	134	130	131	127	134	127	126	128
3	140	132	135	137	140	132	132	134	139	132	131	132
4	137	124	122	118	133	121	119	121	130	121	123	123
5	142	131	134	130	142	130	132	132	140	129	129	133
6	154	131	125	128	154	129	127	125	154	126	125	127
7	119	108	107	108	116	109	110	107	116	104	104	100
8	144	140	141	135	140	139	138	138	140	136	135	134
9	143	133	133	139	143	133	137	134	143	133	137	131
10	161	137	141	143	161	134	140	133	161	138	133	137
11	159	137	138	136	159	133	140	135	159	134	137	134
12	137	134	131	132	136	129	131	132	136	129	130	128
13	153	139	141	138	151	136	133	136	149	136	135	136
14	139	109	110	111	139	107	113	105	139	107	105	107
15	166	144	141	139	166	143	139	140	166	140	140	145
16	144	141	147	144	143	141	140	140	143	141	142	140
17	130	112	115	114	130	112	114	113	130	116	114	113
18	163	141	145	149	163	141	145	142	163	141	141	144
19	150	132	142	130	150	136	133	134	150	132	136	138
20	156	150	151	146	156	146	146	149	155	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	150	137	137	138	150	139	140	141	150	138	136	137
2	141	128	127	132	134	123	133	129	134	126	124	127
3	140	132	135	137	140	132	132	134	139	130	131	133
4	137	124	122	118	133	121	119	121	130	121	123	123
5	142	140	131	135	142	132	128	132	140	129	129	133
6	154	131	125	128	154	129	127	125	154	126	125	127
7	119	108	107	108	116	109	110	107	116	104	104	100
8	144	140	141	135	140	139	138	138	140	136	135	134
9	143	133	133	139	143	137	131	137	143	137	135	133
10	161	137	141	143	161	134	140	133	161	138	133	137
11	159	137	138	136	159	133	140	135	159	134	137	134
12	137	132	134	131	136	133	132	128	136	133	131	128
13	153	139	141	138	151	136	133	136	149	136	135	136
14	139	109	110	111	139	107	113	105	139	107	105	107
15	166	144	141	139	166	143	139	140	166	140	140	145
16	144	141	147	144	143	141	140	140	143	141	142	140
17	130	112	115	114	130	112	114	113	130	116	114	113
18	163	141	145	149	163	141	145	142	163	141	141	144
19	150	132	142	130	155	135	133	136	155	133	137	135
20	161	150	151	146	161	146	146	149	161	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics= LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	150	137	137	138	150	139	140	141	150	138	136	137
2	141	128	127	132	134	123	133	129	134	126	124	127
3	140	133	132	135	140	130	133	133	139	130	131	133
4	137	124	122	118	133	119	125	124	130	119	119	121
5	142	140	131	135	142	132	128	132	140	129	129	133
6	154	131	125	128	154	129	127	125	154	126	125	127
7	119	108	106	108	116	108	109	109	116	106	105	104
8	144	140	141	135	140	139	138	138	140	136	135	134
9	143	137	139	136	143	137	131	137	143	137	135	133
10	161	137	141	143	161	134	140	133	161	138	139	138
11	159	137	138	136	159	133	140	135	159	134	137	134
12	137	132	134	131	136	133	132	128	136	133	131	128
13	153	139	141	138	151	136	133	136	149	136	135	136
14	139	109	110	111	139	107	113	105	139	108	107	107
15	166	144	141	139	166	143	139	140	166	140	140	145
16	144	141	147	144	143	141	140	140	143	141	142	140
17	130	112	115	114	130	112	114	113	130	116	114	113
18	163	141	145	149	163	141	145	142	163	141	141	144
19	155	137	138	138	155	133	140	135	155	133	137	135
20	161	150	151	146	161	146	146	149	161	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics= LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	149	139	139	135	151	136	139	135	151	133	135	137
2	132	126	129	133	132	127	131	126	132	125	128	124
3	138	135	134	136	138	134	135	133	138	134	132	131
4	130	125	125	128	129	125	122	118	129	122	119	119
5	136	134	135	134	136	129	132	130	135	129	131	134
6	139	130	127	130	139	129	124	129	139	126	129	125
7	111	111	108	106	111	108	109	107	111	107	105	107
8	139	131	138	135	139	131	138	138	139	136	132	136
9	137	136	137	135	136	134	139	135	136	136	135	134
10	151	145	139	144	151	140	135	137	151	140	137	139
11	142	140	140	137	142	136	137	135	142	136	136	136
12	137	135	139	132	137	135	131	131	135	130	133	131
13	142	137	135	138	142	135	133	137	142	135	133	136
14	129	110	107	109	129	109	110	105	129	107	107	105
15	157	140	145	140	157	139	144	144	157	143	140	145
16	142	143	142	143	141	141	142	140	141	141	141	141
17	131	119	119	116	131	114	113	116	131	114	112	116
18	163	144	145	150	163	145	141	145	163	144	143	146
19	150	133	137	140	150	133	141	131	150	133	135	132
20	154	151	145	147	154	150	144	150	154	145	147	149

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics= LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	151	139	139	135	151	136	139	135	151	135	137	137
2	132	126	129	133	132	127	131	126	132	125	128	124
3	138	135	134	136	138	134	135	133	138	134	132	131
4	130	125	125	128	129	125	122	118	129	122	119	119
5	136	134	135	134	136	129	132	130	135	129	131	134
6	139	133	134	129	139	128	125	126	139	128	128	132
7	111	111	108	106	111	108	109	107	111	107	105	107
8	139	140	135	133	139	136	132	138	139	136	132	136
9	137	136	137	135	136	134	139	135	136	136	135	134
10	151	145	139	144	151	140	135	137	151	140	137	139
11	142	140	140	137	142	136	137	135	142	136	136	136
12	149	135	139	132	149	135	131	131	149	130	133	131
13	142	139	136	141	142	137	138	136	142	132	132	134
14	129	110	107	109	129	109	110	105	129	107	107	105
15	157	140	145	140	157	139	144	144	157	143	140	145
16	142	143	142	143	141	141	142	140	141	141	141	141
17	131	119	119	116	131	114	113	116	131	114	112	116
18	163	144	145	150	163	145	141	145	163	144	143	146
19	150	133	137	140	150	133	141	131	150	133	135	132
20	154	151	145	147	154	150	144	150	154	145	147	149

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics= LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	151	135	136	138	151	135	130	130	151	135	137	137
2	132	126	129	133	132	127	131	126	132	125	128	124
3	138	135	134	136	138	134	135	133	138	134	132	131
4	130	125	125	128	129	125	122	118	129	122	119	119
5	136	134	135	134	136	129	132	130	135	129	131	134
6	139	133	134	129	139	128	125	126	139	128	128	132
7	111	111	108	106	111	108	109	107	111	107	105	107
8	139	140	135	133	139	136	132	138	139	136	132	136
9	137	136	137	135	136	134	139	135	136	136	135	134
10	151	145	139	144	151	140	135	137	151	140	137	139
11	142	140	140	137	142	136	137	135	142	136	136	136
12	149	135	139	132	149	135	131	131	149	130	133	131
13	142	139	136	141	142	137	138	136	140	132	132	134
14	129	110	107	109	129	109	110	105	129	107	107	105
15	157	140	145	140	157	139	144	144	157	143	140	145
16	142	143	142	143	141	141	142	140	141	141	141	141
17	131	119	119	116	131	114	113	116	131	114	112	116
18	163	145	149	145	163	141	144	147	163	141	144	142
19	150	133	137	140	150	133	141	131	150	133	135	132
20	154	151	145	147	154	150	144	150	154	145	147	149

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	150	137	137	138	150	139	140	141	150	138	136	137
2	289	283	283	283	289	283	283	281	283	280	282	282
3	297	296	296	296	297	296	296	296	297	296	296	296
4	283	279	279	279	283	279	277	279	283	279	279	279
5	303	301	301	301	303	301	301	301	303	301	301	300
6	277	261	253	264	277	262	265	262	277	260	260	260
7	274	274	274	273	274	274	274	274	274	274	274	274
8	297	292	292	292	297	292	292	292	297	297	297	297
9	282	279	282	278	279	279	279	279	279	279	279	278
10	286	268	262	258	286	263	262	267	286	263	268	267
11	323	317	317	318	321	317	316	317	321	317	317	317
12	273	260	260	260	273	261	261	261	273	261	261	261
13	288	287	287	287	287	287	287	286	284	284	284	283
14	263	263	263	263	263	263	263	263	263	263	263	263
15	272	272	271	272	272	272	272	272	272	272	272	272
16	284	283	283	283	280	280	280	280	280	280	280	280
17	272	271	272	272	272	271	272	272	272	271	272	272
18	274	271	271	271	274	271	271	271	274	272	272	272
19	282	276	276	276	282	276	276	276	282	274	274	274
20	283	280	280	280	283	278	278	278	282	280	280	280

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	150	137	137	138	150	139	140	141	150	138	136	137
2	289	283	283	283	289	283	283	281	283	280	282	282
3	297	296	296	296	297	296	296	296	297	296	296	296
4	283	282	282	282	283	282	281	280	283	282	282	282
5	303	301	301	301	303	301	301	301	303	301	301	300
6	277	261	253	264	277	262	265	262	277	260	260	260
7	274	274	274	273	274	274	274	274	274	274	274	274
8	297	297	297	297	297	297	297	297	297	297	297	297
9	282	279	282	278	279	279	279	279	279	279	279	278
10	286	268	262	258	286	263	262	267	286	263	268	267
11	323	317	317	318	321	317	316	317	321	317	317	317
12	273	261	261	258	273	261	261	261	273	261	261	261
13	286	286	286	286	284	284	284	284	284	284	284	283
14	263	263	263	263	263	263	263	263	263	263	263	263
15	272	272	272	272	272	272	272	272	272	272	272	272
16	284	283	283	283	280	277	280	280	280	280	280	279
17	272	271	272	272	272	271	272	272	272	271	272	272
18	274	272	272	272	274	272	272	272	274	272	272	272
19	282	275	275	275	282	274	274	274	282	274	274	274
20	283	280	280	280	283	280	280	280	282	280	280	280

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	150	137	137	138	150	139	140	141	150	138	136	137
2	289	282	289	289	289	282	289	285	283	282	283	283
3	297	297	297	297	297	297	297	297	297	296	296	296
4	283	282	282	282	283	282	281	280	283	282	282	282
5	303	301	301	301	303	301	301	301	301	301	301	300
6	277	261	253	264	277	262	265	262	277	260	260	260
7	274	274	274	274	274	274	274	274	274	273	273	272
8	297	297	297	297	297	297	297	297	297	297	297	297
9	282	279	282	278	271	271	271	271	271	271	271	271
10	292	268	262	258	288	263	262	267	286	263	268	267
11	323	317	317	318	321	317	316	317	321	317	317	317
12	273	261	261	258	273	261	261	261	273	261	261	261
13	286	286	286	286	284	284	284	284	284	284	284	283
14	263	263	263	263	263	263	263	263	263	263	263	263
15	272	272	272	272	272	272	272	272	272	272	272	272
16	284	278	282	284	280	277	280	280	280	280	280	279
17	272	271	272	272	272	271	272	272	272	271	272	272
18	274	272	272	272	274	272	272	272	274	272	272	272
19	282	275	275	275	282	274	274	274	282	274	274	274
20	283	280	280	280	283	280	280	280	282	280	280	280

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics= SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	149	139	139	135	151	136	139	135	151	133	135	137
2	291	290	291	291	291	291	291	291	288	288	288	288
3	302	298	298	298	302	298	298	298	303	298	298	298
4	289	286	284	286	286	286	286	286	286	286	285	284
5	307	307	307	307	306	306	306	306	306	306	306	306
6	291	266	266	266	291	264	265	261	291	263	263	263
7	276	276	273	276	276	276	276	276	274	274	274	274
8	307	305	305	304	307	303	305	304	307	305	305	305
9	285	285	285	285	285	285	283	285	278	278	278	278
10	267	265	264	265	267	263	264	265	267	264	265	264
11	322	322	322	322	322	322	319	322	320	320	320	320
12	264	262	262	262	264	262	262	262	264	259	259	259
13	295	295	295	295	295	295	295	292	295	295	293	292
14	276	274	272	273	276	270	274	274	276	276	269	273
15	276	275	274	275	276	275	275	275	277	272	272	272
16	292	288	286	290	292	284	287	287	289	285	287	287
17	270	268	268	267	270	268	268	268	270	268	268	268
18	277	277	277	277	277	277	277	277	277	277	277	277
19	278	278	278	278	278	278	278	278	278	278	278	278
20	286	286	286	285	286	286	286	285	286	286	286	286

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics= SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	151	139	139	135	151	136	139	135	151	135	137	137
2	291	290	291	291	291	291	291	291	288	288	288	288
3	303	298	298	298	303	298	298	298	303	298	298	298
4	289	286	284	286	286	286	286	286	286	286	285	284
5	307	307	307	307	306	306	306	306	306	306	306	306
6	291	266	266	266	291	264	265	261	291	263	263	263
7	280	277	273	277	277	277	277	277	275	275	275	275
8	307	305	305	304	307	303	305	304	306	306	305	302
9	285	285	285	285	285	285	285	285	278	278	278	278
10	267	265	264	265	267	263	264	265	267	264	265	264
11	322	322	322	322	322	322	319	322	320	320	320	320
12	264	262	262	262	264	264	264	264	264	263	263	263
13	295	295	290	289	295	295	289	293	295	295	292	284
14	276	276	274	276	276	270	274	274	276	276	269	273
15	277	272	274	273	277	276	276	276	277	276	276	276
16	292	288	286	290	292	284	287	287	289	285	287	287
17	270	268	268	267	270	268	268	268	270	268	268	268
18	277	277	277	277	277	277	277	277	277	277	277	277
19	278	278	278	278	278	278	278	278	278	278	278	278
20	286	286	286	285	286	286	286	285	286	285	286	286

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics= SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	151	135	136	138	151	135	130	130	151	135	137	137
2	291	290	291	291	291	291	291	291	288	288	288	288
3	303	298	298	298	303	298	298	298	303	298	298	298
4	289	283	283	283	286	283	283	283	286	283	283	283
5	307	307	307	307	306	306	306	306	306	306	306	306
6	291	266	266	266	291	264	265	261	291	263	263	263
7	280	277	273	277	277	277	277	277	275	275	275	275
8	306	302	305	304	306	303	306	306	306	306	305	302
9	285	285	285	285	285	285	285	285	278	278	278	278
10	267	265	264	265	267	263	264	265	267	264	265	264
11	322	322	322	322	322	322	319	322	320	320	320	320
12	264	264	264	264	264	264	264	264	264	263	263	263
13	295	295	290	289	295	295	289	293	295	295	292	284
14	276	276	274	276	276	270	274	274	276	276	269	273
15	277	275	277	277	277	276	276	276	277	276	276	276
16	292	288	286	290	292	282	282	283	289	287	282	289
17	270	268	268	267	270	268	268	268	270	268	268	268
18	277	277	277	277	285	280	282	279	285	277	281	282
19	278	278	278	278	278	278	278	278	278	278	278	278
20	286	286	286	283	286	285	282	285	286	285	286	286

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50			MI=100				MI=150				
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	319	301	307	299	319	302	300	289	315	302	297	297
2	306	300	296	313	3002	295	298	296	297	291	293	302
3	337	308	317	314	337	312	302	302	337	312	297	310
4	312	297	302	300	312	290	288	297	312	291	287	294
5	336	321	321	317	336	314	316	316	336	316	308	318
6	303	270	277	275	303	266	271	274	303	266	268	261
7	308	294	290	291	306	287	288	288	306	287	283	287
8	334	308	317	318	334	308	309	317	334	306	308	305
9	310	294	301	294	308	279	291	296	308	287	291	287
10	311	271	281	282	307	270	282	269	307	273	275	271
11	333	323	337	331	333	323	321	327	333	323	326	325
12	309	282	285	286	309	275	276	277	309	269	273	271
13	343	299	299	299	337	296	292	291	335	296	296	294
14	298	288	277	279	298	272	269	274	296	272	280	272
15	331	291	293	289	331	282	283	285	331	282	282	273
16	309	295	304	309	305	293	296	296	303	293	296	294
17	325	282	299	285	325	289	285	278	325	289	282	276
18	311	296	291	295	311	292	288	280	311	292	280	286
19	321	310	291	303	320	296	280	288	319	284	285	291
20	312	294	296	301	311	296	300	297	311	290	297	294

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	319	301	307	299	319	302	300	289	315	302	297	297
2	306	300	296	313	302	295	298	296	297	291	293	302
3	337	308	318	319	337	312	302	302	337	312	297	310
4	312	297	302	300	312	290	288	297	312	291	287	294
5	336	330	330	324	336	313	313	318	336	314	313	315
6	276	277	272	282	276	274	267	274	276	262	269	268
7	308	294	290	291	306	287	288	288	306	287	283	287
8	334	308	317	318	334	308	309	317	334	306	308	305
9	310	294	301	294	308	279	291	296	308	290	289	289
10	311	282	270	274	307	271	269	273	307	270	273	271
11	333	330	336	328	333	328	327	329	333	325	335	320
12	309	282	285	286	309	275	276	277	309	269	273	271
13	343	299	299	299	337	296	292	291	335	296	296	294
14	298	288	277	279	298	270	272	272	296	270	270	268
15	331	291	293	289	331	282	283	285	331	282	282	273
16	309	295	304	309	309	293	296	296	319	293	296	294
17	325	282	292	290	325	273	284	280	325	284	280	284
18	311	296	291	295	311	292	288	280	311	292	280	286
19	321	310	291	303	320	296	280	288	325	284	285	291
20	311	294	296	301	311	296	300	297	311	290	297	294

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics= LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	319	301	307	299	319	302	300	289	315	302	297	297
2	306	300	296	313	302	295	298	296	297	291	293	302
3	337	308	318	319	337	312	302	302	337	312	297	310
4	312	297	302	300	312	290	288	297	312	291	287	294
5	336	330	330	324	336	313	313	318	336	314	313	315
6	276	277	272	282	276	274	267	274	276	262	269	268
7	308	294	290	291	306	287	288	288	306	287	283	287
8	334	308	317	318	334	308	309	317	334	302	301	304
9	310	298	301	297	308	291	292	298	308	294	293	292
10	311	282	270	274	307	271	269	273	307	270	273	271
11	333	330	336	328	333	328	327	329	333	325	335	320
12	309	282	285	286	309	275	276	277	309	280	273	274
13	343	299	299	299	337	295	298	300	335	295	291	292
14	298	270	277	272	298	270	272	272	296	270	270	268
15	331	289	287	297	331	275	288	284	331	277	279	282
16	323	295	304	309	323	293	296	296	319	293	296	294
17	325	282	292	290	325	273	284	280	325	284	280	284
18	311	296	291	295	311	292	288	280	311	279	279	280
19	325	310	291	303	325	296	280	288	325	284	285	291
20	311	294	296	301	311	296	300	297	311	289	295	292

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics= LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	316	301	302	304	316	298	295	300	313	292	298	302
2	296	291	301	303	296	294	306	296	296	295	293	294
3	312	308	316	314	312	309	310	312	312	307	304	306
4	303	301	290	296	295	295	293	293	295	293	295	294
5	326	323	318	322	326	318	312	318	326	311	311	312
6	279	282	274	275	277	273	268	272	277	273	266	268
7	301	289	287	293	301	280	284	287	301	286	290	283
8	323	312	311	311	323	310	312	312	323	310	308	308
9	304	294	302	300	304	294	288	296	304	290	288	289
10	285	280	277	277	284	273	265	273	283	268	264	270
11	325	332	330	326	325	332	327	326	325	332	327	331
12	292	271	280	271	291	271	270	276	290	271	273	274
13	307	289	303	295	305	285	295	293	305	285	293	290
14	294	281	277	279	294	276	277	277	294	271	272	278
15	305	278	278	281	305	278	283	279	305	278	282	282
16	308	297	295	283	305	293	291	302	305	291	300	292
17	317	284	291	296	317	276	283	282	317	280	278	280
18	293	280	285	289	293	283	277	283	293	281	285	276
19	302	291	286	296	299	291	294	294	299	285	279	288
20	308	295	295	292	308	292	294	292	308	292	287	289

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics= LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	316	313	301	301	316	303	297	299	313	292	298	302
2	296	297	295	303	321	289	297	290	321	297	295	291
3	312	308	316	314	312	307	310	309	312	307	309	310
4	303	301	290	296	295	295	293	293	295	293	295	294
5	326	323	318	322	326	318	312	318	326	311	311	312
6	279	282	274	275	277	273	268	272	277	273	266	268
7	301	283	295	292	301	283	290	284	301	291	292	282
8	323	312	311	311	323	310	312	312	323	310	308	308
9	304	294	302	300	304	294	288	296	304	290	288	289
10	285	280	277	277	284	273	265	273	283	268	264	270
11	325	332	330	326	344	332	327	326	344	332	327	331
12	292	271	280	271	291	271	270	276	290	271	273	274
13	307	289	303	295	305	285	295	293	305	285	293	290
14	294	281	277	279	294	276	277	277	294	271	272	278
15	305	278	278	281	305	278	283	279	305	278	282	282
16	308	299	303	297	305	294	293	291	305	291	300	292
17	317	284	291	296	317	276	283	282	317	280	278	280
18	293	280	285	289	293	283	277	283	293	281	285	276
19	302	291	286	296	299	291	294	294	299	285	279	288
20	308	295	295	292	308	292	294	292	308	292	287	289

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics= LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	316	313	301	301	316	303	297	299	313	292	298	302
2	321	297	295	303	321	289	297	290	321	297	295	291
3	312	310	312	315	312	307	310	309	312	307	309	310
4	303	301	290	296	295	295	293	293	295	293	295	294
5	326	327	320	320	326	321	317	316	326	314	311	312
6	279	271	275	275	277	271	273	265	277	267	272	263
7	301	283	295	292	301	283	290	284	301	291	292	282
8	323	312	311	311	323	310	312	312	323	310	308	308
9	304	294	302	300	304	294	288	296	304	290	288	289
10	285	275	275	275	284	274	275	273	283	274	272	269
11	344	332	330	326	344	327	326	323	344	321	322	329
12	292	271	280	271	291	271	270	276	290	271	273	274
13	307	289	303	295	305	285	295	293	307	285	293	290
14	294	281	277	279	294	276	279	280	294	273	273	274
15	305	278	278	281	305	278	283	279	305	278	282	282
16	308	299	303	297	305	294	293	291	305	291	300	292
17	317	284	279	288	317	279	281	276	317	273	279	283
18	293	280	285	289	293	283	277	283	293	281	285	276
19	302	291	286	296	299	291	294	294	299	285	279	288
20	308	295	295	292	308	292	294	292	308	292	287	289

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	588	588	588	587	588	588	588	588	588	588	588	588
2	546	543	543	543	544	543	543	543	544	542	542	542
3	528	525	527	527	527	525	527	527	527	525	524	523
4	562	561	559	560	562	561	560	560	562	559	558	559
5	515	511	511	509	515	509	509	509	515	509	509	509
6	598	587	586	586	598	584	584	584	598	584	584	584
7	540	540	540	540	540	540	540	540	540	540	540	540
8	557	551	551	549	557	551	549	551	557	551	550	551
9	553	553	550	551	551	551	548	551	550	549	550	550
10	500	496	496	496	496	494	495	495	493	492	492	490
11	568	568	568	568	568	568	568	568	568	568	568	568
12	543	543	543	543	543	543	543	543	542	542	542	542
13	558	556	556	555	558	554	554	554	558	554	554	554
14	491	491	491	491	491	491	491	491	491	491	491	491
15	508	508	508	504	508	502	499	502	508	502	500	502
16	547	536	534	533	547	535	533	534	547	536	534	536
17	518	515	513	516	518	515	516	516	517	512	516	512
18	509	506	507	507	507	506	506	506	507	506	506	506
19	524	517	518	516	524	517	517	518	524	517	518	518
20	524	523	523	523	524	523	523	523	524	522	523	523

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	588	588	585	588	588	588	588	588	588	588	588	588
2	551	543	543	542	551	542	543	543	551	543	543	543
3	528	525	527	527	527	525	527	527	527	522	521	522
4	562	562	562	562	562	562	562	562	562	562	562	562
5	515	511	511	509	515	509	509	509	515	509	509	509
6	598	587	587	581	598	584	584	584	598	584	584	584
7	540	540	540	540	540	540	537	540	540	540	540	540
8	557	551	551	549	557	551	549	551	557	546	546	546
9	553	548	550	549	551	551	548	551	550	549	550	550
10	496	495	495	495	494	494	494	494	493	492	492	490
11	568	568	568	568	568	568	568	568	568	568	568	568
12	542	542	542	542	540	540	540	540	539	539	539	539
13	558	554	554	554	558	554	554	554	558	554	554	554
14	491	491	491	491	491	491	491	491	491	491	491	491
15	508	508	501	508	508	504	505	508	508	498	508	499
16	547	544	544	544	547	543	542	543	547	542	542	542
17	518	518	518	518	518	518	518	518	517	517	517	517
18	509	506	507	507	507	506	506	506	507	506	506	506
19	524	517	518	516	524	517	517	518	524	523	524	524
20	524	521	521	521	524	520	520	520	524	520	520	520

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	588	588	585	588	588	588	588	588	588	588	588	588
2	551	543	543	542	551	542	543	543	551	543	543	543
3	528	525	525	524	527	523	521	520	527	522	521	522
4	566	566	566	565	565	565	565	565	565	565	564	565
5	515	515	515	515	515	515	514	515	515	515	512	515
6	598	587	587	581	598	584	584	584	598	582	582	582
7	540	540	540	540	540	540	537	540	540	540	537	540
8	557	548	546	548	552	546	546	546	549	546	546	546
9	553	548	550	549	551	551	548	551	550	550	550	550
10	496	495	495	495	494	494	494	494	493	493	493	493
11	568	568	568	568	568	566	564	566	568	566	566	565
12	542	542	542	542	540	540	540	540	539	539	539	539
13	558	554	554	554	558	554	554	554	558	555	555	555
14	491	491	491	491	507	499	499	491	490	490	490	488
15	508	508	501	508	508	504	505	508	508	498	508	499
16	547	544	544	544	547	543	542	543	547	542	542	542
17	518	518	518	518	518	518	518	518	517	517	517	517
18	509	506	507	507	507	507	507	507	507	507	507	507
19	524	523	524	524	524	523	523	524	522	522	522	522
20	524	521	521	521	524	520	520	520	523	520	520	520

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	595	595	594	595	594	594	593	588	594	594	592	592
2	556	549	549	549	556	546	548	546	556	546	547	546
3	533	533	532	533	533	532	525	532	532	531	531	527
4	570	564	562	564	565	564	564	563	565	564	564	564
5	517	517	517	517	517	517	517	517	515	515	515	515
6	596	588	588	592	596	584	584	586	596	581	588	587
7	547	547	547	542	545	545	541	545	545	545	545	545
8	553	553	553	553	552	552	552	552	552	548	549	550
9	551	551	551	551	551	551	551	551	550	550	550	549
10	504	500	500	500	504	500	500	500	504	500	500	498
11	575	569	569	569	575	569	569	569	575	568	567	567
12	545	545	545	545	545	545	545	545	545	545	545	545
13	560	560	560	560	560	560	560	560	560	560	560	560
14	501	497	497	497	494	494	494	494	494	492	494	494
15	503	502	500	503	503	503	498	503	503	501	501	500
16	552	545	544	546	552	547	547	543	552	546	547	548
17	538	524	534	530	532	529	531	529	532	531	531	531
18	514	514	514	514	514	514	514	514	513	512	513	513
19	523	523	523	523	522	522	522	522	522	522	522	522
20	526	526	526	526	526	526	525	526	526	526	526	526

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	595	595	594	595	594	594	593	588	594	594	592	592
2	556	548	547	547	556	546	548	546	556	546	547	546
3	533	533	533	533	532	532	532	532	532	532	532	532
4	570	564	562	564	565	564	564	563	565	564	564	564
5	517	517	517	517	517	516	517	516	515	514	513	514
6	596	588	588	592	596	584	584	586	596	590	592	590
7	547	547	547	542	545	545	541	545	545	545	545	545
8	553	548	547	549	552	548	549	550	552	548	549	550
9	557	552	553	552	550	550	550	550	550	550	550	550
10	504	500	500	500	504	500	500	500	504	501	501	501
11	575	569	569	569	575	569	569	569	575	568	567	567
12	545	545	545	545	545	544	544	544	545	544	545	544
13	560	560	560	560	560	560	560	560	560	560	560	560
14	501	497	497	497	494	494	494	494	494	492	494	494
15	503	503	503	502	503	503	498	503	498	498	498	498
16	552	545	544	546	552	547	547	543	542	542	542	542
17	538	533	538	532	532	529	531	529	539	531	531	531
18	514	514	514	514	514	514	514	514	523	512	514	509
19	523	523	523	523	522	522	522	522	522	522	522	522
20	526	526	526	526	526	526	526	526	526	526	526	526

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	595	595	594	595	594	590	590	589	594	588	589	588
2	556	548	547	547	556	554	550	552	556	554	551	552
3	533	533	533	533	532	532	532	532	532	532	532	532
4	570	564	562	564	565	564	565	565	565	565	565	565
5	517	517	517	517	517	516	517	516	515	514	513	514
6	596	596	596	594	596	596	593	587	586	586	586	586
7	547	547	547	547	545	545	545	545	547	547	544	547
8	553	548	547	549	552	548	549	550	552	548	549	550
9	557	554	552	555	550	550	550	550	550	550	550	550
10	504	501	501	501	504	501	501	501	504	501	501	501
11	575	572	569	575	575	572	574	573	575	570	575	574
12	545	544	544	544	545	544	544	544	545	544	545	544
13	560	560	560	560	560	560	560	560	560	560	560	560
14	501	493	491	493	494	491	491	491	494	491	491	491
15	501	501	501	501	501	501	498	501	500	500	500	500
16	545	545	544	545	545	545	545	543	542	542	542	542
17	539	533	539	532	539	529	531	529	539	532	531	531
18	523	516	516	514	523	515	515	515	523	512	514	509
19	523	523	523	523	522	522	522	522	522	522	522	522
20	526	526	526	526	526	526	526	526	526	526	526	526

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	620	614	616	606	621	605	604	616	621	605	597	606
2	604	566	556	574	604	559	569	557	604	559	553	550
3	593	551	552	567	593	553	548	557	593	541	539	550
4	607	577	578	592	603	574	571	588	602	574	588	583
5	574	532	541	540	574	525	525	537	572	531	528	519
6	627	611	605	607	627	607	601	604	622	603	592	593
7	561	569	560	578	561	552	553	560	561	552	559	549
8	601	559	571	575	601	559	568	568	601	559	561	554
9	574	585	581	571	574	584	562	573	574	566	566	562
10	580	519	525	532	580	523	517	527	580	512	515	524
11	627	598	581	592	627	585	594	585	627	579	576	581
12	592	583	582	587	592	568	564	565	588	561	567	554
13	603	584	586	581	603	575	574	583	603	568	578	573
14	549	540	528	533	548	527	508	514	548	513	521	513
15	605	528	537	527	589	520	528	519	589	509	508	517
16	602	583	573	577	585	557	597	577	585	557	557	554
17	614	542	535	547	612	542	538	546	612	537	541	534
18	597	541	542	546	597	523	530	539	597	526	525	528
19	587	561	561	553	586	541	547	537	580	542	544	540
20	572	550	543	545	572	540	549	536	565	540	536	542

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	625	614	616	606	621	611	613	600	621	603	601	594
2	604	566	556	574	588	559	569	557	588	567	562	554
3	593	551	552	567	593	553	548	557	593	541	539	550
4	607	577	578	592	603	579	576	587	602	575	582	578
5	574	542	569	559	574	550	528	529	572	531	528	519
6	627	613	606	618	627	606	603	608	622	599	601	601
7	561	568	560	578	561	569	561	552	561	563	553	557
8	601	559	571	575	601	559	568	568	601	559	561	554
9	574	574	587	575	574	574	568	573	574	569	563	571
10	561	546	551	555	561	538	526	521	561	502	509	505
11	627	598	581	592	627	581	578	581	627	579	579	579
12	592	598	587	583	615	573	568	566	615	561	567	554
13	603	584	586	581	603	575	574	583	603	566	579	568
14	549	519	535	538	548	519	525	524	548	517	502	518
15	605	528	537	527	589	520	528	519	589	509	508	517
16	602	583	573	577	585	557	597	577	585	557	557	554
17	614	542	535	547	612	542	538	546	612	537	541	534
18	597	541	542	546	597	515	535	527	597	516	528	520
19	587	551	557	558	586	541	547	537	580	542	544	540
20	572	550	543	545	572	540	549	536	565	540	536	542

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	625	621	609	615	621	611	613	600	621	603	601	594
2	588	586	577	561	588	574	552	564	588	567	562	554
3	593	551	552	567	593	546	548	549	593	544	552	546
4	607	589	590	595	635	579	576	587	635	575	582	578
5	574	542	569	559	574	550	528	529	572	530	533	531
6	627	613	606	618	627	606	603	608	622	599	601	601
7	561	589	575	567	561	569	561	552	561	563	553	557
8	601	577	569	577	601	562	560	584	601	561	568	565
9	574	574	587	575	574	574	568	573	574	569	563	571
10	561	546	551	555	561	538	526	521	561	502	509	505
11	627	590	608	597	627	581	578	581	619	579	579	579
12	615	598	587	583	615	573	568	566	615	561	567	554
13	603	602	574	584	603	567	571	578	603	566	579	568
14	549	519	535	538	548	519	525	524	548	517	502	518
15	605	530	526	538	589	519	515	515	589	514	533	518
16	602	586	566	585	585	578	566	557	585	559	560	556
17	614	582	564	541	612	549	538	537	612	530	544	539
18	597	553	543	546	597	515	535	527	597	516	528	520
19	587	551	557	558	586	541	547	537	580	541	537	536
20	572	550	543	545	572	542	548	540	565	535	529	540

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	609	615	604	603	609	601	602	612	608	598	600	596
2	576	576	568	572	576	567	565	550	576	563	554	554
3	551	558	556	543	551	544	541	543	551	541	541	543
4	617	579	588	601	615	577	591	578	615	575	570	574
5	542	540	541	547	574	530	538	540	572	528	524	530
6	606	607	605	600	605	601	599	600	605	601	601	598
7	555	563	562	565	555	563	562	559	555	554	558	560
8	572	571	571	570	572	564	569	566	572	558	558	557
9	573	584	581	571	571	565	566	567	571	562	557	563
10	554	518	532	520	552	515	510	505	552	504	519	518
11	600	584	592	591	599	587	581	581	599	574	574	583
12	579	562	565	571	579	554	558	563	579	551	562	564
13	588	581	579	584	588	570	577	572	587	572	570	572
14	562	544	519	521	560	512	525	528	558	508	510	511
15	537	533	527	533	537	514	526	519	535	522	526	522
16	602	573	568	582	580	569	556	552	578	560	561	552
17	565	554	540	537	565	542	537	532	565	538	524	542
18	554	533	528	525	554	525	520	519	554	525	522	521
19	553	532	535	534	551	532	535	535	550	532	533	532
20	542	549	547	536	549	543	536	535	549	536	528	534

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	609	600	601	598	609	599	601	600	608	598	600	596
2	576	560	564	565	576	555	561	556	576	544	548	547
3	551	558	556	543	576	556	554	551	576	544	539	540
4	617	597	596	603	615	578	581	591	615	572	570	574
5	577	540	541	547	574	530	538	540	572	528	524	530
6	606	607	605	600	605	601	599	600	605	601	601	598
7	555	555	561	561	555	557	551	564	555	554	558	560
8	572	571	571	570	572	565	569	558	572	562	558	561
9	573	563	575	562	574	565	566	567	574	562	557	563
10	554	515	528	516	552	515	510	505	552	504	519	518
11	600	588	590	595	599	579	579	580	599	574	574	583
12	579	562	565	571	579	554	558	563	579	551	562	564
13	588	581	579	584	588	577	581	572	587	577	567	580
14	562	544	519	521	560	512	525	528	558	508	510	511
15	537	533	527	533	537	523	519	541	535	523	524	540
16	580	573	568	582	580	561	571	559	578	556	550	545
17	565	554	540	537	565	533	545	547	565	533	538	534
18	554	526	537	542	554	525	527	534	554	525	522	521
19	551	532	535	534	551	532	535	535	550	532	533	532
20	549	549	547	536	549	543	536	535	549	535	531	528

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	609	600	601	598	609	599	601	600	608	598	600	596
2	576	560	564	565	593	555	561	556	593	544	548	547
3	578	557	544	553	576	556	554	551	576	544	539	540
4	617	597	596	603	615	578	581	591	615	572	570	574
5	577	535	537	559	574	521	523	518	572	525	521	525
6	606	607	605	600	605	593	601	597	605	594	592	594
7	555	555	561	561	555	557	551	564	555	564	554	557
8	572	562	572	569	572	565	569	558	572	562	558	561
9	577	563	575	562	574	565	566	567	574	566	569	562
10	554	515	528	516	552	515	510	505	552	515	515	513
11	600	588	590	595	599	579	579	580	599	574	574	583
12	579	562	565	571	579	552	560	561	579	554	562	561
13	588	577	581	584	588	577	581	572	587	577	567	580
14	562	544	519	521	560	512	525	528	558	508	504	505
15	537	528	542	542	537	523	519	541	554	523	524	540
16	580	574	573	569	584	561	571	559	584	556	550	545
17	565	543	532	539	551	533	545	547	549	533	538	534
18	554	526	537	542	548	525	527	534	541	525	522	521
19	551	550	546	542	551	538	536	532	550	530	539	540
20	549	535	544	543	549	540	531	534	549	535	531	528

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =2											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	126	126	126	126	126	126	126	126	126	126	126	126
2	127	125	125	125	124	125	125	125	124	120	120	120
3	131	127	127	127	131	127	127	127	131	127	127	127
4	127	122	122	122	123	119	119	119	120	119	119	119
5	129	129	129	129	129	128	128	128	129	130	130	130
6	124	124	124	124	124	122	122	122	124	120	120	120
7	104	100	100	100	104	104	104	104	104	104	104	104
8	137	135	135	135	135	130	130	130	135	132	132	132
9	143	139	139	139	127	132	132	132	127	134	134	134
10	138	136	136	136	134	130	131	131	134	132	132	132
11	131	129	129	129	131	130	130	130	131	125	125	125
12	133	128	128	128	130	128	128	128	130	128	128	128
13	136	136	136	136	133	131	131	131	133	131	131	131
14	111	108	108	108	99	104	104	104	99	104	104	104
15	140	139	139	139	140	139	139	139	140	139	139	139
16	143	139	139	139	138	140	140	140	138	140	140	140
17	110	107	107	107	110	111	111	111	110	111	111	111
18	146	145	145	144	141	138	138	138	141	142	142	142
19	135	136	136	136	135	129	129	129	135	133	133	133
20	151	145	145	145	147	146	146	146	147	145	145	145

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =4											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	126	126	126	126	126	126	126	126	126	126	126	126
2	127	125	125	125	124	122	122	122	124	120	120	120
3	131	127	127	127	131	127	127	127	131	127	127	127
4	127	118	125	125	123	124	124	124	123	120	120	120
5	129	131	131	131	129	127	127	127	129	130	130	130
6	124	120	120	120	124	120	120	120	124	124	124	124
7	104	104	104	104	104	104	104	101	104	100	100	100
8	137	130	130	130	135	130	130	130	135	129	129	129
9	143	130	130	130	127	130	130	130	127	130	130	130
10	138	132	132	132	134	132	132	132	134	132	132	132
11	131	139	139	139	131	130	130	130	131	125	125	125
12	133	132	132	132	130	133	133	133	129	133	133	133
13	136	131	131	131	133	131	131	131	133	128	128	128
14	111	104	104	104	99	104	104	104	99	104	104	104
15	140	139	139	139	140	139	139	139	140	139	137	137
16	143	140	140	140	138	140	140	140	138	140	140	140
17	110	112	112	112	110	111	111	111	110	111	111	111
18	146	139	139	139	141	138	138	138	141	142	142	142
19	135	129	129	129	135	129	129	129	135	129	129	129
20	151	145	145	145	147	145	145	145	147	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =6											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	126	126	126	126	126	126	126	126	126	126	126	126
2	127	125	125	125	127	122	122	122	127	120	120	120
3	131	127	127	127	129	127	127	127	129	127	127	127
4	126	123	123	123	126	120	120	120	126	120	120	120
5	132	131	131	131	130	131	131	131	130	128	128	128
6	124	120	120	120	124	120	120	120	124	124	124	124
7	104	100	100	100	104	100	100	100	104	100	100	100
8	130	132	132	132	130	132	132	132	130	132	132	132
9	140	130	130	130	133	130	130	130	133	130	130	130
10	138	132	132	132	138	132	132	132	138	132	132	132
11	131	139	139	139	131	135	135	135	131	135	135	135
12	133	133	133	133	131	133	133	133	131	133	133	133
13	136	133	133	133	135	133	133	133	135	131	131	131
14	107	104	104	104	105	104	104	104	105	104	104	104
15	140	138	138	138	140	137	137	137	140	138	138	138
16	143	140	140	140	139	140	140	140	139	141	141	141
17	110	112	112	112	110	111	111	111	110	111	111	111
18	147	142	142	142	141	142	142	142	141	142	142	142
19	135	129	129	129	132	129	129	129	132	129	129	129
20	148	145	145	145	148	146	146	146	148	145	145	145

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =2											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	134	134	134	134	132	134	134	134	132	134	134	134
2	127	125	125	125	127	125	125	125	127	125	125	125
3	135	132	132	132	135	132	132	132	134	125	125	125
4	126	121	121	121	121	113	113	113	121	113	113	113
5	131	136	136	136	131	134	135	135	131	129	129	129
6	126	127	127	127	126	124	124	124	126	124	124	124
7	107	100	100	100	102	109	109	109	102	109	109	109
8	138	134	134	134	138	132	132	132	135	132	132	132
9	134	135	135	135	134	135	135	135	134	135	135	135
10	137	137	137	137	137	137	137	137	137	139	139	139
11	142	128	128	128	135	132	132	132	135	131	131	131
12	133	128	128	128	130	128	128	128	130	128	128	128
13	139	138	138	138	137	134	134	134	137	134	134	134
14	114	109	110	110	111	104	104	104	108	101	101	101
15	139	136	136	136	139	136	136	136	139	136	136	136
16	141	142	142	142	141	139	139	139	141	140	140	140
17	113	115	115	115	111	112	112	112	111	111	111	111
18	144	140	140	140	144	140	140	140	144	140	140	140
19	136	132	132	132	134	132	132	132	134	132	132	132
20	149	145	145	145	148	145	145	145	146	145	145	145

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =4											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	134	134	134	134	132	133	133	133	132	132	132	132
2	127	124	124	124	127	124	124	124	127	124	124	124
3	135	132	132	132	133	132	132	132	133	131	131	131
4	126	121	121	121	121	113	113	113	121	113	113	113
5	131	131	131	131	131	131	131	131	131	131	131	131
6	126	124	124	124	126	126	126	126	124	124	124	124
7	107	109	109	109	102	109	109	109	102	109	109	109
8	138	138	138	138	137	137	137	137	134	135	135	135
9	134	135	135	135	134	132	132	132	134	131	131	131
10	137	143	143	143	137	137	137	137	137	139	139	139
11	142	137	137	137	138	137	137	137	138	134	134	134
12	133	128	128	128	130	128	128	128	130	128	128	128
13	139	138	138	138	137	134	134	134	135	134	134	134
14	114	105	105	105	111	101	101	101	111	101	101	101
15	139	136	136	136	139	136	136	136	139	136	136	136
16	141	142	142	142	141	139	139	139	141	140	140	140
17	113	120	120	120	111	110	110	110	111	111	111	111
18	144	143	143	143	144	142	142	142	144	140	140	140
19	136	134	134	134	134	134	134	134	134	134	134	134
20	149	147	147	147	148	145	145	145	145	145	145	145

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =6											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	134	134	134	134	134	133	133	133	134	133	133	133
2	127	124	124	124	127	125	125	125	127	123	123	123
3	135	133	133	133	133	131	131	131	133	131	131	131
4	125	121	121	121	117	113	113	113	117	113	113	113
5	129	131	131	131	129	131	131	131	129	131	131	131
6	126	125	125	125	126	123	123	123	123	125	125	125
7	106	109	109	109	104	109	109	109	104	109	109	109
8	137	138	138	138	136	137	137	137	134	136	136	136
9	133	131	131	131	131	131	131	131	131	131	131	131
10	139	143	143	143	137	137	137	137	136	139	139	139
11	140	137	137	137	134	134	134	134	134	130	130	130
12	132	128	128	128	132	128	128	128	132	128	128	128
13	138	138	138	138	138	133	133	133	136	134	134	134
14	114	105	105	105	108	101	101	101	108	101	101	101
15	139	136	136	136	139	136	136	136	139	136	136	136
16	141	142	142	142	141	139	139	139	141	140	140	140
17	114	120	120	120	114	110	110	110	112	110	113	113
18	142	143	143	143	142	142	142	142	142	140	140	140
19	133	134	134	134	133	132	132	132	133	135	135	135
20	150	147	147	147	146	145	145	145	146	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =2											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	138	135	135	135	136	134	134	134	136	132	132	132
2	125	125	125	125	125	123	123	123	125	122	122	122
3	133	133	133	133	133	133	133	133	133	130	130	130
4	125	125	125	125	125	116	116	116	125	116	116	116
5	135	135	135	135	132	132	132	132	132	130	130	130
6	129	129	129	129	126	126	126	126	126	119	119	119
7	111	110	110	110	107	105	105	105	107	105	105	105
8	135	135	135	135	129	129	129	129	129	129	129	129
9	136	133	133	133	136	132	132	132	136	132	132	132
10	138	136	136	136	137	136	136	136	137	135	135	135
11	146	132	132	132	130	130	130	130	130	130	130	130
12	134	132	132	132	132	128	128	128	131	128	128	128
13	139	132	132	132	139	139	139	139	138	129	129	129
14	113	107	107	107	107	105	105	105	107	100	100	100
15	142	142	142	142	142	141	141	141	138	138	138	138
16	141	141	141	141	138	138	138	138	138	138	138	138
17	114	114	114	114	114	113	113	113	113	112	112	112
18	145	142	142	142	141	141	141	141	141	141	141	141
19	135	135	135	135	135	135	135	135	135	135	135	135
20	149	148	148	148	149	146	146	146	146	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =4											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	138	133	133	133	138	132	132	132	138	132	132	132
2	125	125	125	125	125	123	123	123	125	122	122	122
3	133	133	133	133	133	132	132	132	132	132	132	132
4	125	116	116	116	125	116	116	116	125	116	116	116
5	135	135	135	135	132	132	132	132	130	130	130	130
6	129	126	126	126	128	126	126	126	128	127	127	127
7	111	110	110	110	107	105	105	105	105	105	105	105
8	135	133	133	133	131	131	131	131	131	130	130	130
9	136	135	135	135	136	134	134	134	136	134	134	134
10	138	136	136	136	138	136	136	136	138	136	136	136
11	146	132	132	132	133	132	132	132	133	132	132	132
12	134	132	132	132	129	128	128	128	129	128	128	128
13	139	132	132	132	138	137	137	137	138	129	129	129
14	113	107	107	107	107	105	105	105	107	100	100	100
15	142	138	138	138	142	142	142	142	142	142	142	142
16	141	141	141	141	140	140	140	140	140	140	140	140
17	114	114	114	114	114	113	113	113	112	112	112	112
18	145	145	145	145	144	144	144	144	144	142	142	142
19	135	135	135	135	135	135	135	135	135	135	135	135
20	149	148	148	148	149	146	146	146	146	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =6											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	139	133	133	133	135	132	132	132	135	132	132	132
2	129	129	129	129	129	123	123	123	129	122	122	122
3	136	135	135	135	134	132	132	132	133	132	132	132
4	132	116	116	116	123	117	117	117	123	121	121	121
5	133	133	133	133	133	131	131	131	133	131	131	131
6	132	126	126	126	123	123	123	123	123	123	123	123
7	108	108	108	108	108	105	105	105	108	105	108	108
8	136	133	133	133	135	133	133	133	135	133	133	133
9	138	135	135	135	138	134	134	134	133	133	133	133
10	141	136	136	136	140	136	136	136	140	136	136	136
11	145	132	132	132	137	132	132	132	137	132	132	132
12	132	132	132	132	128	128	128	128	128	124	124	124
13	137	132	132	132	137	137	137	137	137	129	129	129
14	107	107	107	107	107	105	105	105	107	100	100	100
15	140	138	138	138	140	140	140	140	140	140	140	140
16	145	142	142	142	138	138	138	138	138	138	138	138
17	115	115	115	115	115	113	113	113	113	112	112	112
18	145	145	145	145	141	141	141	141	141	141	141	141
19	139	139	139	139	136	136	136	136	133	133	133	133
20	148	148	148	148	148	146	146	146	145	145	145	145

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =2											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	140	137	137	137	140	137	137	137	140	134	134	134
2	127	127	127	127	127	124	124	124	127	124	124	124
3	137	134	134	134	136	134	134	134	134	134	134	134
4	118	118	118	118	118	118	118	118	118	118	118	118
5	135	131	131	131	133	131	131	131	130	130	130	130
6	131	127	127	127	128	127	127	127	128	121	121	121
7	106	106	106	106	106	106	106	106	106	106	106	106
8	145	135	135	135	136	129	129	129	136	129	129	129
9	134	134	134	134	134	132	132	132	134	132	132	132
10	137	137	137	137	137	137	137	137	134	133	133	133
11	133	133	133	133	133	133	133	133	133	133	133	133
12	141	130	130	130	133	131	131	131	132	130	130	130
13	135	135	135	135	135	135	135	135	135	134	134	134
14	116	110	110	110	111	109	109	109	108	108	108	108
15	143	143	143	143	142	142	142	142	140	140	140	140
16	140	140	140	140	140	140	140	140	140	140	139	139
17	115	112	112	112	113	113	113	113	113	111	111	111
18	151	142	142	142	145	143	143	143	141	141	141	141
19	138	135	135	135	137	135	135	135	135	132	132	132
20	147	147	147	147	147	146	146	146	147	147	147	147

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =4											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	140	137	137	137	140	137	137	137	140	134	134	134
2	127	127	127	127	127	124	124	124	127	124	124	124
3	137	130	130	130	133	133	133	133	133	133	133	133
4	118	118	118	118	118	118	118	118	118	118	118	118
5	135	131	131	131	126	126	126	126	126	126	126	126
6	131	129	129	129	131	125	125	125	130	127	127	127
7	106	106	106	106	106	106	106	106	105	105	105	105
8	145	137	137	137	138	135	135	135	133	133	133	133
9	134	134	134	134	134	131	131	131	134	131	131	131
10	137	137	137	137	137	137	137	137	133	133	133	133
11	133	133	133	133	133	133	133	133	133	133	133	133
12	141	131	131	131	134	127	127	127	134	127	127	127
13	135	134	134	134	135	135	135	135	135	134	134	134
14	116	110	110	110	111	109	109	109	107	107	107	107
15	143	143	143	143	143	141	141	141	141	138	138	138
16	140	138	138	138	140	139	139	139	139	137	137	137
17	115	112	112	112	114	113	113	113	114	111	111	111
18	151	142	142	142	143	142	142	142	141	141	141	141
19	138	135	135	135	138	135	135	135	134	134	134	134
20	147	146	146	146	147	146	146	146	147	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 20,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =6											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	141	137	137	137	141	139	139	139	140	135	135	135
2	126	126	126	126	126	121	121	121	126	124	124	124
3	135	130	130	130	135	134	134	134	135	134	134	134
4	121	121	121	121	121	118	118	118	120	118	118	118
5	137	131	131	131	132	131	131	131	132	130	130	130
6	130	129	129	129	130	125	125	125	130	127	127	127
7	106	106	106	106	106	106	106	106	106	106	106	106
8	141	135	135	135	141	135	135	135	135	134	134	134
9	138	136	136	136	135	131	131	131	135	131	131	131
10	136	136	136	136	136	136	136	136	136	133	133	133
11	134	134	134	134	134	134	134	131	134	132	132	132
12	135	131	131	131	134	127	127	127	127	127	127	127
13	134	134	134	134	134	134	134	134	134	134	134	134
14	117	108	108	108	114	108	108	108	107	105	105	105
15	144	144	144	144	144	141	141	141	141	141	141	141
16	142	142	142	142	142	139	139	139	138	137	137	137
17	113	112	112	112	113	113	113	113	113	111	111	111
18	151	146	146	146	148	143	143	143	144	144	144	144
19	138	138	138	138	134	134	134	134	133	132	132	132
20	146	146	146	146	146	146	146	146	146	146	146	146

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	297	292	292	292	295	290	290	290	295	286	286	286
2	287	287	287	287	287	280	280	280	287	288	290	290
3	300	300	300	300	300	297	297	297	300	297	297	297
4	285	284	284	284	285	282	282	282	285	283	283	283
5	306	306	306	306	306	306	306	306	306	306	306	306
6	259	259	259	259	259	252	252	252	259	265	265	265
7	284	279	279	279	284	279	279	279	284	279	279	279
8	299	297	297	297	299	293	293	293	299	293	293	293
9	285	285	285	285	285	290	290	290	285	276	276	276
10	281	269	269	269	274	263	263	263	274	263	263	263
11	326	313	313	313	324	321	321	321	324	314	314	314
12	265	263	263	263	265	263	263	263	265	263	263	263
13	291	290	290	290	289	287	287	287	289	287	287	287
14	267	267	267	267	267	262	262	262	267	262	262	262
15	272	272	272	272	272	275	275	275	272	275	275	275
16	280	280	280	280	280	286	286	286	280	284	284	287
17	273	273	273	273	273	273	273	273	273	270	270	270
18	275	267	267	267	275	270	270	270	275	267	267	267
19	282	282	282	282	282	275	278	278	282	272	272	272
20	282	281	281	281	282	284	284	284	282	284	284	284

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	297	288	288	288	295	286	286	286	295	292	292	292
2	287	283	283	283	287	283	283	283	287	290	290	290
3	300	297	297	297	300	297	297	297	300	297	297	297
4	285	282	282	282	285	283	283	283	285	282	282	282
5	306	306	306	306	306	306	306	306	306	306	306	306
6	259	263	263	262	259	260	260	260	259	260	260	260
7	284	277	277	277	284	279	279	279	284	279	279	279
8	299	294	294	297	299	295	295	295	299	295	295	295
9	285	276	276	276	285	276	276	276	285	290	290	290
10	281	261	261	261	274	263	263	263	274	263	263	263
11	326	314	314	314	324	314	314	314	324	315	315	315
12	265	263	260	260	265	258	258	258	265	264	264	264
13	291	288	288	288	289	286	286	286	289	286	286	286
14	267	269	269	269	267	269	269	269	267	262	262	262
15	272	279	279	279	272	275	275	275	272	275	275	275
16	280	281	281	281	280	281	281	281	280	281	281	281
17	273	273	273	273	273	270	270	270	273	273	273	273
18	275	267	267	267	275	267	267	267	275	274	274	274
19	282	278	278	278	282	272	272	272	282	272	272	272
20	282	282	282	282	282	284	284	284	282	284	284	284

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	297	288	288	288	295	286	286	286	295	292	292	292
2	287	283	283	283	287	283	283	283	287	290	290	290
3	300	297	297	297	300	301	301	301	300	301	301	301
4	285	283	283	283	285	282	282	282	285	283	283	283
5	306	306	306	306	306	306	306	306	306	308	308	308
6	259	263	263	263	259	260	260	260	259	260	260	260
7	284	277	277	277	284	279	279	279	284	279	277	277
8	299	295	295	295	299	295	295	295	299	295	295	295
9	285	276	276	276	285	276	276	276	285	286	286	286
10	281	261	261	261	274	263	263	263	274	263	263	263
11	326	319	319	319	324	316	316	316	324	319	319	319
12	265	264	264	264	265	258	258	258	265	264	264	264
13	291	286	286	286	289	286	286	286	289	285	285	285
14	267	268	268	268	267	265	265	265	267	265	265	265
15	272	279	279	279	272	275	275	275	272	276	276	276
16	280	281	281	281	280	281	281	281	280	281	281	281
17	273	270	270	270	273	273	273	273	273	270	270	270
18	275	272	272	272	275	272	272	272	275	272	272	272
19	282	278	278	278	282	272	272	272	282	272	272	272
20	282	282	282	282	282	278	278	278	282	278	278	278

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	293	289	289	289	293	288	288	288	293	288	288	288
2	292	297	297	297	292	297	297	297	292	297	297	297
3	296	304	304	304	296	303	303	303	296	303	303	303
4	290	287	287	287	286	285	286	286	286	288	288	288
5	313	302	302	302	313	313	313	313	313	302	302	302
6	258	258	258	258	258	258	258	258	258	258	258	258
7	280	276	276	276	280	276	276	276	280	276	276	276
8	306	308	308	308	305	298	298	298	305	300	300	300
9	291	293	293	293	291	293	293	293	291	293	293	293
10	269	269	269	269	269	269	269	269	269	269	269	269
11	327	320	320	320	322	319	319	319	322	319	319	319
12	272	266	266	266	272	266	266	266	269	261	261	261
13	294	297	297	297	294	295	295	295	294	295	295	295
14	276	275	275	275	276	266	266	266	273	273	273	273
15	278	281	281	281	278	281	281	281	278	281	274	274
16	292	281	281	281	292	281	281	281	291	281	281	281
17	270	269	270	270	270	268	268	268	270	268	268	268
18	280	277	277	277	280	276	276	276	280	276	276	276
19	287	281	281	281	287	281	281	281	286	281	281	281
20	291	290	290	290	291	281	281	281	291	285	285	285

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	293	288	288	288	293	286	286	286	293	286	286	286
2	292	297	297	297	292	292	292	292	292	293	293	293
3	296	302	302	302	296	303	303	303	296	303	303	303
4	290	288	288	288	286	288	288	288	286	288	288	288
5	313	313	313	313	313	313	313	313	313	302	302	302
6	258	259	259	259	258	259	259	259	258	259	259	259
7	280	276	276	276	280	276	276	276	280	276	276	276
8	306	300	300	300	305	300	300	300	305	300	300	300
9	291	293	293	293	291	293	293	293	291	293	293	293
10	269	269	269	269	269	269	269	269	269	269	269	269
11	327	320	320	320	322	319	319	319	322	319	319	319
12	272	260	260	260	272	264	264	264	269	261	261	261
13	294	295	295	295	294	295	295	295	294	295	295	295
14	276	266	266	266	276	266	266	266	273	273	273	273
15	278	277	277	277	278	275	275	275	278	272	272	272
16	292	281	281	281	292	281	281	281	291	281	281	281
17	270	270	270	270	270	268	268	268	270	268	268	268
18	280	277	277	277	280	276	276	276	280	276	276	276
19	287	277	277	281	287	281	281	281	286	281	281	281
20	291	290	290	290	291	281	281	281	291	285	285	285

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	293	288	288	288	293	289	289	289	293	286	286	286
2	292	297	298	298	292	293	293	293	292	293	293	293
3	296	302	302	302	296	303	303	303	296	303	303	303
4	290	288	288	288	286	288	288	288	286	287	287	287
5	313	313	313	313	313	313	313	313	313	302	302	302
6	258	259	259	259	258	259	260	260	258	260	260	260
7	280	276	276	276	280	276	276	276	280	276	276	276
8	306	300	300	300	305	300	300	300	305	300	300	300
9	291	292	292	292	291	286	286	286	291	286	286	286
10	269	269	269	269	269	269	269	269	269	269	269	269
11	327	319	319	319	322	319	319	319	322	319	319	319
12	272	260	260	264	272	267	267	267	269	265	265	265
13	294	295	296	296	294	286	286	286	294	282	282	282
14	276	266	266	266	276	266	266	266	273	272	272	272
15	278	276	276	276	278	275	275	275	278	272	272	272
16	292	281	281	281	292	287	287	287	291	279	279	279
17	270	270	270	270	270	268	268	268	270	268	268	268
18	280	277	277	277	280	276	276	276	280	275	275	275
19	287	282	282	282	287	281	281	281	286	281	281	281
20	291	290	290	290	291	281	281	281	291	285	285	285

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	310	299	299	299	302	287	287	287	296	296	296	296
2	308	299	299	299	298	288	288	288	293	288	288	288
3	315	307	307	307	313	300	300	300	309	300	300	300
4	302	289	289	289	293	289	289	289	289	288	288	288
5	329	320	320	320	316	316	315	315	316	307	307	307
6	285	271	271	271	274	262	262	262	264	262	262	262
7	291	291	291	291	291	279	279	279	287	283	283	275
8	311	311	311	311	305	305	305	305	305	305	305	305
9	296	296	296	296	293	293	293	293	293	293	293	293
10	284	272	272	272	272	272	272	272	271	271	271	271
11	328	327	327	327	328	321	321	321	326	317	317	317
12	279	273	273	273	271	268	268	268	271	270	270	270
13	307	302	302	302	301	291	291	291	300	291	291	291
14	281	275	275	275	278	273	273	273	278	266	266	266
15	282	282	282	282	282	278	278	278	282	276	276	276
16	294	294	294	294	293	288	288	288	291	287	287	287
17	289	272	272	272	283	280	280	280	283	279	279	279
18	282	282	282	282	282	271	271	271	282	275	275	275

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	310	307	307	307	302	287	287	287	296	296	296	296
2	308	299	299	299	298	288	288	288	293	288	288	288
3	315	306	306	306	313	300	300	300	309	300	300	300
4	302	290	290	290	293	289	292	292	289	287	287	287
5	329	310	310	310	316	316	316	316	316	307	307	307
6	285	271	271	271	274	265	265	265	264	264	264	264
7	291	291	291	291	291	283	283	283	287	285	285	285
8	311	311	311	311	305	305	305	305	305	305	305	305
9	296	289	289	289	293	284	284	284	293	280	280	280
10	284	272	268	268	272	272	272	272	271	270	270	270
11	328	327	327	327	328	321	321	321	326	317	317	317
12	279	273	273	273	271	268	268	268	271	270	270	270
13	307	296	296	296	301	299	299	299	300	291	291	291
14	281	271	271	271	278	275	275	275	278	268	268	268
15	282	282	282	282	282	278	278	278	282	276	276	276
16	294	294	294	294	293	288	288	288	291	288	288	288
17	289	273	273	273	283	276	276	276	283	276	276	276
18	282	282	282	282	282	275	275	275	282	271	271	271
19	290	289	289	289	290	290	290	290	290	286	286	286
20	299	299	299	299	299	286	286	286	294	283	283	283

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	310	310	310	310	302	294	294	294	296	289	289	289
2	308	299	299	299	298	288	288	288	293	288	288	288
3	315	306	306	306	313	300	300	300	309	300	300	300
4	302	288	288	288	293	288	288	288	289	287	287	287
5	329	310	310	310	316	316	316	316	316	307	307	307
6	285	271	271	271	274	265	265	265	264	264	264	264
7	291	291	291	291	291	283	283	283	287	285	285	285
8	311	311	311	311	305	305	305	305	305	305	305	305
9	296	289	289	289	293	284	284	284	293	280	280	280
10	284	269	269	269	272	270	270	270	271	270	270	270
11	328	327	327	327	328	321	321	321	326	317	317	317
12	279	273	273	273	271	268	268	268	271	270	270	270
13	307	296	296	296	301	299	299	299	300	291	291	291
14	281	275	275	275	278	275	275	275	278	268	268	268
15	282	282	282	282	282	276	276	276	282	278	278	278
16	294	294	294	294	293	288	288	288	291	288	288	288
17	289	283	283	283	283	276	276	276	283	276	276	276
18	282	282	282	282	282	275	275	275	282	271	271	271
19	290	290	290	290	290	290	290	290	290	290	290	290
20	299	299	299	299	299	286	286	286	294	283	283	283

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	310	297	297	297	302	292	292	292	301	286	286	286
2	297	289	289	289	297	282	290	290	294	294	294	294
3	312	312	312	312	312	309	309	309	305	305	305	305
4	290	290	290	290	290	287	287	287	287	286	286	286
5	318	307	307	307	314	306	306	306	314	306	306	306
6	274	261	261	261	266	262	262	262	266	265	265	265
7	286	277	277	277	285	285	285	285	285	285	285	285
8	312	312	312	312	305	305	305	305	304	304	304	304
9	295	294	294	294	295	289	289	289	295	288	288	288
10	280	265	265	265	267	267	267	267	267	265	265	265
11	330	326	326	326	327	321	321	321	327	315	315	315
12	276	276	276	276	276	266	266	266	275	268	268	268
13	298	298	298	298	292	292	292	292	292	292	292	292
14	277	275	275	275	273	273	273	273	273	270	270	270
15	288	283	283	283	281	275	275	275	281	275	275	275
16	300	297	295	295	290	290	290	290	290	290	290	290
17	286	275	275	275	279	275	275	275	279	279	279	279
18	281	281	281	281	281	271	271	271	281	271	271	271
19	297	291	291	291	294	291	291	291	289	288	288	288
20	303	293	293	293	291	289	289	289	291	285	285	285

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	310	310	310	310	302	292	292	292	301	286	286	286
2	297	297	297	297	297	297	297	297	294	294	294	294
3	312	312	312	312	312	309	309	309	305	305	305	305
4	290	290	290	290	290	287	287	287	287	286	286	286
5	318	318	318	318	314	312	312	312	314	309	309	309
6	274	269	269	269	266	266	266	266	266	265	265	265
7	286	277	277	277	285	285	285	285	285	285	285	285
8	312	312	312	312	305	305	305	305	304	301	301	301
9	295	294	294	294	295	289	289	289	295	288	288	287
10	280	270	270	270	267	265	265	265	267	265	265	265
11	330	328	328	321	327	321	321	321	327	320	320	320
12	276	272	272	272	276	273	273	273	275	273	273	273
13	298	298	298	298	292	291	291	291	292	292	292	292
14	277	273	273	273	273	269	269	269	273	269	269	269
15	288	283	283	283	281	275	275	275	281	275	275	275
16	300	297	297	297	290	290	290	290	290	290	290	290
17	286	279	279	279	279	275	275	275	279	279	279	278
18	281	281	281	281	281	275	275	275	281	275	275	275
19	297	291	291	291	294	291	291	291	289	288	288	288
20	303	293	293	294	291	289	289	289	291	288	288	288

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	310	310	310	310	302	292	292	292	301	286	286	286
2	297	297	297	297	297	297	297	297	294	294	294	294
3	312	310	310	310	312	312	312	312	305	304	304	304
4	290	290	290	290	290	287	287	290	287	286	286	286
5	318	313	313	313	314	309	309	309	314	314	314	314
6	274	269	269	269	266	266	266	266	266	265	265	265
7	286	277	283	283	285	284	284	284	285	284	284	284
8	312	308	308	308	305	305	305	305	304	303	303	303
9	295	288	288	288	295	288	288	288	295	279	279	279
10	280	270	270	270	267	262	267	267	267	266	266	266
11	330	323	323	323	327	319	319	319	327	319	319	319
12	276	275	275	275	276	273	273	273	275	273	273	273
13	298	298	298	298	292	288	288	288	292	292	292	292
14	277	274	274	274	273	269	269	269	273	269	269	269
15	288	283	283	283	281	275	275	275	281	275	275	275
16	300	297	297	297	290	290	290	290	290	290	290	290
17	286	275	275	275	279	274	274	274	279	279	279	279
18	281	281	281	281	281	281	281	281	281	273	273	273
19	297	291	291	291	294	289	289	289	289	287	287	287
20	303	291	291	291	291	285	285	285	291	288	288	288

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	599	591	591	591	596	591	591	591	596	589	589	589
2	551	549	549	549	551	543	543	543	551	546	546	546
3	533	528	528	528	533	529	529	529	533	525	525	525
4	571	562	562	562	571	561	561	561	571	562	562	562
5	521	519	519	519	521	513	513	513	521	513	513	513
6	590	590	590	590	590	589	589	589	590	589	589	589
7	548	542	542	542	548	542	542	542	547	541	542	542
8	556	554	554	554	556	547	547	547	556	545	545	545
9	556	552	552	552	556	553	553	553	556	552	552	552
10	495	495	495	495	495	496	496	496	495	496	496	496
11	570	570	570	570	570	568	568	568	570	568	568	568
12	545	544	544	544	545	543	543	543	545	543	543	543
13	558	556	556	556	558	558	558	558	558	555	555	555
14	486	485	485	485	486	490	490	490	486	493	493	493
15	532	516	516	516	523	501	501	501	520	501	501	501
16	548	544	544	544	548	540	540	540	548	544	544	544
17	524	521	521	521	524	519	519	519	524	519	519	519
18	513	513	513	513	513	509	509	509	513	508	508	508
19	533	532	532	532	533	527	527	527	533	521	521	521
20	527	524	524	524	527	524	524	524	527	522	522	522

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	599	591	591	591	596	591	591	591	596	599	599	599
2	551	545	545	545	551	543	543	543	551	546	546	546
3	533	525	525	525	533	529	529	529	533	525	525	526
4	571	561	561	561	571	562	562	562	571	561	561	561
5	521	511	511	511	521	511	511	511	521	510	510	510
6	590	589	582	582	590	583	583	583	590	585	585	585
7	548	542	542	542	548	544	544	544	547	541	541	541
8	556	552	552	552	556	549	549	549	556	545	545	556
9	556	554	554	554	556	553	553	553	556	552	552	552
10	495	495	495	495	495	493	493	493	495	496	496	496
11	570	566	566	566	570	567	567	567	570	566	566	566
12	545	543	543	543	545	543	542	542	545	541	541	541
13	558	558	558	558	558	559	559	559	558	559	559	559
14	486	499	499	499	486	499	499	499	486	495	495	495
15	523	498	498	498	523	496	496	496	520	496	496	496
16	548	545	545	545	548	545	545	545	548	541	541	541
17	524	519	519	519	524	523	523	523	524	519	519	519
18	513	507	507	507	513	509	509	509	513	507	507	507
19	533	527	527	527	533	522	522	522	533	527	527	527
20	527	524	524	524	527	521	521	521	527	527	527	527

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	599	594	594	594	596	594	594	594	596	594	594	594
2	551	549	549	549	551	548	548	548	551	547	547	547
3	533	529	529	529	533	525	525	525	533	529	529	529
4	571	565	565	565	571	564	564	564	571	566	566	566
5	521	511	511	511	521	510	510	510	521	510	510	510
6	590	583	583	583	590	583	583	583	590	585	585	585
7	548	542	542	542	548	544	544	544	547	541	541	541
8	556	549	549	549	556	555	555	555	556	555	555	555
9	556	554	554	554	556	549	549	549	556	546	546	546
10	495	496	496	496	495	495	495	495	495	494	494	494
11	570	568	568	568	570	567	567	567	570	566	566	566
12	545	541	541	541	545	541	541	541	545	541	541	541
13	558	559	559	559	558	559	559	559	558	559	559	559
14	486	500	500	500	486	501	501	501	486	499	499	499
15	523	498	498	497	523	504	504	504	520	504	504	504
16	548	541	541	541	548	545	545	545	548	541	541	541
17	524	522	522	522	524	514	514	514	524	514	514	514
18	513	507	507	507	513	509	509	509	513	511	511	511
19	533	525	525	525	533	521	521	521	532	520	520	520
20	527	527	527	527	527	520	520	520	527	520	520	520

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	592	595	595	595	592	595	595	595	592	591	591	591
2	557	550	550	550	557	550	550	550	557	550	550	550
3	539	532	532	532	538	532	532	532	538	532	532	532
4	575	575	575	575	575	575	575	575	575	575	575	575
5	524	520	520	520	524	516	516	516	518	516	516	516
6	596	585	585	585	596	585	584	584	596	585	585	585
7	552	546	549	549	552	547	547	547	552	550	550	550
8	557	552	552	552	557	552	552	552	557	552	552	552
9	556	554	554	554	556	554	554	554	556	554	554	554
10	505	499	499	499	505	501	501	501	505	498	499	499
11	582	571	571	571	582	579	579	579	582	571	571	571
12	549	548	548	548	549	545	545	545	549	544	547	547
13	562	571	571	571	562	561	568	568	562	569	569	569
14	492	490	490	490	492	496	496	496	492	492	492	492
15	506	502	502	502	506	506	506	506	506	506	506	506
16	545	547	547	547	545	545	545	545	545	550	550	550
17	539	520	520	520	539	518	518	518	537	527	527	527
18	520	520	520	520	519	519	519	519	519	520	520	520
19	530	523	523	523	530	523	523	523	530	527	527	527
20	530	524	524	524	530	524	524	524	530	526	526	526

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	592	593	592	592	592	590	590	590	592	590	590	590
2	557	556	556	556	557	549	549	549	557	550	550	550
3	539	534	534	532	538	530	530	530	538	531	531	531
4	575	575	575	575	575	573	573	573	575	571	571	571
5	524	520	520	520	524	513	513	513	518	516	516	516
6	596	586	586	586	596	590	590	590	596	590	590	590
7	552	550	550	550	552	550	550	550	552	550	550	550
8	557	552	552	552	557	556	556	556	557	556	556	556
9	556	554	554	554	556	554	554	554	556	554	554	554
10	505	500	500	500	505	500	500	500	505	500	500	500
11	582	578	578	578	582	578	578	578	582	571	571	571
12	549	548	548	548	549	544	544	544	549	548	548	548
13	562	572	572	572	562	572	572	572	562	572	572	572
14	492	492	492	492	492	496	496	496	492	492	492	492
15	506	506	506	506	506	506	506	503	506	503	503	503
16	545	546	546	546	545	550	550	550	545	550	550	550
17	539	532	532	532	539	532	532	532	537	526	526	526
18	520	520	520	520	519	519	519	519	519	516	516	516
19	530	527	527	527	530	527	528	528	530	523	523	523
20	530	526	526	526	530	528	528	528	530	528	528	528

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	592	595	595	595	592	593	593	593	592	590	590	590
2	557	549	549	549	557	550	550	550	557	550	550	550
3	539	531	531	531	536	531	531	531	536	530	530	530
4	575	571	571	571	575	570	570	570	575	570	570	570
5	524	520	520	520	524	513	513	513	520	524	524	524
6	596	586	586	586	596	590	590	590	596	590	583	583
7	552	550	550	550	552	550	550	550	552	544	544	544
8	557	555	555	555	557	554	554	554	557	554	554	554
9	556	556	556	556	556	558	558	558	556	558	558	558
10	505	499	499	499	505	506	506	506	505	504	504	504
11	582	578	578	578	582	578	578	574	581	572	572	572
12	549	548	548	548	549	544	544	544	549	548	548	548
13	562	572	572	572	562	572	572	572	562	572	568	568
14	492	492	492	492	492	496	495	495	492	493	493	493
15	506	503	503	503	506	503	503	503	506	503	503	503
16	545	546	546	546	545	550	551	551	545	541	541	541
17	539	537	537	537	539	532	532	532	536	526	526	526
18	520	516	516	516	519	520	520	520	513	516	516	516
19	530	520	520	520	530	523	523	523	530	523	523	523
20	530	526	526	526	530	528	528	528	530	528	528	528

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	619	607	607	607	608	599	599	599	598	598	598	598
2	571	571	571	571	565	559	559	559	558	558	558	558
3	566	566	566	566	565	540	540	540	539	539	539	539
4	611	592	592	592	585	577	577	577	573	573	573	573
5	553	544	544	544	541	535	535	535	520	520	520	520
6	614	597	597	597	600	594	594	594	592	585	585	585
7	577	570	570	570	554	554	554	554	549	549	549	549
8	594	565	565	565	565	565	565	565	555	555	555	555
9	572	572	572	572	568	564	564	564	555	555	555	555
10	533	522	522	533	520	516	516	516	511	509	509	509
11	589	585	585	585	586	574	574	574	579	576	576	576
12	577	571	571	570	561	558	558	558	559	557	557	557
13	588	578	578	578	587	566	566	566	572	566	566	566
14	536	530	530	530	513	513	513	513	513	513	513	513
15	565	524	524	524	530	508	508	508	510	508	508	510
16	583	564	564	564	567	562	562	562	552	544	544	544
17	579	554	554	554	538	524	524	524	528	528	528	528
18	529	528	528	528	524	524	524	524	518	518	518	518
19	555	539	539	539	540	540	540	540	531	531	531	531
20	550	546	548	548	541	535	535	535	533	533	533	533

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	619	617	617	617	608	602	602	602	598	598	598	598
2	571	555	555	555	565	554	554	554	558	554	554	554
3	566	564	564	564	565	545	545	545	539	539	539	539
4	611	594	594	594	585	585	585	585	573	569	569	569
5	553	546	546	546	541	541	541	541	520	520	520	520
6	614	598	598	598	600	595	595	595	592	592	592	592
7	577	570	570	570	554	554	554	554	549	549	549	549
8	594	557	557	557	565	556	556	556	555	555	555	555
9	572	572	572	572	568	561	561	561	555	555	555	555
10	533	533	533	533	520	520	520	520	511	511	511	511
11	589	585	585	585	586	574	574	574	579	576	576	576
12	577	573	573	573	561	558	558	558	559	557	557	557
13	588	578	578	578	587	566	566	566	572	566	566	566
14	536	530	530	530	513	513	513	513	513	513	512	512
15	565	537	537	537	530	510	510	510	510	498	498	498
16	583	576	576	576	567	562	562	562	552	544	546	546
17	579	548	548	548	538	528	528	528	528	524	524	524
18	529	528	528	528	524	524	519	519	518	514	514	514
19	555	546	546	546	540	533	533	533	531	531	531	531
20	550	544	544	544	541	541	541	541	533	533	533	533

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	619	617	617	617	608	602	602	602	594	594	594	594
2	571	555	555	555	560	554	554	554	560	550	550	550
3	566	564	564	564	565	545	545	545	540	540	540	540
4	611	594	594	594	585	585	585	585	575	569	569	569
5	553	546	543	543	541	541	541	541	522	522	522	522
6	614	597	593	593	600	600	600	600	598	597	597	597
7	577	564	564	564	554	552	552	552	552	552	552	552
8	594	557	557	557	564	556	556	556	554	554	554	554
9	572	568	568	568	568	561	561	561	555	555	555	555
10	533	533	533	533	520	520	520	512	507	507	507	507
11	589	589	589	589	586	577	577	577	575	575	575	575
12	577	573	573	573	561	558	558	561	561	561	561	561
13	588	578	579	579	587	573	573	573	572	572	572	572
14	536	536	536	536	513	513	513	513	513	513	513	513
15	565	537	537	537	530	510	510	510	507	498	498	498
16	583	583	583	583	567	556	556	556	558	552	552	552
17	579	553	553	553	539	528	528	528	534	524	524	524
18	529	519	519	519	524	511	511	511	523	514	514	514
19	555	546	546	546	540	533	533	533	536	536	536	536
20	550	544	544	544	543	542	542	538	531	531	531	531

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	611	596	596	596	601	596	596	596	596	596	596	596
2	581	571	571	571	561	553	553	553	549	549	549	549
3	565	545	545	545	559	544	544	544	547	542	542	542
4	605	584	584	584	593	580	580	580	575	574	574	574
5	549	538	538	538	529	526	526	526	528	527	527	527
6	597	595	595	595	597	591	591	591	597	591	591	591
7	569	564	564	564	564	553	553	553	548	548	548	548
8	579	568	568	568	568	559	559	559	554	554	554	554
9	587	552	552	552	571	552	552	552	558	558	558	558
10	522	516	516	516	522	510	510	510	512	501	501	501
11	587	585	585	585	581	577	577	577	577	577	577	577
12	572	565	565	565	549	549	549	549	549	549	549	549
13	573	573	573	573	570	570	570	570	567	567	567	567
14	540	519	519	519	504	504	504	504	502	502	502	502
15	537	522	522	522	529	515	515	515	506	506	506	506
16	567	563	563	563	548	548	548	548	546	546	546	546
17	534	534	534	534	534	531	529	529	534	526	526	526
18	542	521	521	521	526	518	518	518	526	521	524	524
19	557	541	541	533	539	532	532	532	531	531	531	531
20	549	534	534	534	546	528	528	528	531	527	527	527

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	611	602	602	602	601	596	596	596	596	596	596	596
2	581	566	566	566	561	553	553	553	549	549	549	549
3	565	545	545	545	559	544	544	544	547	542	542	542
4	605	585	585	585	593	580	580	580	575	574	574	574
5	549	538	538	538	529	526	526	522	528	522	522	522
6	597	595	595	595	597	591	593	593	597	597	597	597
7	569	555	555	563	564	555	555	555	548	548	548	548
8	579	560	560	560	568	559	559	559	554	554	554	554
9	587	576	576	576	571	571	571	571	558	558	558	558
10	522	522	522	522	522	510	510	510	512	501	501	508
11	587	585	585	585	581	579	581	581	577	577	577	577
12	572	572	572	572	549	549	549	549	549	549	549	549
13	573	573	573	573	570	570	570	570	567	558	558	558
14	540	519	519	518	504	503	503	503	502	502	502	502
15	537	528	528	528	529	507	507	507	506	506	506	506
16	567	563	563	563	548	548	548	548	546	541	541	541
17	534	534	534	534	534	534	534	534	534	526	526	526
18	542	533	533	533	526	522	522	522	526	513	513	513
19	557	531	531	531	539	532	532	532	531	531	531	531
20	549	534	534	534	546	528	528	528	531	527	527	529

APPENDIX 7 - SOLUTIONS OF LARGE SCALE PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	611	602	602	602	601	596	596	596	597	591	591	591
2	581	566	566	566	561	553	551	551	555	555	555	555
3	565	545	545	545	565	541	541	541	543	535	535	535
4	605	585	585	585	590	580	584	584	571	571	571	571
5	549	532	532	532	529	522	522	522	528	522	522	522
6	597	597	597	597	597	597	597	597	597	597	597	597
7	569	566	566	566	564	555	555	555	548	548	548	548
8	579	560	560	560	568	559	559	559	555	555	555	555
9	587	576	576	576	571	571	571	571	558	558	558	558
10	522	522	522	522	522	507	507	507	515	508	508	508
11	587	575	575	575	582	581	581	581	577	577	577	577
12	572	560	560	560	549	549	549	549	549	549	549	549
13	573	573	573	573	570	570	570	570	565	558	558	558
14	540	516	516	516	507	507	507	507	503	503	503	503
15	537	528	528	528	527	507	507	507	506	506	506	506
16	567	564	564	564	548	548	548	548	546	546	546	546
17	534	534	534	534	534	534	534	534	534	526	532	532
18	542	533	533	533	526	522	522	522	522	513	513	513
19	557	531	531	531	538	532	532	532	530	529	529	529
20	549	545	545	545	546	536	536	536	533	533	533	533

APPENDIX 8 – SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	4313.9	4040.9	3916.5	4034.4	4313.9	4034.4	4061.7	4055.6	4313.9	4034.4	4160.4	4081.3
2	7990.0	7979.3	7979.3	7979.3	7990.0	7979.3	7979.3	7990.0	7990.0	7979.3	7979.3	7979.3
3	15564.6	15564.6	15564.6	15564.6	15564.6	15550.3	15550.3	15564.6	15564.6	15550.3	15552.0	15551.6
4	10551.5	10353.3	10415.3	10400.5	10551.5	10353.3	10363.2	10360.1	10551.5	10353.3	10356.3	10363.2
5	6130.8	5677.4	5695.7	5689.3	6130.8	5677.4	5644.7	5719.3	6130.8	5677.4	5681.4	5695.7
6	5246.2	4988.5	4988.5	4988.5	5246.2	4973.1	4973.1	4662.1	5246.2	4973.1	4987.4	4844.9
7	4799.0	4586.2	4449.9	4435.9	4799.0	4423.4	4432.9	4435.0	4799.0	4416.7	4458.3	4417.5
8	4155.1	4013.3	3920.8	3980.8	4155.1	3911.6	3927.1	3924.4	4155.1	3916.3	3967.8	3916.3
9	5953.5	5904.3	5849.1	5852.0	5953.5	5893.6	5806.8	4830.4	5953.5	5862.1	5863.2	5388.6
10	6302.3	4972.7	5377.1	5043.3	6302.3	4972.7	4930.0	4972.2	6302.3	4961.4	4901.4	4887.3
11	6432.3	6173.0	6306.6	6188.8	6432.3	6173.0	6173.4	6173.4	6432.3	6173.0	6173.0	6173.0
12	5865.6	5865.6	5840.6	5840.6	5865.6	5858.9	5840.6	5377.8	5865.6	5841.0	5840.6	5522.5
13	5879.6	4592.0	4592.0	4592.0	5879.6	4592.0	4592.0	4592.0	8302.6	4592.0	4522.9	4592.0
14	7519.2	6956.6	6864.1	6847.0	7519.2	6874.5	6619.3	6847.0	7519.2	6874.5	6940.3	6857.3
15	5427.4	3859.7	4150.3	3853.6	5427.4	3859.7	3853.6	3859.7	5427.4	3859.7	3853.6	3859.7
16	4641.7	3980.8	4037.3	3957.4	4632.1	3925.8	3944.3	3876.1	4632.1	3931.3	3864.6	3851.7
17	7740.3	6272.7	6258.8	6271.8	7740.3	6272.7	6258.8	6258.8	7740.3	6258.8	6258.8	6258.8
18	4195.1	3967.1	4143.5	3972.5	4195.1	3987.1	3927.1	3916.3	4195.1	3904.6	3923.3	3923.3
19	5300.4	4576.9	4720.6	4576.9	5300.4	4515.6	4578.2	4309.9	5300.4	4576.9	4431.7	4576.9
20	5440.6	4709.8	4634.3	4692.0	5440.6	4652.1	4692.0	4305.2	5440.6	4634.3	4600.0	4397.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	4313.9	4040.9	3916.5	4034.4	4313.9	4034.4	4061.7	4055.6	4313.9	4034.4	4160.4	4081.3
2	7990.0	7979.3	7979.3	7979.3	7990.0	7979.3	7979.3	7990.0	7990.0	7979.3	7979.3	7979.3
3	15564.6	15564.6	15564.6	15550.3	15564.6	15550.3	15550.3	15564.6	15564.6	15550.3	15552.0	15551.6
4	10551.5	10353.3	10415.3	10400.5	10551.5	10353.3	10363.2	10360.1	10551.5	10353.3	10356.3	10363.2
5	6130.8	5677.4	5695.7	5689.3	6130.8	5677.4	5644.7	5719.3	6130.8	5677.4	5681.4	5695.7
6	5246.2	4988.5	4988.5	4988.5	5246.2	4973.1	4973.1	4662.1	5246.2	4973.1	4987.4	4844.9
7	5797.2	4432.2	4563.5	4640.9	5774.1	4432.0	4584.6	4467.9	5774.1	4432.0	4464.1	4445.5
8	4155.1	4013.3	3920.8	3980.8	4155.1	3911.6	3927.1	3924.4	4155.1	3916.3	3967.8	3916.3
9	5953.5	5904.3	5849.1	5852.0	5953.5	5893.6	5806.8	4830.4	5953.5	5862.1	5863.2	5388.6
10	6302.3	4972.7	5377.1	5043.3	6302.3	4972.7	4930.0	4972.2	5450.9	4938.9	4923.0	4890.9
11	6371.3	6173.4	6198.0	6279.4	6339.5	6173.4	6190.2	6200.9	6339.5	6173.4	6173.4	6173.0
12	5865.6	5865.6	5840.6	5840.6	5865.6	5858.9	5840.6	5377.8	5865.6	5841.0	5840.6	5522.5
13	8302.6	4592.0	4592.0	4592.0	8302.6	4592.0	4592.0	4394.1	8302.6	4592.0	4522.9	4592.0
14	6703.7	6703.7	6538.3	6703.7	6703.7	6703.7	6703.7	6703.7	6703.7	6684.4	6703.7	6703.7
15	5394.2	4075.4	3859.7	3956.7	5307.6	3853.6	3950.6	3859.7	5307.6	3853.6	3859.7	3859.7
16	4641.7	3980.8	4037.3	3957.4	4632.1	3925.8	3944.3	3876.1	4632.1	3931.3	3864.6	3851.7
17	7740.3	6272.7	6258.8	6271.8	7740.3	6272.7	6258.8	6258.8	7740.3	6258.8	6258.8	6258.8
18	4195.1	3967.1	4143.5	3972.5	4195.1	3987.1	3927.1	3916.3	4195.1	3904.6	3923.3	3923.3
19	5300.4	4576.9	4720.6	4576.9	5300.4	4515.6	4578.2	4309.9	5300.4	4576.9	4431.7	4576.9
20	5440.6	4709.8	4634.3	4692.0	5440.6	4652.1	4692.0	4305.2	5440.6	4634.3	4600.0	4397.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	4313.9	4040.9	3916.5	4034.4	4313.9	4034.4	4061.7	4055.6	4313.9	4034.4	4160.4	4081.3
2	7990.0	7979.3	7979.3	7979.3	7990.0	7979.3	7979.3	7990.0	7990.0	7979.3	7979.3	7979.3
3	15564.6	15564.6	15564.6	15550.3	15564.6	15550.3	15550.3	15564.6	15564.6	15550.3	15552.0	15551.6
4	10401.6	10386.5	10363.2	10353.3	10401.6	10363.2	10353.3	10353.3	10401.6	10363.2	10353.3	10357.1
5	6130.8	5677.4	5695.7	5689.3	6130.8	5677.4	5644.7	5719.3	6130.8	5677.4	5681.4	5695.7
6	5246.2	4988.5	4988.5	4988.5	5246.2	4973.1	4973.1	4662.1	5343.3	4973.1	4059.2	4987.4
7	5797.2	4432.2	4563.5	4640.9	5774.1	4432.0	4584.6	4467.9	5774.1	4432.0	4464.1	4445.5
8	4360.4	3960.8	3908.4	3902.1	4360.4	3927.1	3904.6	3916.3	4323.3	3960.8	3904.6	3902.1
9	5953.5	5904.3	5849.1	5852.0	5953.5	5893.6	5806.8	4830.4	5953.5	5862.1	5863.2	5388.6
10	5450.9	4946.4	4978.7	5010.6	5450.9	4938.9	4954.9	4916.7	5450.9	4938.9	4923.0	4890.9
11	6371.3	6173.4	6198.0	6279.4	6339.5	6173.4	6190.2	6200.9	6339.5	6173.4	6173.4	6173.0
12	5865.6	5865.6	5840.6	5840.6	5865.6	5858.9	5840.6	5377.8	5865.6	5841.0	5840.6	5522.5
13	8302.6	4592.0	4592.0	4592.0	8302.6	4592.0	4592.0	4394.1	8302.6	4592.0	4522.9	4592.0
14	6703.7	6703.7	6538.3	6703.7	6703.7	6703.7	6703.7	6703.7	6703.7	6684.4	6703.7	6703.7
15	5394.2	4075.4	3859.7	3956.7	5307.6	3853.6	3950.6	3859.7	5307.6	3853.6	3859.7	3859.7
16	4641.7	3980.8	4037.3	3957.4	4632.1	3925.8	3944.3	3876.1	4632.1	3931.3	3864.6	3851.7
17	7740.3	6272.7	6258.8	6271.8	7740.3	6272.7	6258.8	6258.8	7740.3	6258.8	6258.8	6258.8
18	4195.1	3967.1	4143.5	3972.5	4195.1	3987.1	3927.1	3916.3	4195.1	3904.6	3923.3	3923.3
19	5300.4	4576.9	4720.6	4576.9	5300.4	4515.6	4578.2	4309.9	4792.4	4576.9	4627.8	4576.9
20	5440.6	4709.8	4634.3	4692.0	5440.6	4652.1	4692.0	4305.2	5440.6	4634.3	4600.0	4397.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	4710.5	3858.2	4086.9	3839.3	4710.5	3858.2	3851.0	4114.0	4710.5	3858.2	4139.1	4007.1
2	8714.9	7979.3	7984.8	7985.9	8714.9	7979.3	7984.8	7980.4	8714.9	7985.9	7980.4	7997.8
3	15571.2	15565.7	15555.8	15567.4	15571.2	15555.8	15550.3	15567.0	15571.2	15555.8	15552.0	15550.3
4	10401.6	10357.1	10401.6	10400.6	10401.6	10389.5	10357.1	10353.3	10401.6	10357.1	10360.2	10356.3
5	6264.6	5727.1	5669.3	5850.0	6264.6	5688.1	5635.6	5679.7	6264.6	5617.0	5636.9	5644.7
6	5745.2	4989.8	5022.7	4998.1	5712.9	4973.1	4974.4	4974.4	5712.9	4973.1	4973.1	4951.8
7	5628.3	4644.8	4600.1	4453.2	5532.5	4506.9	4413.2	4451.3	5532.5	4472.4	4408.9	4499.2
8	4176.9	3997.4	3916.3	3997.4	4176.9	3927.1	3997.4	3978.8	4176.9	3927.1	3904.6	3904.6
9	7440.9	5852.0	5866.3	5867.4	7440.9	5818.7	5849.5	5847.8	7440.9	5818.7	5863.2	5862.1
10	8450.5	5527.4	4896.6	4990.1	8450.5	4982.3	4891.5	4898.8	8450.5	4935.5	4906.9	4908.7
11	7946.9	6177.2	6173.0	6177.2	7946.9	6177.2	6173.4	6173.0	7946.9	6173.0	6173.0	6173.0
12	8243.1	5871.0	5937.6	5905.7	8243.1	5841.0	5841.0	5840.6	8243.1	5841.0	5844.8	5841.0
13	9483.0	4761.0	4592.0	4668.2	9483.0	4592.0	4592.0	4592.0	9483.0	4592.0	4592.0	4054.8
14	7792.8	6847.0	6857.3	6847.0	7663.9	6530.6	6846.6	6847.0	7663.9	6530.6	6528.1	6445.0
15	5455.8	3912.4	3956.3	4053.7	5356.9	3950.2	3965.4	3907.6	5356.9	3507.2	3859.7	3853.6
16	5778.8	3864.6	3931.3	3967.2	5778.8	3851.7	3851.7	3851.7	5778.8	3891.8	3864.6	3901.7
17	8007.4	6271.8	6283.4	6271.8	8007.4	6258.8	6271.8	6271.8	8007.4	6258.8	6258.8	6258.8
18	4610.9	3996.4	4417.3	4075.6	4610.9	3937.7	3945.6	4090.2	4610.9	3904.6	3923.3	3997.4
19	4565.4	4565.4	4565.4	4565.4	4442.6	4442.6	4430.4	4303.6	4442.6	4442.6	4442.6	4442.6
20	7236.7	4525.0	4633.6	4380.0	7236.7	4537.4	4598.3	4411.7	7236.7	4525.0	4437.8	4598.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	4850.2	4042.3	4099.7	4146.7	4808.0	3996.6	4042.5	3993.7	4808.0	3996.6	4034.4	4070.9
2	8714.9	7979.3	7984.8	7985.9	8714.9	7979.3	7984.8	7980.4	8714.9	7979.3	7984.8	7979.3
3	15571.2	15565.7	15555.8	15567.4	15571.2	15555.8	15550.3	15567.0	15571.2	15555.8	15552.0	15550.3
4	10401.6	10357.1	10401.6	10400.6	10401.6	10389.5	10357.1	10353.3	10401.6	10357.1	10360.2	10356.3
5	6264.6	5727.1	5669.3	5850.0	6499.8	5636.9	5689.4	5658.4	6499.8	5636.4	5667.3	5670.1
6	5745.2	4989.8	5022.7	4998.1	5712.9	4973.1	4974.4	4974.4	5712.9	4973.1	4973.1	4951.8
7	5628.3	4644.8	4600.1	4453.2	5532.5	4506.9	4413.2	4451.3	5532.5	4472.4	4408.9	4499.2
8	4176.9	3997.4	3916.3	3997.4	4176.9	3927.1	3997.4	3978.8	4176.9	3927.1	3904.6	3904.6
9	7440.9	5866.3	5863.8	5852.0	7440.9	5818.7	5849.5	5847.8	7440.9	5818.7	5863.2	5862.1
10	8450.5	5527.4	4896.6	4990.1	8450.5	4982.3	4891.5	4898.8	8450.5	4935.5	4906.9	4908.7
11	7946.9	6177.2	6173.0	6177.2	7946.9	6177.2	6173.4	6173.0	7946.9	6173.0	6173.0	6173.0
12	8243.1	5871.0	5937.6	5905.7	8751.0	5840.6	5856.4	5844.8	8751.0	5840.6	5841.0	5840.6
13	9483.0	4761.0	4592.0	4668.2	9483.0	4592.0	4592.0	4592.0	9483.0	4592.0	4592.0	4592.0
14	7792.8	6847.0	6857.3	6847.0	7663.9	6530.6	6846.6	6847.0	7663.9	6530.6	6528.1	6445.0
15	5455.8	3912.4	3956.3	4053.7	5356.9	3950.2	3965.4	3907.6	5356.9	3507.2	3859.7	3853.6
16	5778.8	3864.6	3931.3	3967.2	6340.0	3944.5	3876.1	3931.3	6340.0	3912.9	3851.7	3955.8
17	8007.4	6271.8	6283.4	6271.8	8007.4	6258.8	6271.8	6271.8	8007.4	6258.8	6258.8	6258.8
18	4610.9	3904.6	3938.6	3916.3	4610.9	3960.7	3934.8	3941.8	4610.9	3904.6	3923.3	3997.4
19	4565.4	4565.4	4565.4	4565.4	4442.6	4442.6	4430.4	4303.6	4442.6	4442.6	4442.6	4442.6
20	7236.7	4525.0	4633.6	4380.0	7218.1	4600.0	4711.1	4599.6	7218.1	4600.0	4616.8	4598.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15	No TS	TS with Tabu =5	TS with Tabu =10	TS with Tabu =15
1	4850.2	4042.3	4099.7	4146.7	4808.0	3996.6	4042.5	3993.7	4808.0	3996.6	4034.4	4070.9
2	8714.9	7980.4	7979.3	7984.8	8714.9	7984.8	7984.8	7984.8	8714.9	7979.3	7984.8	7979.3
3	15571.2	15555.8	15565.7	15550.3	15571.2	15555.8	15550.3	15551.6	15571.2	15555.8	15551.6	15552.0
4	10401.6	10357.1	10401.6	10400.6	10401.6	10389.5	10357.1	10353.3	10401.6	10357.1	10360.2	10356.3
5	6499.8	5636.9	5653.5	5711.0	6499.8	5636.9	5689.4	5658.4	6499.8	5636.4	5667.3	5670.1
6	5745.2	4989.8	5022.7	4998.1	5712.9	4973.1	4974.4	4974.4	5712.9	4973.1	4973.1	4951.8
7	5628.3	4644.8	4600.1	4453.2	6690.1	4468.8	4503.9	4475.8	6690.1	4468.8	4435.5	4451.2
8	4176.9	3997.4	3916.3	3997.4	4176.9	3927.1	3997.4	3978.8	4176.9	3927.1	3904.6	3904.6
9	7440.9	5866.3	5863.8	5852.0	7440.9	5818.7	5849.5	5847.8	7440.9	5818.7	5863.2	5862.1
10	8450.5	5527.4	4896.6	4990.1	8450.5	4982.3	4891.5	4898.8	8450.5	4935.5	4906.9	4908.7
11	7946.9	6177.2	6173.0	6177.2	7998.3	6175.9	6203.2	6249.2	7998.3	6175.9	6173.0	6173.0
12	8751.0	5844.8	5860.2	5875.3	8751.0	5840.6	5856.4	5844.8	8751.0	5840.6	5841.0	5840.6
13	9483.0	4684.8	4744.4	4592.0	9483.0	4592.0	4592.0	4592.0	9483.0	4592.0	4592.0	4592.0
14	7792.8	6847.0	6857.3	6847.0	7663.9	6530.6	6846.6	6847.0	7272.1	6715.8	6830.0	6846.6
15	6541.7	4107.3	4013.8	4385.8	6541.7	3956.3	3950.2	3859.7	6541.7	3950.2	3950.6	3859.7
16	6340.0	3955.7	4138.4	3993.4	6340.0	3944.5	3876.1	3931.3	6340.0	3912.9	3851.7	3955.8
17	8007.4	6271.8	6283.4	6271.8	8007.4	6258.8	6271.8	6271.8	8007.4	6258.8	6258.8	6258.8
18	4610.9	3904.6	3938.6	3916.3	4610.9	3960.7	3934.8	3941.8	4610.9	3904.6	3923.3	3997.4
19	4565.4	4565.4	4565.4	4565.4	4442.6	4442.6	4430.4	4303.6	4442.6	4442.6	4442.6	4442.6
20	7218.1	4615.8	4960.8	4647.1	7218.1	4600.0	4711.1	4599.6	7218.1	4600.0	4616.8	4598.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	4549.7	4015.9	4175.7	4061.7	4546.8	4099.1	4048.7	4154.8	4546.8	4059.4	4031.5	4059.4
2	8483.0	7984.8	7979.3	7985.9	8483.0	7984.8	7984.8	7979.3	8483.0	7984.8	7979.3	7979.3
3	15615.0	15565.9	15580.8	15554.5	15615.0	15551.6	15554.5	15551.6	15615.0	15550.3	15550.3	15550.3
4	10369.7	10369.7	10369.7	10369.7	10369.7	10363.2	10363.2	10357.1	10399.1	10357.1	10363.2	10363.2
5	6146.5	5694.3	5658.6	5658.3	6146.5	5647.2	5655.5	5674.4	6146.5	5647.2	5623.0	5692.3
6	5008.6	4987.4	4974.4	5008.6	5008.6	4987.4	5008.6	4974.4	5008.6	4973.1	4974.4	4974.4
7	5354.0	4505.5	4532.9	4539.9	5354.0	4424.9	4557.9	4516.9	5354.0	4410.4	4431.6	4408.7
8	5134.0	3941.9	3945.6	4017.2	5263.2	3938.8	3916.3	3920.1	5263.2	3938.8	3923.3	4001.2
9	5894.7	5675.5	5879.3	5864.5	5894.7	5446.4	5864.5	5849.5	5894.7	5326.8	5847.8	5721.1
10	5531.4	4918.1	4950.7	4939.0	5531.4	4902.3	4900.4	4885.4	5531.4	4902.3	4926.5	4961.2
11	6211.4	6177.2	5434.0	6173.4	6211.4	6173.0	6173.4	6173.0	6211.4	6173.0	6173.0	6173.0
12	6013.2	5844.8	5868.5	5856.0	6013.2	5840.6	5866.0	5856.4	6013.2	5840.6	5840.6	5792.0
13	7935.4	4592.0	4592.0	4592.0	7935.4	4592.0	4592.0	4592.0	7935.4	4592.0	4592.0	4592.0
14	6902.5	6857.7	6857.3	6857.7	6902.5	6847.0	6863.8	6856.0	6902.5	6445.4	6846.6	6846.6
15	5088.9	3956.3	3859.7	3859.7	5088.9	3956.3	3859.7	3823.9	5088.9	3950.2	3658.2	3859.7
16	4713.1	3976.0	4040.0	4135.8	4658.2	3976.0	3857.4	3944.5	4610.7	3851.7	3851.7	3851.7
17	7601.2	6280.0	6258.8	6280.0	7601.2	6280.0	6280.0	6258.8	7601.2	6258.8	6280.0	6258.8
18	5471.9	4056.1	4183.0	3911.6	5471.9	3923.3	3911.6	4076.1	5471.9	3923.3	3923.3	3904.6
19	5572.8	4576.9	4576.9	4576.9	5454.7	4576.9	4576.9	4619.6	5454.7	4576.9	4576.9	4578.2
20	4479.7	4479.7	4146.8	4479.7	4479.7	4130.8	4321.3	4200.1	4479.7	4130.8	4479.7	4343.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	4549.7	4015.9	4175.7	4061.7	4546.8	4099.1	4048.7	4154.8	4546.8	4059.4	4031.5	4059.4
2	8483.0	7984.8	7979.3	7985.9	8483.0	7984.8	7984.8	7979.3	8483.0	7984.8	7979.3	7979.3
3	15615.0	15565.9	15580.8	15554.5	15615.0	15551.6	15554.5	15551.6	15615.0	15550.3	15550.3	15550.3
4	10399.1	10399.1	10363.2	10360.1	10399.1	10363.2	10360.2	10360.2	10399.1	10357.1	10363.2	10363.2
5	6146.5	5694.3	5658.6	5658.3	6146.5	5647.2	5655.5	5674.4	6146.5	5647.2	5623.0	5692.3
6	5008.6	4974.4	4988.5	4973.1	5008.6	4973.1	4696.1	4974.4	5008.6	4973.1	5002.8	4973.1
7	5354.0	4505.5	4532.9	4539.9	5354.0	4424.9	4557.9	4516.9	5354.0	4410.4	4431.6	4408.7
8	5263.2	3978.8	3938.8	3945.6	5263.2	3938.8	3916.3	3920.1	5263.2	3938.8	3923.3	4001.2
9	5894.7	5675.5	5879.3	5864.5	5894.7	5446.4	5864.5	5849.5	5879.3	5853.3	5438.0	5341.3
10	5531.4	4918.1	4950.7	4939.0	5531.4	4902.3	4900.4	4885.4	5531.4	4902.3	4926.5	4961.2
11	6211.4	6177.2	5434.0	6173.4	6211.4	6173.0	6173.4	6173.0	6211.4	6173.0	6173.0	6173.0
12	6013.2	5844.8	5868.5	5856.0	6013.2	5840.6	5866.0	5856.4	6013.2	5840.6	5840.6	5792.0
13	7935.4	4592.0	4592.0	4592.0	7935.4	4592.0	4592.0	4592.0	7935.4	4592.0	4592.0	4592.0
14	6902.5	6857.7	6857.3	6857.7	6902.5	6847.0	6863.8	6856.0	6902.5	6445.4	6846.6	6846.6
15	5088.9	3956.3	3859.7	3859.7	5088.9	3956.3	3859.7	3823.9	5088.9	3950.2	3658.2	3859.7
16	4713.1	3976.0	4040.0	4135.8	4658.2	3976.0	3857.4	3944.5	4610.7	3851.7	3851.7	3851.7
17	7601.2	6280.0	6258.8	6280.0	7339.5	6280.0	6271.8	6280.0	7339.5	6280.0	6258.8	6258.8
18	5471.9	4056.1	4183.0	3911.6	5471.9	3923.3	3911.6	4076.1	5483.6	3925.2	3949.4	3920.1
19	5582.9	4578.2	4604.2	4576.9	5582.9	4576.9	4576.9	4576.9	5580.2	4576.9	4576.9	4576.9
20	4479.7	4479.7	4146.8	4479.7	4479.7	4130.8	4321.3	4200.1	4479.7	4130.8	4479.7	4343.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	4549.7	4015.9	4175.7	4061.7	5339.2	4034.4	3969.8	4046.4	5339.2	4034.4	3986.0	4035.7
2	8483.0	7984.8	7979.3	7985.9	8483.0	7984.8	7984.8	7979.3	8483.0	7984.8	7979.3	7979.3
3	15615.0	15565.9	15580.8	15554.5	15615.0	15551.6	15554.5	15551.6	15615.0	15550.3	15550.3	15550.3
4	10399.1	10399.1	10363.2	10360.1	10399.1	10363.2	10360.2	10360.2	10399.1	10357.1	10363.2	10363.2
5	6146.5	5694.3	5658.6	5658.3	6146.5	5647.2	5655.5	5674.4	6944.2	5669.5	5614.3	5663.2
6	5008.6	4974.4	4988.5	4973.1	5008.6	4973.1	4696.1	4974.4	5008.6	4973.1	5002.8	4973.1
7	5354.0	4505.5	4532.9	4539.9	5354.0	4424.9	4557.9	4516.9	5354.0	4410.4	4431.6	4408.7
8	5263.2	3978.8	3938.8	3945.6	5263.2	3938.8	3916.3	3920.1	5263.2	3938.8	3923.3	4001.2
9	5879.3	5879.3	5229.2	5879.3	5879.3	5879.3	5849.5	5784.4	5879.3	5853.3	5438.0	5341.3
10	5531.4	4918.1	4950.7	4939.0	5531.4	4902.3	4900.4	4885.4	5531.4	4902.3	4926.5	4961.2
11	6211.4	6177.2	5434.0	6173.4	6211.4	6173.0	6173.4	6173.0	6211.4	6173.0	6173.0	6173.0
12	6013.2	5844.8	5868.5	5856.0	6013.2	5840.6	5866.0	5856.4	6086.3	5843.5	5843.5	5841.0
13	7935.4	4592.0	4592.0	4592.0	7935.4	4592.0	4592.0	4592.0	7935.4	4592.0	4592.0	4592.0
14	6902.5	6857.7	6857.3	6857.7	6902.5	6847.0	6863.8	6856.0	6902.5	6445.4	6846.6	6846.6
15	5088.9	3956.3	3859.7	3859.7	5088.9	3956.3	3859.7	3823.9	5088.9	3950.2	3658.2	3859.7
16	4713.1	3976.0	4040.0	4135.8	4658.2	3976.0	3857.4	3944.5	4640.5	3851.7	3944.5	3947.5
17	7339.5	6280.0	6271.8	6271.8	7339.5	6280.0	6271.8	6280.0	7339.5	6280.0	6258.8	6258.8
18	5483.6	3925.2	4128.6	4144.0	5483.6	3925.2	3923.3	4042.6	5483.6	3925.2	3949.4	3920.1
19	5582.9	4578.2	4604.2	4576.9	5582.9	4576.9	4576.9	4576.9	5580.2	4576.9	4576.9	4576.9
20	4479.7	4479.7	4146.8	4479.7	4479.7	4130.8	4321.3	4200.1	4479.7	4130.8	4479.7	4343.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	5247.3	4084.0	4137.9	4049.8	5247.3	4099.7	3894.8	4048.7	5247.3	4099.7	4017.8	4062.8
2	8717.3	7979.3	7980.4	8014.6	8717.3	7984.8	7997.8	7990.0	8717.3	7984.8	7980.4	7979.3
3	15733.9	15571.2	15554.5	15576.6	15733.9	15571.2	15565.9	15550.3	15733.9	15565.7	15550.3	15551.6
4	10399.1	10399.1	10357.1	10399.1	10399.1	10363.2	10360.2	10360.2	10399.1	10357.1	10357.1	10399.1
5	6966.1	5673.1	5715.3	5671.9	6966.1	5673.1	5749.8	5614.6	6966.1	5732.5	5686.6	5663.5
6	6201.3	4974.4	4973.1	4974.4	6201.3	4974.4	4974.4	4988.5	6201.3	4987.4	4987.4	4974.4
7	4871.5	4540.1	4534.7	4497.4	4871.5	4540.1	4466.9	4474.9	4871.5	4460.6	4487.6	4449.9
8	4065.5	3920.1	4004.4	3954.4	4065.5	3902.1	3960.8	3902.1	4065.5	3902.1	3911.6	3915.4
9	6122.1	5853.3	5852.0	5866.3	6107.8	5853.3	5847.8	5872.8	6107.8	5093.7	5849.1	5557.4
10	6093.1	4982.8	4913.7	4955.6	6058.9	4952.4	4986.8	4949.7	6058.9	4952.4	4937.1	4912.9
11	5979.2	5979.2	5304.4	5979.2	5979.2	5979.2	5979.2	5596.2	5979.2	5979.2	5979.2	5715.0
12	7624.0	4912.8	5822.6	5841.0	7624.0	4912.8	5840.6	5584.4	7624.0	4912.8	5383.5	4908.8
13	9122.4	4592.0	3874.8	4579.7	9122.4	4568.0	4592.0	4592.0	9122.4	4209.3	4592.0	4592.0
14	8456.0	6885.0	6847.0	6863.8	8409.1	6847.0	6845.3	6823.9	8409.1	6847.0	6846.6	5886.8
15	5662.5	3859.7	3956.3	4166.2	5662.5	3859.7	3859.7	3950.6	5662.5	3859.7	3859.7	4053.3
16	5568.8	3931.3	4216.2	4103.5	5568.8	3944.5	3876.1	3963.0	5568.8	3876.1	3925.8	3851.7
17	6520.7	6258.8	6258.8	6258.8	6520.7	6258.8	6258.8	6258.8	6520.7	6258.8	6258.8	6258.8
18	5279.9	3923.3	4017.4	4061.2	5279.9	3923.3	3975.6	3945.6	5279.9	3923.3	3923.3	3915.4
19	5429.6	4578.2	4530.6	4604.2	5429.6	4578.2	4578.2	4669.7	5429.6	4578.2	4576.9	4576.9
20	4867.8	4500.8	4713.4	4693.0	4867.8	4445.1	4599.6	4769.9	4867.8	4445.1	4600.0	4158.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	5247.3	4084.0	4137.9	4049.8	5247.3	4099.7	3894.8	4048.7	5247.3	4099.7	4017.8	4062.8
2	8717.3	7984.8	8146.1	7997.8	8717.3	7984.8	7997.8	7990.0	8717.3	7984.8	7980.4	7979.3
3	15733.9	15604.1	15555.8	15555.8	15733.9	15565.7	15555.8	15550.3	15733.9	15565.7	15550.3	15551.6
4	10399.1	10399.1	10357.1	10399.1	10399.1	10363.2	10360.2	10360.2	10399.1	10357.1	10357.1	10399.1
5	6966.1	5673.1	5715.3	5671.9	6966.1	5673.1	5749.8	5614.6	6966.1	5732.5	5686.6	5663.5
6	6201.3	4974.4	4973.1	4974.4	6201.3	4974.4	4974.4	4988.5	6201.3	4987.4	4987.4	4974.4
7	4871.5	4552.6	4459.7	4445.4	4871.5	4551.9	4417.5	4431.7	4871.5	4460.6	4487.6	4449.9
8	4065.5	3920.1	4004.4	3954.4	4065.5	3902.1	3960.8	3902.1	4065.5	3911.6	3927.1	3920.8
9	6122.1	5853.3	5852.0	5866.3	6107.8	5853.3	5847.8	5872.8	6107.8	5093.7	5849.1	5557.4
10	6093.1	4982.8	4913.7	4955.6	6058.9	4951.0	4928.0	4935.8	6058.9	4931.3	4943.9	4946.9
11	8339.0	6177.2	6163.3	6175.9	8339.0	6177.2	6173.0	6177.2	8339.0	6175.9	6173.0	6173.0
12	7624.0	4912.8	5822.6	5841.0	7624.0	4912.8	5840.6	5584.4	7624.0	4912.8	5383.5	4908.8
13	9122.4	4568.0	4705.6	4592.0	9122.4	4568.0	4592.0	4592.0	9122.4	4209.3	4592.0	4592.0
14	8301.6	6863.8	6828.0	6845.3	8301.6	6349.1	6520.2	6845.3	8301.6	6349.1	6856.0	6856.0
15	5662.5	4047.2	4103.4	4010.3	5662.5	3859.7	3859.7	3950.6	5662.5	3859.7	3859.7	4053.3
16	5568.8	3931.3	4216.2	4103.5	5568.8	3944.5	3876.1	3963.0	5568.8	3876.1	3925.8	3851.7
17	6520.7	6258.8	6258.8	6258.8	6520.7	6258.8	6258.8	6258.8	6520.7	6258.8	6258.8	6258.8
18	5279.9	3923.3	4017.4	4061.2	5279.9	3923.3	3975.6	3945.6	5279.9	3923.3	3923.3	3915.4
19	5429.6	4578.2	4530.6	4604.2	5429.6	4578.2	4578.2	4669.7	5429.6	4578.2	4576.9	4576.9
20	4867.8	4500.8	4713.4	4693.0	4867.8	4445.1	4599.6	4769.9	4867.8	4445.1	4600.0	4158.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6	No TS	TS with Tabu =2	TS with Tabu =4	TS with Tabu =6
1	5247.3	4084.0	4137.9	4049.8	5247.3	4099.7	3894.8	4048.7	5247.3	4099.7	4017.8	4062.8
2	8717.3	7984.8	8146.1	7997.8	8717.3	7984.8	7997.8	7990.0	8717.3	7984.8	7980.4	7979.3
3	15733.9	15604.1	15555.8	15555.8	15733.9	15565.7	15555.8	15550.3	15733.9	15565.7	15550.3	15551.6
4	10399.1	10399.1	10357.1	10399.1	10399.1	10363.2	10360.2	10363.2	10399.1	10363.2	10353.3	10363.2
5	6966.1	5673.1	5715.3	5671.9	6966.1	5673.1	5749.8	5614.6	6966.1	5732.5	5686.6	5663.5
6	6201.3	4974.4	4973.1	4974.4	6201.3	4974.4	4974.4	4988.5	5424.9	4974.4	4987.4	4973.1
7	4871.5	4552.6	4459.7	4445.4	4871.5	4551.9	4417.5	4431.7	4871.5	4460.6	4487.6	4449.9
8	4520.8	3918.1	3933.4	3911.6	4520.8	3918.1	3911.6	3916.3	4520.8	3918.1	3916.3	3916.3
9	6122.1	5853.3	5852.0	5866.3	6107.8	5853.3	5847.8	5872.8	6107.8	5093.7	5849.1	5557.4
10	6058.9	4984.7	5009.2	4859.4	6058.9	4951.0	4928.0	4935.8	6058.9	4931.3	4943.9	4946.9
11	8339.0	6198.4	6163.3	6175.9	8339.0	6177.2	6173.0	6177.2	8339.0	6175.9	6173.0	6173.0
12	7624.0	4912.8	5822.6	5841.0	7624.0	4912.8	5840.6	5584.4	7624.0	4912.8	5383.5	4908.8
13	9122.4	4568.0	4705.6	4592.0	9122.4	4568.0	4592.0	4592.0	9122.4	4209.3	4592.0	4592.0
14	8301.6	6863.8	6828.0	6845.3	8301.6	6349.1	6520.2	6845.3	8301.6	6349.1	6856.0	6856.0
15	5662.5	4047.2	4103.4	4010.3	5662.5	3859.7	3859.7	3950.6	5662.5	3859.7	3859.7	4053.3
16	5568.8	3931.3	4216.2	4103.5	5568.8	3944.5	3876.1	3963.0	5568.8	3876.1	3925.8	3851.7
17	6520.7	6258.8	6258.8	6258.8	6520.7	6258.8	6258.8	6258.8	6520.7	6258.8	6258.8	6258.8
18	5279.9	3923.3	4017.4	4061.2	5279.9	3923.3	3975.6	3945.6	5279.9	3923.3	3923.3	3915.4
19	5429.6	4578.2	4530.6	4604.2	5531.4	4593.6	4480.9	4578.2	5531.4	4578.2	4599.1	4485.6
20	4867.8	4500.8	4713.4	4693.0	4867.8	4445.1	4599.6	4769.9	4867.8	4445.1	4600.0	4158.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75, Construction Heuristics=SPT1, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	7674.9	7674.9	7674.9	7409.4	7674.9	7581.8	7665.3	7664.0	7674.9	7581.8	7298.2	7674.9
2	9627.9	9015.0	9044.8	9009.5	9205.8	9106.5	8926.6	8995.2	9205.8	9009.5	9000.7	8921.5
3	15580.6	15566.3	15563.8	15340.1	15580.6	15566.3	15551.6	15568.8	15580.6	15550.3	15550.3	15554.5
4	13333.5	10447.8	10434.8	10320.8	13333.5	10404.4	10230.1	10386.5	13333.5	10360.2	10412.5	10400.6
5	7557.8	6586.6	7001.9	6742.4	7557.8	6452.0	6583.3	6473.1	7353.9	6423.4	6443.6	6426.2
6	8833.2	7998.3	7988.4	7989.5	8833.2	7989.5	7989.5	7985.0	8833.2	7998.3	7974.1	7988.4
7	10479.8	7142.0	7300.1	7434.8	10479.8	7048.4	7137.1	6618.1	10479.8	7048.4	7040.5	7130.8
8	6617.7	6102.3	6133.8	6059.3	6617.7	6102.3	6059.3	6110.1	6617.7	6155.6	6023.3	6104.4
9	9151.3	8907.3	9018.7	8485.6	9151.3	8707.4	8986.1	8806.4	9151.3	8707.4	8986.5	9001.9
10	11156.2	7630.3	8490.6	7606.9	11156.2	7630.3	7606.9	7600.1	11156.2	7603.4	7590.5	7620.7
11	8661.9	8661.9	8661.9	8628.3	8299.0	8246.5	8299.0	8299.0	8299.0	8271.5	7890.2	8299.0
12	10185.9	8925.7	8549.7	8817.6	9351.3	8149.4	8688.4	8694.5	9991.1	8694.1	8809.0	8697.0
13	12290.6	7137.9	7667.4	7137.9	12290.6	7073.7	7092.4	7135.9	12290.6	7137.9	7137.9	7137.9
14	12185.7	11217.7	11216.0	11586.6	12185.7	11216.0	11249.4	11217.7	12185.7	11135.9	11217.7	11217.3
15	8875.9	7494.9	7591.9	7488.8	8875.9	7512.2	7488.8	7488.8	8875.9	7488.8	7488.8	7488.8
16	8717.5	6779.3	5763.0	5870.0	7973.3	5781.5	5859.8	5736.9	7973.3	5763.0	5694.6	5657.3
17	10682.9	7914.1	6796.7	7162.6	9677.4	6911.1	6666.5	6924.7	9677.4	6620.2	6904.1	6642.9
18	6985.2	5192.9	5270.4	5691.6	7841.2	4984.6	4990.7	4994.2	7841.2	4918.7	5030.9	5087.5
19	8237.5	5678.4	5663.6	5700.2	8237.5	5443.8	5437.2	5476.7	8237.5	5428.4	5427.1	5499.9
20	10065.9	7544.0	7190.6	7441.7	10065.9	7236.8	7249.7	7257.0	10065.9	7187.1	7261.4	7150.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75, Construction Heuristics=SPT1, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	7674.9	7597.2	7673.6	7673.6	7674.9	7597.2	7574.4	7674.9	7674.9	7597.2	7674.9	7673.6
2	9444.0	9189.3	9010.8	9009.5	9205.8	9106.5	8926.6	8995.2	9205.8	9009.5	9000.7	8921.5
3	15580.6	15566.3	15563.8	15340.1	15580.6	15566.3	15551.6	15568.8	15580.6	15550.3	15550.3	15554.5
4	13333.5	10447.8	10434.8	10320.8	13333.5	10404.4	10230.1	10386.5	13333.5	10360.2	10412.5	10400.6
5	8037.9	6695.2	6519.6	6477.9	8037.9	6549.9	6519.5	6463.6	8037.9	6549.9	6467.1	6473.6
6	8833.2	7998.3	7988.4	7989.5	8833.2	7989.5	7989.5	7985.0	8924.7	7988.4	7641.1	7974.1
7	10479.8	7142.0	7300.1	7434.8	10479.8	7048.4	7137.1	6618.1	10479.8	7048.4	7040.5	7130.8
8	6617.7	6155.6	6209.3	6016.3	6617.7	6155.6	6004.6	6095.3	6617.7	6155.6	6023.3	6104.4
9	9151.3	8907.3	9018.7	8485.6	9151.3	8707.4	8986.1	8806.4	9151.3	8707.4	8986.5	9001.9
10	11156.2	7630.3	8490.6	7606.9	11156.2	7630.3	7606.9	7600.1	11156.2	7603.4	7590.5	7620.7
11	9530.8	8929.8	9013.1	8949.2	9464.1	9022.5	8590.5	8991.9	9464.1	9022.5	8975.5	8830.2
12	9991.1	8719.5	8429.6	8619.6	9991.1	8694.1	8694.1	8698.3	9991.1	8694.1	8809.0	8697.0
13	12290.6	7137.9	7667.4	7137.9	12290.6	7073.7	7092.4	7135.9	12290.6	7137.9	7137.9	7137.9
14	12185.7	11135.9	11293.9	11228.0	12185.7	11217.3	11234.5	11217.7	12185.7	11135.9	11217.7	11217.3
15	8875.9	7494.9	7591.9	7488.8	8875.9	7512.2	7488.8	7488.8	8875.9	7488.8	7488.8	7488.8
16	8717.5	6779.3	5763.0	5870.0	7973.3	5781.5	5859.8	5736.9	9147.2	5670.2	5681.7	5681.7
17	9677.4	6913.9	7922.6	7700.6	9677.4	6911.1	6666.5	6924.7	9677.4	6620.2	6904.1	6642.9
18	7841.2	4991.6	5058.3	5344.5	7841.2	4984.6	4990.7	4994.2	7841.2	4918.7	5030.9	5087.5
19	8237.5	5678.4	5663.6	5700.2	8237.5	5443.8	5437.2	5476.7	8237.5	5428.4	5427.1	5499.9
20	10065.9	7544.0	7190.6	7441.7	10065.9	7236.8	7249.7	7257.0	10065.9	7187.1	7261.4	7150.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75, Construction Heuristics=SPT1, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	7674.9	7597.2	7673.6	7673.6	7674.9	7597.2	7574.4	7674.9	7674.9	7597.2	7674.9	7673.6
2	9444.0	9189.3	9010.8	9009.5	9205.8	9106.5	8926.6	8995.2	9205.8	9009.5	9000.7	8921.5
3	15963.6	15564.6	15568.8	15675.9	15963.6	15564.6	15568.8	15551.6	15963.6	15564.6	15564.6	15552.0
4	13333.5	10447.8	10434.8	10320.8	13333.5	10404.4	10230.1	10386.5	13333.5	10360.2	10412.5	10400.6
5	8037.9	6695.2	6519.6	6477.9	8037.9	6549.9	6519.5	6463.6	8037.9	6549.9	6467.1	6473.6
6	8924.7	7989.5	8158.6	7989.5	8924.7	7989.5	7999.1	7988.4	8924.7	7988.4	7641.1	7974.1
7	10479.8	7142.0	7300.1	7434.8	9425.6	7248.6	7042.3	7147.0	9425.6	7040.5	7034.4	7076.3
8	6617.7	6155.6	6209.3	6016.3	6617.7	6155.6	6004.6	6095.3	6617.7	6155.6	6023.3	6104.4
9	9151.3	8907.3	9018.7	8485.6	9151.3	8707.4	8986.1	8806.4	9151.3	8707.4	8986.5	9001.9
10	11156.2	7630.3	8490.6	7606.9	11156.2	7630.3	7606.9	7600.1	11156.2	7603.4	7590.5	7620.7
11	9530.8	8929.8	9013.1	8949.2	9464.1	9022.5	8590.5	8991.9	9464.1	9022.5	8975.5	8830.2
12	9991.1	8719.5	8429.6	8619.6	9991.1	8694.1	8694.1	8698.3	9991.1	8694.1	8809.0	8697.0
13	13284.0	8188.1	7967.0	7137.9	13284.0	7137.9	7137.9	7137.9	13284.0	7137.9	7137.9	7137.9
14	12185.7	11135.9	11293.9	11228.0	12185.7	11217.3	11234.5	11217.7	12185.7	11135.9	11217.7	11217.3
15	10373.5	7488.8	7585.8	7488.8	10373.5	7488.8	7488.8	7494.9	10373.5	7488.8	7488.8	7494.9
16	9147.2	5845.6	5943.9	6040.7	9147.2	5670.2	5772.8	5681.7	9147.2	5670.2	5681.7	5681.7
17	9677.4	6913.9	7922.6	7700.6	9677.4	6911.1	6666.5	6924.7	9677.4	6620.2	6904.1	6642.9
18	7841.2	4991.6	5058.3	5344.5	7841.2	4984.6	4990.7	4994.2	7841.2	4918.7	5030.9	5087.5
19	8237.5	5678.4	5663.6	5700.2	8237.5	5443.8	5437.2	5476.7	5498.5	5274.3	5234.3	5427.1
20	10065.9	7544.0	7190.6	7441.7	10065.9	7236.8	7249.7	7257.0	8852.5	7111.7	7160.5	7095.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=SPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	10126.1	7913.6	7966.9	7964.4	10126.1	7883.5	7887.3	7540.8	10126.1	7883.5	7810.2	7883.1
2	9975.0	9015.0	9025.7	9106.5	9975.0	9009.5	9041.0	9000.7	10713.8	9015.0	9009.5	9015.0
3	16565.0	15568.8	15566.3	15569.9	16565.0	15565.9	15554.5	15551.6	16565.0	15565.9	15551.6	15550.3
4	12041.2	10448.9	10436.7	10495.1	12041.2	10397.6	10548.5	10405.4	12041.2	10357.1	10281.1	9905.5
5	9486.0	6887.5	6590.9	6904.5	9486.0	6763.5	6556.4	7193.7	9486.0	6572.6	6438.9	6454.7
6	11552.6	8425.5	8356.9	8000.4	11552.6	7975.4	7905.2	7990.8	11552.6	8013.4	7975.4	7975.4
7	11616.8	7806.3	7134.7	7474.2	11616.8	7042.3	7040.5	7013.3	11616.8	7042.3	7097.1	7040.9
8	6735.7	6105.5	6217.3	6079.4	6735.7	6023.3	6004.6	6012.5	6735.7	6023.3	6004.6	6109.8
9	12066.1	9221.3	9015.3	8984.8	12066.1	8990.3	8984.8	9004.4	12066.1	8986.5	8518.1	9003.3
10	13507.5	7634.3	8727.9	8472.6	12318.0	7600.1	7659.8	7600.1	12318.0	7600.1	7611.1	7590.5
11	12723.1	8950.5	8975.5	9028.9	12723.1	8949.2	8946.3	8959.6	12723.1	8946.3	8731.9	9042.1
12	13572.8	9360.7	8773.2	10066.5	13572.8	8694.1	8726.3	8836.3	13860.9	8694.5	7986.2	8697.0
13	15648.3	8040.0	7334.4	7235.3	15648.3	7290.3	7137.9	7137.9	15648.3	6646.5	7097.0	7137.9
14	12983.8	11319.5	11327.3	11216.0	12983.8	11216.0	11216.0	11226.7	12983.8	11216.0	11226.7	11216.0
15	13964.7	7838.7	7688.1	7876.8	13964.7	7494.9	7494.9	7591.5	13964.7	7494.9	7488.8	7488.8
16	10044.0	5749.8	6309.3	5670.2	8873.4	5774.5	5781.6	5721.8	8873.4	5927.8	5750.1	5755.6
17	11503.3	7588.4	7131.7	6642.9	12283.0	7118.5	6798.3	6849.0	12283.0	6605.3	6726.7	6605.3
18	9967.9	5509.5	5677.6	6118.5	10007.1	5292.4	5775.8	5214.0	10007.1	4978.9	5210.2	5183.0
19	7840.3	5696.7	5505.1	5478.0	7519.3	5341.2	5271.8	5377.7	7465.4	5427.1	5427.1	5427.1
20	12595.2	7712.4	7416.7	8370.3	12588.5	7680.5	7508.5	7160.4	12588.5	7185.2	7751.0	7288.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=SPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	9914.0	7887.3	7886.0	7887.3	9914.0	7887.3	7883.1	7883.5	9914.0	7883.5	7192.6	7883.5
2	10713.8	9020.2	9067.3	9050.3	10713.8	9020.2	9009.5	9000.7	10713.8	9015.0	9009.5	9015.0
3	16565.0	15568.8	15566.3	15569.9	16565.0	15565.9	15554.5	15551.6	16565.0	15565.9	15551.6	15550.3
4	12041.2	10448.9	10436.7	10495.1	12041.2	10397.6	10548.5	10405.4	12041.2	10357.1	10281.1	9905.5
5	9486.0	6887.5	6590.9	6904.5	9164.1	6413.0	6723.5	6619.5	9164.1	6413.0	6425.3	6523.3
6	11552.6	8425.5	8356.9	8000.4	11552.6	7975.4	7905.2	7990.8	11552.6	8013.4	7975.4	7975.4
7	11616.8	7806.3	7134.7	7474.2	11616.8	7042.3	7040.5	7013.3	11616.8	7042.3	7097.1	7040.9
8	6735.7	6197.6	6159.2	6206.5	6735.7	6101.9	6100.6	6131.6	6735.7	6086.8	6082.1	6042.5
9	12066.1	9221.3	9015.3	8984.8	12066.1	8990.3	8984.8	9004.4	12066.1	8986.5	8518.1	9003.3
10	12318.0	7612.1	8315.0	7772.0	12318.0	7600.1	7659.8	7600.1	12318.0	7600.1	7611.1	7590.5
11	12723.1	8950.5	8975.5	9028.9	12745.9	8950.5	8949.2	8946.7	12745.9	8950.5	8946.7	8528.1
12	13860.9	8943.1	8826.7	8844.6	13860.9	8709.9	8694.5	8698.3	13860.9	8694.5	7986.2	8697.0
13	15648.3	8040.0	7334.4	7235.3	15648.3	7290.3	7137.9	7137.9	15648.3	6646.5	7097.0	7137.9
14	13085.7	11217.3	11403.2	11252.0	13085.7	11226.7	11234.5	11234.5	13085.7	11226.7	11233.5	11217.7
15	13964.7	7838.7	7688.1	7876.8	13964.7	7494.9	7494.9	7591.5	13964.7	7494.9	7488.8	7488.8
16	10044.0	5749.8	6309.3	5670.2	8873.4	5774.5	5781.6	5721.8	8873.4	5682.4	5785.7	5730.5
17	12283.0	7331.8	7238.5	7020.4	12283.0	7118.5	6798.3	6849.0	12283.0	6605.3	6726.7	6605.3
18	10007.1	5945.6	5991.1	6687.1	10007.1	5292.4	5775.8	5214.0	10007.1	4978.9	5210.2	5183.0
19	7840.3	5696.7	5505.1	5478.0	7519.3	5341.2	5271.8	5377.7	7465.4	5427.1	5427.1	5427.1
20	12595.2	7712.4	7416.7	8370.3	12588.5	7680.5	7508.5	7160.4	12588.5	7185.2	7751.0	7288.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=SPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	9914.0	7887.3	7886.0	7887.3	9914.0	7887.3	7883.1	7883.5	9914.0	7883.5	7192.6	7883.5
2	10713.8	9020.2	9067.3	9050.3	10713.8	9020.2	9009.5	9000.7	10713.8	9015.0	9009.5	9015.0
3	16565.0	15568.8	15566.3	15569.9	15550.2	14803.4	15550.2	15550.2	15459.4	15459.4	15076.4	15046.4
4	12041.2	10448.9	10436.7	10495.1	12041.2	10397.6	10548.5	10405.4	12041.2	10357.1	10281.1	9905.5
5	9164.1	6623.4	6625.8	6723.1	9164.1	6413.0	6723.5	6619.5	9164.1	6413.0	6425.3	6523.3
6	10079.0	8027.0	8140.2	8142.8	10019.7	7857.0	7912.4	7143.0	10019.7	7857.0	7990.8	7974.1
7	11616.8	7806.3	7134.7	7474.2	11616.8	7042.3	7040.5	7013.3	10660.7	7034.4	6958.0	7040.5
8	6735.7	6197.6	6159.2	6206.5	6735.7	6101.9	6100.6	6131.6	6735.7	6086.8	6082.1	6042.5
9	12066.1	9221.3	9015.3	8984.8	12066.1	8990.3	8984.8	9004.4	12066.1	8986.5	8518.1	9003.3
10	12318.0	7612.1	8315.0	7772.0	12318.0	7600.1	7659.8	7600.1	12318.0	7600.1	7611.1	7590.5
11	12769.2	8950.5	8983.3	9790.2	12745.9	8950.5	8949.2	8946.7	12745.9	8950.5	8946.7	8528.1
12	13860.9	8943.1	8826.7	8844.6	13860.9	8709.9	8694.5	8698.3	13860.9	8694.5	7986.2	8697.0
13	15648.3	8040.0	7334.4	7235.3	11489.2	7137.9	7137.9	7228.2	11489.2	7137.9	7137.9	7137.9
14	13085.7	11217.3	11403.2	11252.0	13085.7	11226.7	11234.5	11234.5	13085.7	11226.7	11233.5	11217.7
15	13510.3	8038.8	7696.8	7591.9	13510.3	7591.5	7494.9	7585.4	13510.3	7585.8	7494.9	7488.8
16	11899.3	6241.2	6762.0	6382.1	11899.3	5880.2	6290.5	5780.3	11899.3	5867.3	5749.8	5774.5
17	12283.0	7331.8	7238.5	7020.4	12283.0	7118.5	6798.3	6849.0	12283.0	6605.3	6726.7	6605.3
18	10007.1	5945.6	5991.1	6687.1	10007.1	5292.4	5775.8	5214.0	10007.1	4978.9	5210.2	5183.0
19	7840.3	5696.7	5505.1	5478.0	7519.3	5341.2	5271.8	5377.7	8737.5	5298.2	5521.2	5239.4
20	12595.2	7712.4	7416.7	8370.3	12588.5	7680.5	7508.5	7160.4	11536.5	7118.4	7170.5	7137.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	8575.3	7921.5	7887.3	7898.9	8575.3	7887.3	7898.9	7886.0	8575.3	7883.1	7883.5	7883.1
2	9711.2	9013.7	9009.5	9226.8	9711.2	8995.2	9016.1	8996.5	9711.2	8995.2	9010.8	9009.5
3	15851.7	15555.8	15583.1	15590.0	15345.0	15345.0	15345.0	15003.5	15345.0	15345.0	14979.7	15345.0
4	10491.9	10386.5	10302.2	10043.3	10260.3	10049.6	10260.3	10253.6	10260.3	10049.6	10260.3	10260.3
5	6706.0	6565.2	6706.0	6700.9	6706.0	6528.8	6706.0	6509.1	6706.0	6490.9	6511.3	6636.9
6	8785.6	7988.4	8001.4	8009.6	8431.6	7738.3	8025.0	8009.6	8431.6	7738.3	8009.6	8009.6
7	8566.3	7113.2	8041.5	7265.7	8566.3	7040.5	7040.5	7040.5	8566.3	7040.5	7097.1	7165.7
8	7973.1	6241.6	6116.1	6227.5	7973.1	6198.7	6112.3	6016.3	7555.4	6090.2	6023.3	6015.4
9	9056.3	8523.1	8984.8	9004.4	8509.6	8352.3	8509.6	8509.6	8509.4	8479.4	8398.1	8503.2
10	10216.0	7894.2	8083.5	8253.8	10216.0	7519.6	7649.7	7531.7	9026.6	7416.9	7590.5	7620.7
11	9018.7	8963.5	8984.7	8991.9	9018.7	8886.4	8965.9	8963.5	9018.7	8886.4	8963.5	8950.5
12	9731.5	8731.1	8764.3	8694.5	9731.5	8731.1	8694.5	8330.4	9666.7	8722.0	8694.1	8353.8
13	10398.1	7137.9	6572.1	7228.2	10398.1	7137.9	7137.9	7214.1	10398.1	7137.9	7137.9	6787.5
14	11520.2	11255.7	11234.5	10314.2	11520.2	10615.8	10314.2	11216.0	11520.2	10615.8	11217.7	11217.7
15	10479.2	7494.9	7494.9	7585.8	10479.2	7494.9	7494.9	7488.8	10479.2	7494.9	7585.8	7494.9
16	10538.2	6253.8	6637.0	6658.4	10538.2	6000.1	5730.2	5755.6	10538.2	5753.7	5681.7	5670.2
17	11241.0	6787.6	7524.8	8000.3	11241.0	6710.3	7228.2	6770.7	10449.0	6626.5	6651.1	6729.4
18	9284.1	6092.2	5862.0	5441.2	9284.1	5268.0	5151.6	4974.0	8648.6	5331.1	5284.2	4837.4
19	8091.5	5454.4	5454.4	6710.1	8091.5	5442.5	5767.5	5442.5	8091.5	5076.1	5427.1	5469.8
20	8464.2	7297.0	7443.3	7849.8	8464.2	7297.0	7148.5	7211.5	8464.2	7297.0	7167.5	7185.7

APPENDIX 8- SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	8575.3	7921.5	7887.3	7898.9	8603.3	7887.3	7883.5	7883.1	8603.3	7867.1	7901.4	7883.1
2	8889.4	8842.8	8889.4	8619.8	8889.4	8842.8	8889.4	8889.4	8889.4	8842.8	8889.4	8889.4
3	15851.7	15555.8	15583.1	15590.0	15345.0	15345.0	15345.0	15003.5	15345.0	15345.0	14979.7	15345.0
4	10491.9	10386.5	10302.2	10043.3	10260.3	10049.6	10260.3	10253.6	10260.3	10049.6	10260.3	10260.3
5	6706.0	6565.2	6706.0	6700.9	6706.0	6528.8	6706.0	6509.1	6931.9	6532.8	6480.9	6505.2
6	8785.6	7988.4	8001.4	8009.6	8431.6	7738.3	8025.0	8009.6	8431.6	7738.3	8009.6	8009.6
7	8566.3	7113.2	8041.5	7265.7	8566.3	7040.5	7040.5	7040.5	8566.3	7040.5	7097.1	7165.7
8	7973.1	6241.6	6116.1	6227.5	7666.5	6020.8	6023.3	6112.4	7666.5	6081.5	6093.6	6081.9
9	9056.3	9024.5	9047.6	9024.5	8509.6	8352.3	8509.6	8509.6	8509.4	8479.4	8398.1	8503.2
10	9026.6	7679.9	7950.2	7637.1	9026.6	7521.5	7525.0	7604.3	9026.6	7416.9	7590.5	7620.7
11	9018.7	8963.5	8984.7	8991.9	9018.7	8886.4	8965.9	8963.5	9156.1	8949.2	8964.6	8961.7
12	9123.4	8732.5	8694.5	8694.5	9123.4	8697.0	8694.5	8694.5	9123.4	8681.1	8229.2	8694.5
13	10398.1	7137.9	6572.1	7228.2	10398.1	7137.9	7137.9	7214.1	10398.1	7137.9	7137.9	6787.5
14	11306.3	11234.5	11255.7	11255.7	11283.0	11217.7	11235.2	11245.2	11283.0	10723.3	11226.7	11217.7
15	10479.2	7494.9	7494.9	7585.8	10479.2	7494.9	7494.9	7488.8	10479.2	7494.9	7585.8	7494.9
16	10538.2	6253.8	6637.0	6658.4	10538.2	6000.1	5730.2	5755.6	10538.2	5753.7	5681.7	5670.2
17	10449.0	6626.5	7367.7	6755.9	10449.0	6626.5	6731.3	7102.7	10449.0	6626.5	6651.1	6729.4
18	8648.6	5368.2	5356.4	5232.7	8648.6	5331.1	4990.5	4954.8	8648.6	5331.1	5284.2	4837.4
19	8091.5	5454.4	5454.4	6710.1	8091.5	5442.5	5767.5	5442.5	8091.5	5076.1	5427.1	5469.8
20	8464.2	7297.0	7443.3	7849.8	8464.2	7297.0	7148.5	7211.5	8464.2	7297.0	7167.5	7185.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	8603.3	7914.6	7921.5	7921.5	8603.3	7887.3	7883.5	7883.1	8603.3	7867.1	7901.4	7883.1
2	8889.4	8842.8	8889.4	8619.8	8889.4	8842.8	8889.4	8889.4	8889.4	8842.8	8889.4	8889.4
3	15851.7	15555.8	15583.1	15590.0	15345.0	15345.0	15345.0	15003.5	15604.3	15564.6	15551.6	15554.5
4	10491.9	10386.5	10302.2	10043.3	10260.3	10049.6	10260.3	10253.6	10260.3	10049.6	10260.3	10260.3
5	7251.8	6638.4	6642.1	6671.3	6931.9	6557.9	6720.2	6549.1	6931.9	6532.8	6480.9	6505.2
6	8642.7	8009.6	7303.6	8001.4	8510.8	8009.6	8055.0	7988.4	8510.8	8003.8	7974.1	8001.4
7	8566.3	7113.2	8041.5	7265.7	8566.3	7040.5	7040.5	7040.5	8566.3	7029.8	7040.1	7040.5
8	7666.5	6103.0	6086.8	6152.5	7666.5	6020.8	6023.3	6112.4	7666.5	6081.5	6093.6	6081.9
9	9056.3	9024.5	9047.6	9024.5	8509.6	8352.3	8509.6	8509.6	8509.4	8479.4	8398.1	8503.2
10	9026.6	7679.9	7950.2	7637.1	9026.6	7521.5	7525.0	7604.3	9026.6	7416.9	7590.5	7620.7
11	9156.1	9008.3	8964.6	8976.5	9156.1	8949.2	8950.5	8946.7	9156.1	8949.2	8964.6	8961.7
12	9123.4	8732.5	8694.5	8694.5	9123.4	8697.0	8694.5	8694.5	9123.4	8681.1	8229.2	8694.5
13	10398.1	7137.9	6572.1	7228.2	10398.1	7137.9	7137.9	7214.1	13009.6	7137.9	7137.9	7137.9
14	11306.3	11234.5	11255.7	11255.7	11283.0	11217.7	11235.2	11245.2	11283.0	10723.3	11226.7	11217.7
15	10479.2	7494.9	7494.9	7585.8	9343.7	7494.9	7585.4	7494.9	9343.7	7494.9	7488.8	7488.8
16	9123.6	6458.1	6661.6	5770.7	9123.6	5870.0	5757.8	5763.0	9123.6	5768.6	5897.1	5781.6
17	10449.0	6626.5	7367.7	6755.9	10449.0	6626.5	6731.3	7102.7	10449.0	6626.5	6651.1	6729.4
18	8648.6	5368.2	5356.4	5232.7	8648.6	5331.1	4990.5	4954.8	8648.6	5331.1	5284.2	4837.4
19	8091.5	5454.4	5454.4	6710.1	8091.5	5442.5	5767.5	5442.5	9267.4	5428.4	5454.4	5443.8
20	8464.2	7297.0	7443.3	7849.8	8464.2	7297.0	7148.5	7211.5	8464.2	7297.0	7167.5	7185.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	8218.3	7900.3	7564.3	7441.5	8218.3	7886.0	7441.5	6811.4	8218.3	7642.2	7638.6	7687.5
2	10338.7	9009.5	9009.5	9036.8	10338.7	9009.5	9013.7	9013.7	10338.7	9009.5	8996.5	9013.7
3	16211.6	15571.2	15570.1	15552.0	16211.6	15567.4	15554.5	15550.3	16211.6	15552.0	15550.3	15551.6
4	11443.1	10007.4	10356.8	9973.1	10768.9	10400.5	10282.9	10366.2	10768.9	10182.3	10363.2	10231.2
5	7364.4	6774.3	6478.2	6531.2	7364.4	6416.3	6492.5	6495.7	7364.4	6416.3	6454.9	6432.4
6	10875.7	7975.4	7988.4	8013.4	10445.2	7975.4	7988.4	7988.4	10445.2	7975.4	6858.2	7988.4
7	11191.1	7310.2	7269.4	7643.3	11191.1	7102.8	7178.5	7040.5	11191.1	7102.8	7040.5	7149.9
8	6593.8	6109.1	6019.5	6109.1	6593.8	6086.8	6081.5	6113.6	6593.8	6086.8	6012.5	6000.8
9	9868.6	8697.8	8984.8	9255.6	9726.2	8886.2	9039.9	8777.1	12267.2	9139.4	8607.4	8986.5
10	10397.2	7821.8	7872.9	7862.9	10397.2	7650.4	7624.7	7552.4	10397.2	7650.4	7594.7	7361.6
11	12767.6	9538.2	8370.8	8478.4	12767.6	8975.5	8959.8	9186.6	12767.6	8949.2	8950.5	7397.4
12	11532.8	8942.3	8271.5	8556.2	11532.8	8496.9	8698.3	8694.5	11532.8	8496.9	8707.7	8694.1
13	13211.3	6628.9	7137.9	7396.5	13211.3	6628.9	7137.9	7137.9	13211.3	6628.9	7137.9	7320.3
14	13767.0	11269.8	11485.5	11255.7	13684.2	11245.2	11217.7	11216.0	13684.2	11216.0	11216.0	11226.7
15	11575.1	7591.5	7370.3	8309.3	11575.1	7494.9	7488.8	7591.5	11575.1	7494.9	7494.9	7441.1
16	9924.8	5846.9	6665.3	6698.7	9924.8	5794.5	5870.1	5744.3	9924.8	5773.6	5681.7	5836.6
17	11710.8	6842.1	6858.6	7013.2	11710.8	6721.7	6814.6	6659.9	9704.8	6605.3	6275.0	6605.3
18	7288.6	5387.8	5255.2	5467.3	7281.1	5274.7	5310.1	5006.6	7281.1	5089.9	5086.0	4985.5
19	9770.4	5439.3	6371.8	5388.6	9770.4	5427.1	5454.4	5427.1	9770.4	5427.1	5372.8	5428.4
20	11172.9	7483.3	8083.4	7963.1	11172.9	7181.8	7402.1	7220.3	11172.9	7181.8	7122.6	7111.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75, Construction Heuristics=LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	8218.3	7900.3	7564.3	7441.5	10168.4	7983.0	7900.3	7107.9	10168.4	7911.0	7615.1	7913.3
2	10338.7	9009.5	9009.5	9036.8	10354.1	9041.0	8995.2	9015.0	10354.1	9041.0	9010.6	9013.7
3	16211.6	15571.2	15570.1	15552.0	16211.6	15567.4	15554.5	15550.3	16211.6	15552.0	15550.3	15551.6
4	10768.9	10768.9	10337.1	10138.2	10768.9	10400.5	10282.9	10366.2	10768.9	10182.3	10363.2	10231.2
5	7364.4	6774.3	6478.2	6531.2	7364.4	6416.3	6492.5	6495.7	7364.4	6416.3	6454.9	6432.4
6	10875.7	7975.4	7988.4	8013.4	10445.2	7975.4	7988.4	7988.4	10445.2	7975.4	6858.2	7988.4
7	11191.1	7310.2	7269.4	7643.3	11191.1	7102.8	7178.5	7040.5	11191.1	7102.8	7040.5	7149.9
8	6593.8	6109.1	6019.5	6109.1	6593.8	6086.8	6081.5	6113.6	7792.7	6028.3	6054.9	6101.9
9	12267.2	9499.4	8796.5	9004.6	12267.2	9139.4	8990.3	9112.3	12267.2	9139.4	8607.4	8986.5
10	13165.3	8631.3	9085.0	7899.8	13165.3	8326.5	7608.3	7620.7	13165.3	7630.3	7590.9	7295.3
11	12767.6	9538.2	8370.8	8478.4	12767.6	8975.5	8959.8	9186.6	12767.6	8949.2	8950.5	7397.4
12	11532.8	8942.3	8271.5	8556.2	8560.4	7968.2	8560.4	8560.4	8560.4	8472.9	8280.9	8560.4
13	13211.3	6628.9	7137.9	7396.5	13211.3	6628.9	7137.9	7137.9	13211.3	6628.9	7137.9	7320.3
14	13767.0	11269.8	11485.5	11255.7	15725.7	11226.7	11234.5	11228.4	15725.7	11216.0	11051.2	10627.7
15	11575.1	7591.5	7370.3	8309.3	11575.1	7494.9	7488.8	7591.5	11575.1	7494.9	7494.9	7441.1
16	9924.8	5846.9	6665.3	6698.7	9924.8	5794.5	5870.1	5744.3	9924.8	5773.6	5681.7	5836.6
17	9704.8	7374.8	6791.1	6875.0	9704.8	6688.8	6820.7	6629.9	9704.8	6605.3	6275.0	6605.3
18	7657.2	5747.1	5190.5	5831.4	7657.2	5261.6	5671.4	5510.5	7657.2	5261.6	5477.3	5218.2
19	9770.4	5439.3	6371.8	5388.6	9770.4	5427.1	5454.4	5427.1	9770.4	5427.1	5372.8	5428.4
20	11172.9	7483.3	8083.4	7963.1	11172.9	7181.8	7402.1	7220.3	11172.9	7181.8	7122.6	7111.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPTcomp,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22	No TS	TS with Tabu =8	TS with Tabu =15	TS with Tabu =22
1	10168.4	8011.8	8018.9	7998.4	10168.4	7983.0	7900.3	7107.9	10168.4	7911.0	7615.1	7913.3
2	10354.1	9041.0	9051.7	8995.2	10354.1	9041.0	8995.2	9015.0	10354.1	9041.0	9010.6	9013.7
3	16211.6	15571.2	15570.1	15552.0	16211.6	15567.4	15554.5	15550.3	16211.6	15552.0	15550.3	15551.6
4	10768.9	10768.9	10337.1	10138.2	10768.9	10400.5	10282.9	10366.2	10768.9	10182.3	10363.2	10231.2
5	7625.3	6508.6	6699.6	6567.4	7625.3	6508.6	6540.2	6505.1	7625.3	6508.6	6479.7	6470.7
6	10875.7	7975.4	7988.4	8013.4	10545.9	7688.0	7792.1	7668.8	10545.9	7975.4	7595.2	7121.2
7	11191.1	7310.2	7269.4	7643.3	11191.1	7102.8	7178.5	7040.5	11191.1	7102.8	7040.5	7149.9
8	7792.7	6093.2	6116.3	6125.3	7792.7	6031.2	6109.8	6086.4	7792.7	6028.3	6054.9	6101.9
9	12267.2	9499.4	8796.5	9004.6	12267.2	9139.4	8990.3	9112.3	12267.2	9139.4	8607.4	8986.5
10	13165.3	8631.3	9085.0	7899.8	13165.3	8326.5	7608.3	7620.7	13165.3	7630.3	7590.9	7295.3
11	10236.9	8528.8	8151.8	8950.5	9842.3	8605.7	7667.9	8964.6	9759.6	8793.9	8834.3	9064.7
12	8560.4	8472.9	8254.0	8092.8	8560.4	7968.2	8560.4	8560.4	8560.4	8472.9	8280.9	8560.4
13	13211.3	6628.9	7137.9	7396.5	13211.3	6628.9	7137.9	7137.9	13211.3	6628.9	7137.9	7320.3
14	15725.7	11251.9	11207.3	10641.0	15725.7	11226.7	11234.5	11228.4	15725.7	11216.0	11051.2	10627.7
15	11575.1	7591.5	7370.3	8309.3	11575.1	7494.9	7488.8	7591.5	10149.2	7494.9	7488.8	7591.5
16	9924.8	5846.9	6665.3	6698.7	7806.3	5838.4	5846.7	5790.9	7689.1	5716.1	5718.6	5750.1
17	9704.8	7374.8	6791.1	6875.0	9704.8	6688.8	6820.7	6629.9	9704.8	6605.3	6275.0	6605.3
18	7657.2	5747.1	5190.5	5831.4	7657.2	5261.6	5671.4	5510.5	7657.2	5261.6	5477.3	5218.2
19	9770.4	5439.3	6371.8	5388.6	9770.4	5427.1	5454.4	5427.1	9770.4	5427.1	5372.8	5428.4
20	11172.9	7483.3	8083.4	7963.1	11172.9	7181.8	7402.1	7220.3	11172.9	7181.8	7122.6	7111.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	7850.8	7687.1	7687.1	7687.1	7891.9	7392.3	7392.3	7392.3	7842.1	7792.5	7792.5	7792.5
2	12832.2	11429.4	11428.4	11577.2	12832.2	11429.4	11413.7	11398.3	12832.2	11461.3	11412.0	11396.6
3	15209.9	15003.0	14927.3	15097.1	15209.9	15003.0	15003.0	15209.9	15209.9	15003.0	14986.2	15003.0
4	12399.6	10859.0	10374.8	10581.8	12165.7	10482.1	10454.9	10413.2	12099.0	10441.0	10400.5	10136.7
5	12126.2	8635.0	8494.7	8356.4	12126.2	8119.9	7011.0	6741.7	12126.2	7767.1	6763.4	6859.4
6	13415.5	10788.0	9753.7	9896.0	13415.5	9744.1	9728.7	10048.5	13415.5	9511.6	9728.7	9129.8
7	14240.8	9162.7	9862.9	9079.1	14240.8	8638.7	8840.8	8569.0	14240.8	8599.4	8535.6	8541.7
8	10941.2	7919.5	7921.0	7829.8	10941.2	7565.6	7703.7	7773.2	10941.2	7695.1	7624.7	7582.3
9	12089.9	11469.5	11285.8	11923.8	12089.9	11260.8	11018.8	11030.4	12089.9	10728.4	11034.6	11279.3
10	14722.7	9796.6	11592.1	10209.0	14722.7	9796.6	9788.9	9872.7	14722.7	9796.6	10380.1	9613.6
11	12980.5	12009.0	12258.5	11985.9	12941.2	11960.8	11931.5	11945.8	12941.2	11323.0	11948.2	11599.3
12	13452.6	11469.6	11780.4	11825.5	13429.1	11613.1	11565.1	11457.2	14538.7	11553.9	11549.7	11525.5
13	15812.3	10873.8	10070.8	9320.1	15812.3	9461.4	9077.1	9210.1	15812.3	9320.1	9320.1	9320.1
14	15926.1	14184.6	14190.1	14173.9	15926.1	14172.6	14173.9	14184.6	15926.1	14172.6	14172.6	14172.6
15	13614.5	9766.9	9863.5	9863.5	13614.5	9766.9	9857.8	9522.4	13614.5	9766.9	9760.8	9760.8
16	13195.5	8604.0	7865.4	9983.9	13195.5	7568.6	7664.1	7488.7	13195.5	7542.5	7656.9	7688.5
17	14092.2	10037.7	10602.8	9322.7	14024.0	8749.2	9486.8	8585.1	13979.9	8418.3	8639.3	8655.9
18	11532.0	8277.0	8293.0	8577.6	11532.0	7809.1	8154.2	8015.3	11532.0	7616.2	7795.4	7809.7
19	8561.2	7498.4	7455.4	7019.0	9728.2	7110.3	6719.2	6618.8	9728.2	6841.1	6711.6	6955.9
20	12940.6	9695.5	10137.0	9712.6	12940.6	9087.5	9046.5	9083.5	13023.7	9019.5	9034.3	9004.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	7891.9	7887.3	7887.3	7887.3	7697.8	7697.8	7697.8	7697.8	7823.7	6980.1	6980.1	6980.1
2	12832.2	11429.4	11428.4	11577.2	12832.2	11429.4	11413.7	11398.3	12832.2	11461.3	11412.0	11396.6
3	15209.9	15003.0	14927.3	15097.1	15209.9	15003.0	15003.0	15209.9	16301.0	15552.0	15550.3	15552.0
4	13488.1	10828.9	10630.5	10554.3	13488.1	10386.5	10357.1	10533.0	13488.1	10386.9	10513.9	10386.5
5	12126.2	8635.0	8494.7	8356.4	12126.2	8119.9	7011.0	6741.7	11600.2	7025.1	6998.7	7097.1
6	13415.5	10788.0	9753.7	9896.0	13415.5	9744.1	9728.7	10048.5	13415.5	9511.6	9728.7	9129.8
7	14240.8	9162.7	9862.9	9079.1	14240.8	8638.7	8840.8	8569.0	14240.8	8599.4	8535.6	8541.7
8	10941.2	7919.5	7921.0	7829.8	10941.2	7641.3	7659.0	7786.6	10941.2	7693.6	7727.0	7622.6
9	11678.1	11304.3	11293.6	11269.5	11508.0	11192.4	11287.5	10606.6	11508.0	11279.3	11030.5	11262.1
10	12980.8	10948.1	10065.3	10666.1	12980.8	9942.6	9637.1	9870.6	12980.8	9964.0	9704.4	9875.8
11	12980.5	12009.0	12258.5	11985.9	12941.2	11960.8	11931.5	11945.8	12941.2	11323.0	11948.2	11599.3
12	14538.7	12139.9	11794.8	11227.1	14538.7	11750.3	11553.9	11516.8	14538.7	11553.9	11549.7	11525.5
13	15812.3	10873.8	10070.8	9320.1	15812.3	9461.4	9077.1	9210.1	15812.3	9320.1	9320.1	9320.1
14	15926.1	14184.6	14190.1	14173.9	14766.3	14268.0	14172.6	14174.3	14766.3	14172.6	14172.6	14174.3
15	13614.5	9766.9	9863.5	9863.5	13614.5	9766.9	9857.8	9522.4	13787.9	9760.8	9766.9	9760.8
16	13195.5	8604.0	7865.4	9983.9	13195.5	7568.6	7664.1	7488.7	13195.5	7542.5	7656.9	7688.5
17	14092.2	10037.7	10602.8	9322.7	14024.0	8749.2	9486.8	8585.1	13979.9	8418.3	8639.3	8655.9
18	11532.0	8277.0	8293.0	8577.6	11532.0	7809.1	8154.2	8015.3	11532.0	7616.2	7795.4	7809.7
19	9728.2	7386.4	7621.3	7468.8	9728.2	7110.3	6719.2	6618.8	9728.2	6841.1	6711.6	6955.9
20	13408.7	10092.9	10867.5	9214.1	13023.7	9209.6	9052.8	9051.7	13023.7	9019.5	9034.3	9004.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	7891.9	7891.9	7891.9	7891.9	7839.3	7839.3	7839.3	7839.3	7839.3	7839.3	7839.3	7839.3
2	13432.3	11868.5	11563.0	11446.2	13432.3	11429.4	11398.3	11412.6	13432.3	11433.9	11429.4	11429.4
3	16301.0	15552.0	15228.9	15661.5	16301.0	15094.6	15422.3	15752.1	16301.0	15552.0	15550.3	15552.0
4	13488.1	10828.9	10630.5	10554.3	13488.1	10386.5	10357.1	10533.0	13488.1	10386.9	10513.9	10386.5
5	11600.2	8290.3	8278.9	7996.0	11600.2	8033.5	7126.9	7556.2	11600.2	7025.1	6998.7	7097.1
6	13415.5	10788.0	9753.7	9896.0	12888.0	9755.0	9753.7	9728.7	12888.0	9755.0	9755.0	9606.2
7	14776.0	10114.0	9073.6	9010.1	14776.0	8571.9	9080.9	9119.5	14776.0	8403.7	8535.6	8500.3
8	10941.2	7985.8	7771.6	7988.3	10941.2	7641.3	7659.0	7786.6	10941.2	7693.6	7727.0	7622.6
9	11678.1	11304.3	11293.6	11269.5	11508.0	11192.4	11287.5	10606.6	11508.0	11279.3	11030.5	11262.1
10	12980.8	10948.1	10065.3	10666.1	12980.8	9942.6	9637.1	9870.6	12980.8	9964.0	9704.4	9875.8
11	12980.5	12009.0	12258.5	11985.9	13035.2	11967.0	11928.6	11932.8	13035.2	11931.5	11931.5	11945.8
12	14538.7	12139.9	11794.8	11227.1	14538.7	11750.3	11553.9	11516.8	14538.7	11553.9	11549.7	11525.5
13	15812.3	10873.8	10070.8	9320.1	15812.3	9461.4	9077.1	9210.1	13188.2	9320.1	9396.3	9320.1
14	15297.7	14299.2	13819.9	14172.6	14766.3	14268.0	14172.6	14174.3	14766.3	14172.6	14172.6	14174.3
15	13787.9	10018.7	10377.2	10124.8	13787.9	9760.8	9857.4	9766.9	13787.9	9760.8	9766.9	9760.8
16	10489.5	8101.9	8192.0	9945.3	10489.5	7591.3	7741.0	8324.4	10489.5	7591.3	8153.8	7694.4
17	14092.2	10037.7	10602.8	9322.7	15097.9	8832.6	9211.4	8739.3	15097.9	8462.2	9129.5	8856.7
18	10445.4	7902.6	8575.4	8243.9	10445.4	7661.3	7858.5	8266.6	10445.4	7661.3	7960.2	7755.1
19	9728.2	7386.4	7621.3	7468.8	9728.2	7110.3	6719.2	6618.8	9270.2	6648.4	7032.1	7023.5
20	13408.7	10092.9	10867.5	9214.1	13023.7	9209.6	9052.8	9051.7	13023.7	9019.5	9034.3	9004.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	8125.1	8125.1	8125.1	8125.1	7932.1	7915.7	7915.7	7915.7	7883.1	7883.1	7883.1	7883.1
2	15400.6	11416.4	11434.9	11427.1	15400.6	11416.4	11451.7	11427.1	15400.6	11416.4	11402.1	11398.3
3	18318.7	15550.3	15554.5	15580.8	18297.3	15565.9	15554.5	15571.2	18297.3	15552.0	15503.4	15568.8
4	12089.8	10589.6	10663.7	10735.4	13257.2	10453.9	10441.0	10123.9	13257.2	10453.9	10447.8	10411.5
5	12632.2	8267.0	7964.1	7294.4	12632.2	7232.2	7074.3	7291.0	12632.2	7232.2	6933.8	6965.5
6	15087.7	10140.1	9779.6	10926.8	15087.7	10140.1	9779.6	9755.0	14779.4	9755.0	9798.5	9896.8
7	17065.1	10228.8	9551.1	11173.2	17065.1	8755.4	9346.1	8280.0	17065.1	8421.4	8527.2	8397.6
8	13523.7	8182.7	9194.2	7775.2	13523.7	7693.2	7670.7	7607.3	13523.7	7688.8	7612.0	7634.3
9	15946.0	11315.9	12877.6	13560.7	15946.0	11265.0	11262.1	11659.2	15946.0	10995.2	11290.0	10924.7
10	18413.6	13881.9	12202.8	11634.7	18413.6	10875.4	11670.8	11350.4	15368.3	9536.1	9592.5	9802.1
11	16455.9	13569.2	11948.2	12507.5	16410.5	11932.8	11928.6	11931.5	16410.5	11932.8	11929.0	11967.0
12	16857.0	12380.1	11830.4	12808.8	15630.6	11300.9	11578.9	11565.1	15630.6	11460.8	11018.3	11254.1
13	19453.3	9903.5	9482.8	11496.6	19453.3	9320.1	9320.1	9320.1	19453.3	9320.1	9175.7	9320.1
14	18270.8	14380.1	14550.7	14276.1	18270.8	14265.4	14173.9	14191.1	18270.8	14173.9	14173.9	14191.1
15	19397.9	11656.4	11107.9	12259.4	19397.9	9954.0	9857.8	10298.7	19397.9	9954.0	9825.7	9863.9
16	14320.8	8733.2	10010.0	10579.6	14320.8	7719.4	7699.2	7791.2	14320.8	7457.1	7488.7	7749.3
17	16960.1	9015.4	9560.3	10537.7	16960.1	8291.5	8466.0	9311.4	16960.1	8291.5	9216.8	8861.8
18	14818.5	9104.5	9593.1	8341.0	14818.5	8468.5	7826.8	7814.6	14818.5	7906.3	7809.1	7797.9
19	13283.8	9108.2	7801.4	7501.3	13283.8	7120.7	7122.7	7405.2	13283.8	6827.6	6702.7	7322.2
20	18179.5	11775.8	12424.7	10941.1	18179.5	9542.6	9036.9	9161.8	18179.5	9812.4	8881.3	9333.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	9545.2	9545.2	9545.2	9545.2	7932.1	7915.7	7915.7	7915.7	7898.5	7883.1	7883.1	7883.1
2	15400.6	11416.4	11434.9	11427.1	15400.6	11416.4	11451.7	11427.1	15400.6	11416.4	11402.1	11398.3
3	18009.2	15570.1	15584.8	15554.5	17851.5	15555.8	15554.5	15018.2	17851.5	15550.3	15566.3	15555.8
4	13729.1	10703.6	10403.6	10949.8	13257.2	10453.9	10441.0	10123.9	13257.2	10453.9	10447.8	10411.5
5	12632.2	8267.0	7964.1	7294.4	9597.2	7763.7	7258.5	7821.6	9597.2	7457.2	6976.8	7209.4
6	15087.7	10140.1	9779.6	10926.8	15087.7	10140.1	9779.6	9755.0	14779.4	9755.0	9798.5	9896.8
7	17065.1	10228.8	9551.1	11173.2	15279.7	8653.0	8535.6	9423.9	15279.7	8500.3	8411.6	8590.0
8	13297.1	8244.4	8538.8	8231.0	13297.1	7703.7	7638.5	7617.6	13297.1	7529.8	7537.7	7800.3
9	15946.0	11311.7	12088.8	11921.2	15946.0	11265.0	11262.1	11659.2	15946.0	10995.2	11290.0	10924.7
10	15383.2	11516.8	11806.5	12098.0	15368.3	10267.8	9841.9	10206.6	15368.3	9536.1	9592.5	9802.1
11	16455.9	13569.2	11948.2	12507.5	16410.5	11932.8	11928.6	11931.5	17690.0	11932.8	11928.6	11928.6
12	16857.0	12380.1	11830.4	12808.8	15630.6	11300.9	11578.9	11565.1	15630.6	11460.8	11018.3	11254.1
13	19453.3	9903.5	9482.8	11496.6	19453.3	9320.1	9320.1	9320.1	19453.3	9320.1	9175.7	9320.1
14	18668.9	15805.6	14322.3	15565.1	18668.9	14172.6	14184.6	14191.1	18668.9	14172.6	14174.3	14183.3
15	19397.9	11656.4	11107.9	12259.4	19783.5	10051.0	9857.4	9760.8	19783.5	9857.4	9863.5	9766.9
16	14320.8	8733.2	10010.0	10579.6	14320.8	7719.4	7699.2	7791.2	11619.9	7515.9	7657.0	7917.1
17	16960.1	9015.4	9560.3	10537.7	16960.1	8291.5	8466.0	9311.4	16960.1	8291.5	9216.8	8861.8
18	14818.5	9104.5	9593.1	8341.0	13585.7	7799.2	7861.0	7993.5	13585.7	7567.0	7487.2	7876.7
19	13283.8	9108.2	7801.4	7501.3	13283.8	7120.7	7122.7	7405.2	13283.8	6827.6	6702.7	7322.2
20	18179.5	11775.8	12424.7	10941.1	18179.5	9542.6	9036.9	9161.8	18179.5	9812.4	8881.3	9333.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	8888.9	8692.6	8692.6	8692.6	8886.2	8710.4	8710.4	8710.4	8006.1	8006.1	8006.1	8006.1
2	14400.1	11416.4	11987.1	11508.3	14400.1	11416.4	11402.1	11412.6	14400.1	11412.0	11410.9	11396.6
3	18009.2	15570.1	15584.8	15554.5	17851.5	15555.8	15554.5	15018.2	17851.5	15550.3	15566.3	15555.8
4	13729.1	10703.6	10403.6	10949.8	13257.2	10453.9	10441.0	10123.9	13257.2	10453.9	10447.8	10411.5
5	9597.2	8756.6	7222.0	7299.2	9597.2	7763.7	7258.5	7821.6	9597.2	7457.2	6976.8	7209.4
6	15277.1	10537.5	10537.6	11224.4	15277.1	9807.6	9730.0	10083.0	15277.1	9728.7	9494.5	9733.1
7	15279.7	9035.8	10402.7	9383.0	15279.7	8630.1	8684.1	8541.7	15279.7	8500.3	8411.6	8590.0
8	13297.1	8244.4	8538.8	8231.0	13297.1	7703.7	7638.5	7617.6	13297.1	7529.8	7537.7	7800.3
9	15946.0	11311.7	12088.8	11921.2	15946.0	11265.0	11262.1	11659.2	15946.0	10995.2	11290.0	10924.7
10	15383.2	11516.8	11806.5	12098.0	15368.3	10267.8	9841.9	10206.6	15368.3	9536.1	9592.5	9802.1
11	17690.0	12044.8	13693.5	12704.7	17690.0	11965.6	11929.0	11944.0	17690.0	11932.8	11928.6	11928.6
12	16857.0	12380.1	11830.4	12808.8	15630.6	11300.9	11578.9	11565.1	17203.5	11549.7	11550.1	11549.7
13	19453.3	9903.5	9482.8	11496.6	17326.6	9396.3	9257.7	9450.6	17326.6	8829.3	9396.3	9320.1
14	18668.9	15805.6	14322.3	15565.1	18668.9	14172.6	14184.6	14191.1	18668.9	14172.6	14174.3	14183.3
15	19783.5	11275.8	11950.0	9983.5	19783.5	10051.0	9857.4	9760.8	19783.5	9857.4	9863.5	9766.9
16	11853.5	9083.6	8737.3	9519.8	11619.9	7916.9	7656.9	7666.9	11619.9	7515.9	7657.0	7917.1
17	12729.4	9720.5	9834.9	9298.6	12729.4	8332.7	8856.1	8600.7	12729.4	8501.3	8505.8	8957.1
18	13631.8	7831.0	9463.4	8590.7	13585.7	7799.2	7861.0	7993.5	13585.7	7567.0	7487.2	7876.7
19	13283.8	9108.2	7801.4	7501.3	12813.6	6794.6	7519.3	6914.8	12813.6	6770.3	7045.1	6556.3
20	18179.5	11775.8	12424.7	10941.1	18179.5	9542.6	9036.9	9161.8	14623.1	9131.2	8988.8	9031.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	8227.4	8227.4	8227.4	8227.4	8140.8	8126.5	8126.5	8126.5	7642.2	7642.2	7642.2	7642.2
2	12806.0	11468.1	11429.4	11446.2	12806.0	11436.3	11410.9	11416.4	12806.0	11396.6	11443.5	11429.4
3	15928.9	15583.1	15550.3	15564.6	15928.9	15550.3	15564.6	15584.2	16023.8	15551.6	15564.6	15555.8
4	12891.5	10907.2	10415.7	11058.0	12891.5	10412.1	10493.1	10386.5	12891.5	10188.1	10424.7	10588.6
5	8782.9	7576.3	7593.1	7047.7	8782.9	7529.3	7169.1	7785.8	11203.7	6955.3	6931.2	6673.4
6	11383.9	10455.2	10221.1	10000.4	11383.9	9891.5	9882.5	9756.0	11383.9	9745.4	9778.3	9730.0
7	13419.7	8837.5	8810.7	11050.8	13419.7	8535.6	8541.7	8501.9	13419.7	8508.9	8463.7	8565.0
8	11426.2	8289.6	7662.8	8730.3	11894.5	7695.5	7641.7	7659.0	11894.5	7688.8	7656.5	7552.3
9	10867.5	10447.6	10604.1	10867.5	10867.5	10474.6	10867.5	10536.5	10867.5	10447.6	10867.5	10531.7
10	13485.3	10733.7	10966.8	11424.9	13485.3	10716.0	10286.4	9916.6	12848.7	9772.1	9742.1	9772.3
11	12827.2	11544.3	11977.6	11571.4	12827.2	11169.7	11548.2	11928.6	12827.2	11169.7	11450.9	11929.0
12	14193.0	12016.5	11619.9	12070.1	14193.0	11565.1	11549.7	11588.1	13758.8	11550.1	11550.1	11549.7
13	14080.3	9320.1	9320.1	10149.8	14080.3	9320.1	9320.1	9396.3	14080.3	9320.1	9286.3	9320.1
14	15874.9	13308.5	14212.3	14223.0	15874.9	13308.5	14201.8	14173.9	14875.2	12890.2	14174.3	14212.3
15	14591.8	9863.5	9965.8	10101.5	14591.8	9857.4	9766.9	9766.9	14591.8	9857.4	9760.8	9766.9
16	12803.0	8225.7	8827.7	8776.3	12140.6	7605.4	7574.1	7534.6	12140.6	7500.2	7579.9	7738.7
17	13650.3	9675.9	9607.4	9676.0	12517.4	8602.5	8549.6	8521.0	12517.4	8516.0	8655.4	8475.2
18	11297.3	7939.8	8812.5	8185.4	11297.3	8095.0	7795.0	7828.2	11297.3	7908.8	7701.2	7795.0
19	12267.9	8069.4	7117.9	7362.2	12267.9	7036.7	6766.8	6926.8	12267.9	7036.7	6899.4	6592.0
20	11893.9	9884.2	9494.8	10232.1	11318.0	8970.3	9103.3	9199.2	11318.0	8454.7	8987.5	9269.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	8227.4	8227.4	8227.4	8227.4	8140.8	7990.2	7990.2	7990.2	8238.8	7719.2	7719.2	7719.2
2	12806.0	11468.1	11429.4	11446.2	12806.0	11436.3	11410.9	11416.4	13495.6	11415.1	11396.6	11429.4
3	16023.8	15552.0	15566.3	15290.6	16023.8	15552.0	15290.6	15555.8	16023.8	15551.6	15564.6	15555.8
4	12891.5	10907.2	10415.7	11058.0	12891.5	10412.1	10493.1	10386.5	12891.5	10188.1	10424.7	10588.6
5	11203.7	7759.4	8622.3	8629.0	11203.7	7368.4	7206.6	7811.9	11203.7	6955.3	6931.2	6673.4
6	11383.9	10455.2	10221.1	10000.4	11383.9	9891.5	9882.5	9756.0	12114.0	9165.6	9728.7	9728.7
7	14331.6	10131.9	9872.2	9167.3	14331.6	9046.8	8591.6	8565.0	14331.6	8397.6	8494.2	8453.8
8	11894.5	8563.7	8060.8	7879.7	11894.5	7695.5	7641.7	7659.0	11894.5	7688.8	7656.5	7552.3
9	10867.5	10447.6	10604.1	10867.5	10867.5	10474.6	10867.5	10536.5	10867.5	10447.6	10867.5	10531.7
10	13485.3	10733.7	10966.8	11424.9	13485.3	10716.0	10286.4	9916.6	12848.7	9772.1	9742.1	9772.3
11	12827.2	11544.3	11977.6	11571.4	11738.6	11738.6	11738.6	11672.2	11738.6	11738.6	11377.7	11583.7
12	14193.0	12016.5	11619.9	12070.1	14193.0	11565.1	11549.7	11588.1	13758.8	11550.1	11550.1	11549.7
13	14080.3	9320.1	9320.1	10149.8	14080.3	9320.1	9320.1	9396.3	14080.3	9320.1	9286.3	9320.1
14	15917.2	12816.2	14421.8	14191.4	14875.2	12890.2	14185.0	14172.6	14875.2	12890.2	14174.3	14212.3
15	13204.2	9766.9	9863.5	9766.9	13118.6	9766.9	9766.9	9940.5	13118.6	9766.9	9760.8	9766.9
16	12803.0	8225.7	8827.7	8776.3	14677.9	8120.6	7500.2	7632.5	14677.9	7617.5	7632.5	7500.2
17	13650.3	9675.9	9607.4	9676.0	15272.3	8881.2	9303.0	8633.8	15272.3	8553.0	8524.6	8576.9
18	12688.0	8172.0	8755.3	9411.1	12688.0	7951.3	8257.4	7799.2	12688.0	7797.9	7795.4	7795.0
19	12267.9	8069.4	7117.9	7362.2	12267.9	7036.7	6766.8	6926.8	12267.9	7036.7	6899.4	6592.0
20	11893.9	9884.2	9494.8	10232.1	11318.0	8970.3	9103.3	9199.2	11318.0	8454.7	8987.5	9269.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	8701.8	8499.7	8499.7	8499.7	8617.6	8334.3	8334.3	8334.3	8238.8	7719.2	7719.2	7719.2
2	13495.6	11442.4	11429.4	11711.5	13495.6	11398.3	11436.3	11396.6	13495.6	11415.1	11396.6	11429.4
3	16023.8	15552.0	15566.3	15290.6	16023.8	15552.0	15290.6	15555.8	16023.8	15551.6	15564.6	15555.8
4	12891.5	10907.2	10415.7	11058.0	12891.5	10412.1	10493.1	10386.5	10922.4	10446.4	10386.5	10315.9
5	11203.7	7759.4	8622.3	8629.0	11203.7	7368.4	7206.6	7811.9	11203.7	6955.3	6931.2	6673.4
6	12614.9	10262.1	9805.6	10687.7	12114.0	10014.2	10176.9	9904.8	12114.0	9165.6	9728.7	9728.7
7	14331.6	10131.9	9872.2	9167.3	14331.6	9046.8	8591.6	8565.0	14331.6	8397.6	8494.2	8453.8
8	11894.5	8563.7	8060.8	7879.7	11894.5	7695.5	7641.7	7659.0	11894.5	7688.8	7656.5	7552.3
9	10867.5	10447.6	10604.1	10867.5	10867.5	10474.6	10867.5	10536.5	10648.6	10417.7	10274.1	10505.1
10	13485.3	10733.7	10966.8	11424.9	13485.3	10716.0	10286.4	9916.6	15194.9	9940.1	9568.3	9803.0
11	12817.3	11982.4	11970.8	11928.6	11738.6	11738.6	11738.6	11672.2	11738.6	11738.6	11377.7	11583.7
12	14193.0	12016.5	11619.9	12070.1	13929.9	11553.9	11552.6	11599.8	13929.9	11549.7	11552.6	11549.7
13	17720.1	11649.2	10301.4	10264.2	17720.1	9320.1	9320.1	9650.1	17720.1	9320.1	9320.1	9192.4
14	15917.2	12816.2	14421.8	14191.4	14875.2	12890.2	14185.0	14172.6	14875.2	12890.2	14174.3	14212.3
15	13204.2	9766.9	9863.5	9766.9	13118.6	9766.9	9766.9	9940.5	13118.6	9766.9	9760.8	9766.9
16	14677.9	9184.5	7946.3	9136.9	14677.9	8120.6	7500.2	7632.5	14677.9	7617.5	7632.5	7500.2
17	15272.3	9449.0	10738.1	9945.6	15272.3	8881.2	9303.0	8633.8	15272.3	8553.0	8524.6	8576.9
18	12688.0	8172.0	8755.3	9411.1	12688.0	7951.3	8257.4	7799.2	12688.0	7797.9	7795.4	7795.0
19	12364.5	7129.5	7723.2	7733.1	12364.5	6865.7	6981.3	6953.0	12364.5	6865.7	6924.8	7052.4
20	14539.7	8371.7	10607.2	9309.7	14539.7	8371.7	9103.0	9319.0	14539.7	8371.7	8790.8	8853.1

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.8$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	8678.8	8195.7	8195.7	8195.7	8008.5	8008.5	8008.5	8008.5	7991.3	7900.7	7900.7	7991.3
2	15166.8	11396.6	11422.9	11659.9	15166.8	11396.6	11040.2	11421.6	15166.8	11412.0	11430.7	11412.0
3	18085.2	15600.6	15568.8	15599.9	18844.9	15568.8	15671.5	15605.4	18844.9	15554.5	15555.8	15552.0
4	13000.3	10399.1	10642.8	10720.4	12883.1	10232.8	10567.0	9919.2	12883.1	9981.2	10349.9	10389.3
5	8992.1	7931.6	8128.1	7695.4	9066.0	7609.8	7009.8	7114.0	9066.0	7127.0	6875.9	6976.5
6	16010.3	10352.3	10433.7	10475.8	16010.3	9577.4	10037.1	9759.0	16010.3	9758.4	9730.0	9779.6
7	15216.9	9549.8	10803.7	8903.4	15216.9	8609.6	8535.6	8775.1	11424.7	8380.1	8094.2	8498.2
8	9430.8	7878.9	8562.4	8857.7	9356.2	7742.6	7699.2	7634.5	9259.2	7630.9	7724.3	7719.4
9	15636.8	11287.5	10826.0	9311.7	15636.8	10930.5	9311.7	10747.9	15636.8	10930.5	10387.0	11279.3
10	18358.3	11007.6	10916.6	12145.8	18358.3	9936.5	10265.0	9608.7	18358.3	9936.5	9781.7	10779.0
11	15655.8	12203.6	12896.2	11942.3	15655.8	12291.1	11912.3	11128.4	15655.8	11984.6	12058.6	11932.8
12	11385.0	11120.8	11385.0	10992.1	11385.0	11385.0	11385.0	11385.0	11385.0	11385.0	11120.8	11038.5
13	21360.2	12714.2	11646.8	10670.2	21360.2	9643.3	9320.1	9396.3	21360.2	9320.1	9320.1	9320.1
14	19557.0	14173.9	14209.6	14230.8	19074.6	14174.3	13592.3	14267.1	19074.6	14172.6	14283.7	13761.4
15	12626.5	9863.5	10030.8	10323.2	12626.5	9863.5	9857.4	9916.6	17555.2	9766.9	9760.8	9766.9
16	13477.6	8867.8	9808.7	9154.6	13477.6	7717.0	7675.6	7475.8	13477.6	7538.9	7591.3	7939.9
17	17763.6	9738.5	10963.9	10967.1	17763.6	8775.7	9490.4	8777.1	17763.6	8466.0	8439.9	8939.3
18	13913.5	10233.7	8771.9	8693.8	13075.9	7796.5	7909.9	7845.9	13075.9	7747.2	8022.7	7795.0
19	14129.3	9321.8	7054.4	8893.4	14129.3	6920.5	7025.8	7522.9	14129.3	6920.5	6677.7	6614.2
20	19224.6	10098.7	10171.6	11152.5	19224.6	9339.6	9531.2	9067.9	19224.6	8804.4	8776.1	8276.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.9$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	8281.8	8266.4	8266.4	8266.4	7883.5	7883.5	7883.5	7883.5	7575.7	7560.3	7560.3	7560.3
2	14349.9	11412.0	11505.0	11412.2	13897.9	11423.3	11429.4	11629.7	13895.8	11170.3	11412.2	11415.1
3	18844.9	15896.8	15631.4	15693.0	18844.9	15568.8	15671.5	15605.4	18844.9	15554.5	15555.8	15552.0
4	13000.3	10399.1	10642.8	10720.4	12883.1	10232.8	10567.0	9919.2	12883.1	9981.2	10349.9	10389.3
5	9066.0	8629.9	7124.0	7175.2	9066.0	7609.8	7009.8	7114.0	9066.0	7127.0	6875.9	6976.5
6	16010.3	10352.3	10433.7	10475.8	14342.8	9882.0	10076.9	9647.1	14342.8	9758.4	9730.0	9728.7
7	11583.0	8631.4	7831.8	8531.3	11583.0	8565.0	9130.8	9298.6	11424.7	8380.1	8094.2	8498.2
8	9430.8	7878.9	8562.4	8857.7	9356.2	7742.6	7699.2	7634.5	9259.2	7630.9	7724.3	7719.4
9	15636.8	11287.5	10826.0	9311.7	15636.8	10930.5	9311.7	10747.9	15636.8	10930.5	10387.0	11279.3
10	18358.3	11007.6	10916.6	12145.8	18358.3	9936.5	10265.0	9608.7	18358.3	9936.5	9781.7	10779.0
11	17136.0	13277.9	13010.6	10510.9	17136.0	12311.2	11057.9	10752.2	17136.0	11916.7	11108.2	11928.6
12	11988.0	11621.9	11048.7	11602.9	11988.0	11622.2	9814.4	11644.2	11988.0	10830.2	11191.1	11499.4
13	21360.2	12714.2	11646.8	10670.2	15435.1	8886.6	9816.3	9320.1	15435.1	8886.6	9320.1	9436.2
14	19557.0	14173.9	14209.6	14230.8	19074.6	14174.3	13592.3	14267.1	19074.6	14172.6	14283.7	13761.4
15	17555.2	10269.2	11078.3	10746.1	17555.2	9857.4	9760.8	9857.8	17555.2	9766.9	9760.8	9766.9
16	12561.6	9192.2	8800.2	8869.7	10798.3	7919.1	7715.8	7587.1	10798.3	7475.8	7678.8	7504.9
17	17220.8	9879.9	10650.8	10933.4	17220.8	8386.6	8706.1	8930.3	17220.8	8906.1	8495.5	8466.0
18	13075.9	8525.1	9411.9	9709.1	13075.9	7796.5	7909.9	7845.9	13075.9	7747.2	8022.7	7795.0
19	14129.3	9321.8	7054.4	8893.4	14129.3	6920.5	7025.8	7522.9	11472.7	7630.9	6989.1	7096.0
20	19224.6	10098.7	10171.6	11152.5	19224.6	9339.6	9531.2	9067.9	13862.2	9065.6	8764.9	8669.1

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: SA-TS

Problem #	Simulated Annealing											
	$\alpha=0.99$											
	MI=50				MI=100				MI=150			
	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30	No TS	TS with Tabu =10	TS with Tabu =20	TS with Tabu =30
1	7864.2	7864.2	7864.2	7864.2	7883.5	7883.5	7883.5	7883.5	7575.7	7560.3	7560.3	7560.3
2	14349.9	11412.0	11505.0	11412.2	13897.9	11423.3	11429.4	11629.7	13895.8	11170.3	11412.2	11415.1
3	18844.9	15896.8	15631.4	15693.0	18844.9	15568.8	15671.5	15605.4	18844.9	15554.5	15555.8	15552.0
4	13338.3	10530.5	10596.1	11469.5	13338.3	10371.8	10404.4	10369.7	13338.3	10371.8	10397.5	10399.1
5	9066.0	8629.9	7124.0	7175.2	9066.0	7609.8	7009.8	7114.0	9066.0	7127.0	6875.9	6976.5
6	14342.8	10184.9	9728.7	10179.4	14342.8	9882.0	10076.9	9647.1	14342.8	9758.4	9730.0	9728.7
7	11583.0	8631.4	7831.8	8531.3	11583.0	8565.0	9130.8	9298.6	11424.7	8380.1	8094.2	8498.2
8	9430.8	7878.9	8562.4	8857.7	9356.2	7742.6	7699.2	7634.5	9699.6	7696.7	7628.6	7626.5
9	15636.8	11287.5	10826.0	9311.7	15655.2	11027.5	10808.5	11868.8	15655.2	11027.5	11262.1	10544.5
10	18358.3	11007.6	10916.6	12145.8	10235.4	9774.4	10235.4	10235.4	10235.4	9774.4	9860.1	9987.1
11	17136.0	13277.9	13010.6	10510.9	17136.0	12311.2	11057.9	10752.2	17136.0	11916.7	11108.2	11928.6
12	11988.0	11621.9	11048.7	11602.9	11988.0	11622.2	9814.4	11644.2	11988.0	10830.2	11191.1	11499.4
13	15435.1	12644.5	11850.9	11092.6	15435.1	8886.6	9816.3	9320.1	15435.1	8886.6	9320.1	9436.2
14	19557.0	14173.9	14209.6	14230.8	19074.6	14174.3	13592.3	14267.1	18093.1	14173.9	14086.4	14172.6
15	17555.2	10269.2	11078.3	10746.1	17555.2	9857.4	9760.8	9857.8	17555.2	9766.9	9760.8	9766.9
16	12561.6	9192.2	8800.2	8869.7	10798.3	7919.1	7715.8	7587.1	10798.3	7475.8	7678.8	7504.9
17	17220.8	9879.9	10650.8	10933.4	17220.8	8386.6	8706.1	8930.3	17220.8	8906.1	8495.5	8466.0
18	13075.9	8525.1	9411.9	9709.1	13075.9	7796.5	7909.9	7845.9	13075.9	7747.2	8022.7	7795.0
19	11472.7	8798.4	8058.7	7981.6	11472.7	6591.1	6824.1	7717.9	11472.7	7630.9	6989.1	7096.0
20	13862.2	10345.4	9379.7	10028.3	13862.2	8675.3	8766.7	10089.2	13862.2	9065.6	8764.9	8669.1

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4124.1	4040.9	4040.9	4040.9	3915.5	3915.5	3915.5	3915.5	3915.5	3915.5	3915.5	3915.5
2	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15564.6	15564.6	15564.6	15564.6	15564.6	15564.6	15564.6	15564.6	15564.6	15564.6	15564.6	15564.6
4	10400.5	10356.3	10356.3	10356.3	10357.1	10357.1	10357.1	10357.1	10353.3	10353.3	10353.3	10353.3
5	5768.5	5729.3	5729.3	5764.3	5657.7	5622.2	5622.2	5622.2	5627.3	5627.3	5627.3	5627.3
6	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1
7	4441.9	4441.9	4441.9	4441.9	4466.2	4454.2	4454.2	4454.2	4456.0	4411.9	4411.9	4411.9
8	3920.1	3920.1	3920.1	3920.1	3904.6	3892.9	3892.9	3892.9	3916.3	3904.6	3904.6	3904.6
9	5849.5	5849.5	5849.5	5849.5	5866.3	5866.3	5866.3	5866.3	5847.8	5847.8	5847.8	5847.8
10	4948.3	4948.3	4948.3	4948.3	4908.0	4908.0	4908.0	4908.0	4991.6	4991.6	4991.6	4991.6
11	6205.6	6177.2	6177.2	6177.2	6188.4	6173.0	6173.0	6173.0	6188.4	6030.9	6030.9	6030.9
12	5840.6	5840.6	5840.6	5840.6	5840.6	5624.2	5624.2	5624.2	5677.8	5677.8	5677.8	5677.8
13	4684.8	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	6874.5	6874.5	6874.5	6874.5	6847.0	6847.0	6847.0	6847.0	6846.6	6296.7	6296.7	6770.0
15	3956.3	3862.8	3862.8	3862.8	3859.7	3859.7	3859.7	3859.7	3911.1	3911.1	3911.1	3911.1
16	3833.0	3833.0	3833.0	3833.0	3857.4	3833.0	3833.0	3833.0	3857.4	3833.0	3833.0	3833.0
17	6283.4	6283.4	6283.4	6283.4	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	3904.6	3904.6	3904.6	3904.6	3916.3	3904.6	3904.6	3904.6	3916.3	3904.6	3904.6	3904.6
19	4198.8	4138.7	4138.7	4138.7	4592.3	4576.9	4576.9	4576.9	4521.7	4521.7	4521.7	4521.7
20	4598.3	4598.3	4598.3	4598.3	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	3915.5	3915.5	3915.5	3915.5	4046.0	3997.9	3997.9	4046.0	4030.2	4030.2	4030.2	4030.2
2	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15564.6	15550.3	15550.3	15550.3	15564.6	15550.3	15550.3	15550.3	15554.5	15550.3	15550.3	15550.3
4	10353.3	10353.3	10353.3	10353.3	10357.1	10353.3	10353.3	10353.3	10357.1	10357.1	10357.1	10357.1
5	6054.5	6054.5	6054.5	6054.5	5679.7	5657.0	5657.0	5657.0	5658.9	5606.6	5606.6	5606.6
6	4998.1	4998.1	4998.1	4998.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1	4973.1
7	4557.5	4423.5	4423.5	4423.5	4466.2	4454.2	4454.2	4454.2	4456.0	4411.9	4411.9	4411.9
8	3904.6	3904.6	3904.6	3904.6	3920.1	3920.1	3920.1	3920.1	3916.3	3904.6	3904.6	3904.6
9	5866.3	5866.3	5866.3	5866.3	5866.3	5866.3	5866.3	5866.3	5728.3	5728.3	5728.3	5728.3
10	4989.0	4961.5	4961.5	4961.5	4908.0	4908.0	4908.0	4908.0	4991.6	4991.6	4991.6	4991.6
11	6215.2	6198.0	6198.0	6198.0	6188.4	6173.0	6173.0	6173.0	6188.4	6030.9	6188.4	6188.4
12	5865.6	5865.6	5865.6	5865.6	5841.0	5841.0	5841.0	5841.0	5677.8	5677.8	5677.8	5677.8
13	4684.8	4684.8	4684.8	4684.8	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	6874.5	6863.8	6863.8	6863.8	6846.6	6846.6	6846.6	6846.6	6846.6	6846.6	6846.6	6846.6
15	3859.7	3859.7	3859.7	3859.7	3859.7	3859.7	3859.7	3859.7	3911.1	3911.1	3911.1	3911.1
16	3857.4	3857.4	3857.4	3857.4	3857.4	3833.0	3833.0	3833.0	3857.4	3833.0	3833.0	3833.0
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4166.6	3922.7	3922.7	3922.7	3916.3	3904.6	3904.6	3904.6	3916.3	3904.6	3904.6	3904.6
19	4669.7	4669.7	4669.7	4669.7	4578.2	4578.2	4578.2	4578.2	4576.9	4576.9	4576.9	4576.9
20	4598.3	4598.3	4598.3	4598.3	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4072.0	4041.3	4041.3	4041.3	4030.2	4030.2	4030.2	4030.2	4020.7	4020.7	4020.7	4020.7
2	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15564.6	15550.3	15550.3	15550.3	15564.6	15550.3	15550.3	15550.3	15554.5	15550.3	15550.3	15550.3
4	10353.3	10353.3	10353.3	10353.3	10357.1	10353.3	10353.3	10353.3	10357.1	10357.1	10357.1	10357.1
5	6054.5	6054.5	6054.5	6054.5	5679.7	5657.0	5657.0	5657.0	5658.9	5606.6	5606.6	5606.6
6	4998.1	4998.1	4998.1	4998.1	4987.4	4987.4	4987.4	4987.4	4987.4	4987.4	4987.4	4987.4
7	4557.5	4423.5	4423.5	4423.5	4466.2	4454.2	4454.2	4454.2	4456.0	4411.9	4411.9	4411.9
8	3904.6	3904.6	3904.6	3904.6	3920.1	3920.1	3920.1	3920.1	3916.3	3904.6	3904.6	3904.6
9	5866.3	5866.3	5866.3	5866.3	5853.3	5853.3	5853.3	5853.3	5728.3	5728.3	5728.3	5728.3
10	4989.0	4961.5	4961.5	4961.5	4908.0	4860.0	4860.0	4860.0	4942.8	4942.8	4942.8	4942.8
11	6175.9	6175.9	6175.9	6175.9	6175.9	6175.9	6175.9	6175.9	6175.9	6175.9	6175.9	6175.9
12	5865.6	5865.6	5865.6	5865.6	5841.0	5841.0	5841.0	5841.0	5840.6	5840.6	5840.6	5840.6
13	4684.8	4684.8	4684.8	4684.8	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	6874.5	6863.8	6863.8	6863.8	6846.6	6846.6	6846.6	6846.6	6846.6	6846.6	6846.6	6846.6
15	3859.7	3800.2	3800.2	3800.2	3859.7	3800.2	3800.2	3800.2	3859.7	3800.2	3800.2	3800.2
16	3857.4	3857.4	3857.4	3857.4	3857.4	3833.0	3833.0	3833.0	3857.4	3833.0	3833.0	3833.0
17	6283.4	6283.4	6283.4	6283.4	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4166.6	3922.7	3922.7	3922.7	3916.3	3904.6	3904.6	3904.6	3916.3	3904.6	3916.3	3916.3
19	4578.2	4578.2	4578.2	4578.2	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4598.3	4598.3	4598.3	4598.3	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8	4475.8

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4211.3	4121.8	4121.8	4121.8	4034.4	4034.4	4034.4	4034.4	4021.2	4021.2	4021.2	4021.2
2	7995.5	7995.5	7995.5	7995.5	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8
3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3
4	10396.7	10396.7	10396.7	10396.7	10353.3	10353.3	10353.3	10353.3	10357.1	10357.1	10357.1	10357.1
5	5679.7	5673.6	5673.6	5673.6	5679.7	5673.6	5673.6	5673.6	5669.1	5663.0	5663.0	5663.0
6	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4
7	4587.1	4445.1	4445.1	4445.1	4453.5	4403.7	4403.7	4403.7	4405.8	4405.8	4405.8	4405.8
8	3973.4	3904.6	3904.6	3904.6	3997.5	3946.0	3946.0	3946.0	3985.8	3920.1	3920.1	3920.1
9	5867.6	5853.3	5853.3	5853.3	5863.8	5863.8	5863.8	5863.8	5847.8	5847.8	5847.8	5847.8
10	5662.8	5662.8	5662.8	5662.8	4914.7	4907.2	4907.2	4907.2	5032.8	5032.8	5032.8	5032.8
11	6175.9	6175.9	6175.9	6175.9	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0
12	5865.6	5865.6	5865.6	5865.6	5844.8	5844.8	5844.8	5844.8	5841.0	5841.0	5841.0	5841.0
13	4819.6	4819.6	4819.6	4819.6	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	6874.5	6874.5	6874.5	6874.5	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0
15	4387.6	4112.1	4112.1	4112.1	4031.5	3859.7	3859.7	3859.7	3859.7	3838.8	3838.8	3838.8
16	3985.9	3867.5	3890.7	3890.7	4000.2	3851.7	3851.7	3851.7	3851.7	3851.7	3851.7	3851.7
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4012.9	4012.9	4012.9	4012.9	3934.6	3904.6	3904.6	3904.6	3902.1	3902.1	3902.1	3902.1
19	4593.6	4578.2	4578.2	4578.2	4592.3	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4652.4	4637.2	4637.2	4637.2	4548.1	4548.1	4548.1	4548.1	4548.1	4548.1	4548.1	4548.1

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4211.3	4121.8	4121.8	4121.8	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4
2	7995.5	7995.5	7995.5	7995.5	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8
3	15555.8	15552.0	15552.0	15552.0	15555.8	15552.0	15552.0	15552.0	15550.3	15550.3	15550.3	15550.3
4	10365.9	10362.9	10362.9	10362.9	10353.3	10353.3	10353.3	10353.3	10357.1	10357.1	10357.1	10357.1
5	5679.7	5673.6	5673.6	5673.6	5679.7	5673.6	5673.6	5673.6	5669.1	5663.0	5664.3	5664.3
6	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4973.1
7	4551.9	4418.6	4418.6	4418.6	4544.8	4436.6	4436.6	4436.6	4404.5	4404.5	4404.5	4404.5
8	4018.5	4018.5	4018.5	4018.5	4016.1	3999.1	3999.1	3999.1	3985.8	3920.1	3920.1	3920.1
9	5867.6	5853.3	5853.3	5853.3	5863.8	5863.8	5863.8	5863.8	5847.8	5847.8	5847.8	5847.8
10	5662.8	5662.8	5662.8	5662.8	4914.7	4907.2	4907.2	4907.2	5032.8	5032.8	5032.8	5032.8
11	6175.9	6175.9	6175.9	6175.9	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0
12	5865.6	5865.6	5865.6	5865.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6
13	4819.6	4819.6	4819.6	4819.6	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	6874.5	6874.5	6874.5	6874.5	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0
15	4103.6	3956.3	4073.6	4073.6	3950.2	3950.2	3950.2	3950.2	3950.2	3950.2	3950.2	3950.2
16	4000.2	3851.7	3851.7	3851.7	4000.2	3851.7	3851.7	3851.7	3851.7	3851.7	3851.7	3851.7
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4031.6	4031.6	4031.6	4031.6	3902.1	3902.1	3902.1	3902.1	3934.6	3904.6	3904.6	3904.6
19	4662.0	4578.2	4578.2	4578.2	4592.3	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4598.3	4598.3	4598.3	4598.3	4548.1	4548.1	4548.1	4548.1	4615.8	4615.8	4615.8	4615.8

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50, Construction Heuristics=SPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4211.3	4121.8	4121.8	4121.8	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4	4034.4
2	7995.5	7995.5	7995.5	7995.5	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8	7984.8
3	15555.8	15552.0	15552.0	15552.0	15555.8	15552.0	15552.0	15555.8	15551.6	15551.6	15551.6	15551.6
4	10365.9	10362.9	10362.9	10362.9	10353.3	10353.3	10353.3	10353.3	10357.1	10357.1	10357.1	10357.1
5	5675.5	5645.0	5645.0	5645.0	5665.1	5661.2	5661.2	5661.2	5665.1	5661.2	5661.2	5661.2
6	5008.6	4973.1	4973.1	4973.1	4974.4	4974.4	4974.4	4974.4	4973.1	4973.1	4973.1	4973.1
7	4551.9	4418.6	4418.6	4418.6	4544.8	4436.6	4436.6	4436.6	4404.5	4404.5	4404.5	4404.5
8	4018.5	4018.5	4018.5	4018.5	4016.1	3999.1	3999.1	3999.1	3985.8	3920.1	3920.1	3920.1
9	5878.3	5878.3	5878.3	5878.3	5849.1	5849.1	5849.1	5849.1	5558.7	5276.5	5276.5	5276.5
10	5662.8	5662.8	5662.8	5662.8	4914.7	4907.2	4907.2	4907.2	5032.8	5032.8	5032.8	5032.8
11	6175.9	6175.9	6175.9	6175.9	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0
12	5903.8	5871.0	5871.0	5871.0	5841.0	5841.0	5841.0	5841.0	5841.0	5841.0	5841.0	5841.0
13	4819.6	4761.0	4761.0	4761.0	4240.3	4240.3	4240.3	4240.3	4240.3	4240.3	4240.3	4240.3
14	6874.5	6874.5	6874.5	6874.5	6847.0	6847.0	6847.0	6847.0	6393.2	6393.2	6393.2	6393.2
15	4177.5	4052.5	4052.5	4052.5	3950.2	3950.2	3950.2	3950.2	3950.2	3950.2	3950.2	3950.2
16	4000.2	3851.7	3851.7	3851.7	4000.2	3851.7	3851.7	3851.7	3851.7	3851.7	3851.7	3851.7
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4113.3	4031.3	4031.3	4031.3	3902.1	3902.1	3902.1	3902.1	3934.6	3904.6	3904.6	3904.6
19	4662.0	4578.2	4578.2	4578.2	4592.3	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4615.8	4615.8	4615.8	4615.8	4615.8	4615.8	4615.8	4615.8	4454.7	4344.2	4344.2	4344.2

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4065.5	4065.5	4065.5	4065.5	4054.3	4054.3	4054.3	4054.3	4072.7	4072.7	4072.7	4072.7
2	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15576.6	15576.6	15576.6	15576.6	15554.5	15554.5	15554.5	15554.5	15550.3	15550.3	15550.3	15550.3
4	10386.5	10386.5	10386.5	10386.5	10375.8	10375.8	10375.8	10375.8	10366.7	10366.7	10366.7	10366.7
5	5632.2	5632.2	5632.2	5632.2	5678.5	5678.5	5678.5	5678.5	5632.2	5632.2	5632.2	5632.2
6	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4973.1	4973.1	4973.1	4973.1
7	4523.5	4473.0	4473.0	4473.0	4519.6	4496.1	4496.1	4496.1	4473.1	4394.2	4394.2	4394.2
8	3938.8	3927.1	3927.1	3927.1	3904.6	3898.1	3898.1	3898.1	3904.6	3898.1	3898.1	3898.1
9	5847.8	5847.8	5847.8	5847.8	5835.6	5417.7	5417.7	5417.7	5847.8	4973.8	4973.8	4973.8
10	5034.0	5034.0	5034.0	5034.0	4922.6	4922.6	4922.6	4922.6	4857.1	4857.1	4857.1	4857.1
11	6191.3	6191.3	6191.3	6191.3	6177.2	6177.2	6177.2	6177.2	6173.4	6173.4	6173.4	6173.4
12	5856.0	5856.0	5856.0	5856.0	5841.0	5333.6	5333.6	5333.6	5843.5	5843.5	5843.5	5843.5
13	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1
14	6895.7	6895.7	6895.7	6895.7	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0
15	3966.2	3956.7	3956.7	3956.7	3853.6	3853.6	3853.6	3853.6	3859.7	3859.7	3859.7	3859.7
16	4080.2	3922.1	3922.1	3922.1	3876.1	3851.7	3851.7	3851.7	3968.9	3833.0	3833.0	3833.0
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4570.8	4398.7	4398.7	4398.7	3963.3	3923.3	3923.3	3923.3	3963.3	3923.3	3923.3	3923.3
19	4619.6	4604.2	4604.2	4604.2	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4633.0	4633.0	4633.0	4633.0	4072.7	4072.7	4072.7	4072.7	4072.7	4072.7	4072.7	4072.7
2	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15576.6	15576.6	15576.6	15576.6	15554.5	15554.5	15554.5	15554.5	15550.3	15550.3	15550.3	15550.3
4	10386.5	10386.5	10386.5	10386.5	10375.8	10375.8	10375.8	10375.8	10366.7	10366.7	10366.7	10366.7
5	5632.2	5632.2	5632.2	5632.2	5678.5	5678.5	5678.5	5678.5	5632.2	5632.2	5632.2	5632.2
6	4987.4	4973.1	4973.1	4973.1	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4
7	4520.2	4443.5	4443.5	4443.5	4523.5	4466.6	4466.6	4466.6	4523.5	4466.6	4466.6	4466.6
8	3947.0	3904.6	3904.6	3904.6	3904.6	3898.1	3892.9	3892.9	3904.6	3904.6	3904.6	3904.6
9	5835.6	5449.7	5449.7	5449.7	5847.8	4973.8	4973.8	4973.8	5847.8	4973.8	4973.8	4973.8
10	4922.6	4922.6	4922.6	4922.6	4920.5	4878.2	4878.2	4878.2	4912.2	4872.8	4872.8	4872.8
11	6211.4	6211.4	6211.4	6211.4	6173.4	6173.4	6173.4	6173.4	6198.4	6198.4	6198.4	6198.4
12	5856.0	5856.0	5856.0	5856.0	5841.0	5333.6	5333.6	5333.6	5843.5	5843.5	5843.5	5843.5
13	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2
14	6895.7	6895.7	6895.7	6895.7	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0
15	3956.3	3956.3	3956.3	3956.3	3853.6	3853.6	3853.6	3853.6	3853.6	3853.6	3853.6	3853.6
16	3991.6	3851.7	3851.7	3851.7	3968.9	3833.0	3833.0	3833.0	3968.9	3857.4	3857.4	3857.4
17	6296.4	6271.8	6271.8	6271.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4570.8	4398.7	4398.7	4398.7	3963.3	3923.3	3923.3	3923.3	4016.1	4007.3	4007.3	4007.3
19	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4633.0	4633.0	4633.0	4633.0	4072.7	4072.7	4072.7	4072.7	4072.7	4072.7	4072.7	4072.7
2	7984.8	7984.8	7984.8	7984.8	7980.4	7980.4	7980.4	7980.4	7979.3	7979.3	7979.3	7979.3
3	15576.6	15576.6	15576.6	15576.6	15554.5	15554.5	15554.5	15554.5	15550.3	15550.3	15550.3	15550.3
4	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5
5	5632.2	5632.2	5632.2	5632.2	5678.5	5678.5	5678.5	5678.5	5632.2	5632.2	5632.2	5632.2
6	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4973.1	4973.1	4973.1	4973.1
7	4523.5	4511.9	4511.9	4470.5	4544.1	4492.3	4492.3	4492.3	4480.3	4408.9	4408.9	4408.9
8	3941.5	3941.5	3941.5	3941.5	3941.5	3941.5	3941.5	3941.5	3933.9	3933.9	3933.9	3933.9
9	5835.6	5449.7	5449.7	5449.7	5847.8	4973.8	4973.8	4973.8	5847.8	4973.8	4973.8	4973.8
10	5001.0	4971.0	4971.0	4971.0	4963.3	4963.3	4963.3	4963.3	4963.3	4963.3	4963.3	4963.3
11	6211.4	6211.4	6211.4	6211.4	6173.4	6173.4	6173.4	6173.4	6198.4	6198.4	6198.4	6198.4
12	5856.0	5856.0	5856.0	5856.0	5841.0	5333.6	5805.7	5805.7	5840.6	5840.6	5840.6	5840.6
13	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2
14	6895.7	6895.7	6895.7	6895.7	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0	6847.0
15	3956.3	3956.3	3956.3	3956.3	3853.6	3853.6	3853.6	3853.6	3898.0	3898.0	3898.0	3898.0
16	4051.5	3965.4	3965.4	3965.4	3864.6	3851.7	3851.7	3851.7	3864.6	3851.7	3851.7	3851.7
17	6296.4	6271.8	6271.8	6271.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	4020.3	4008.6	4008.6	4008.6	4008.6	3974.5	3974.5	3974.5	3916.3	3904.6	3904.6	3904.6
19	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4479.7	4396.2	4396.2

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =5											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	3956.1	3956.1	3956.1	3956.1
2	7980.4	7979.3	7979.3	7979.3	7980.4	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15567.0	15567.0	15567.0	15567.0	15567.0	15567.0	15567.0	15567.0	15550.3	15550.3	15550.3	15550.3
4	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5
5	5724.3	5651.6	5651.6	5651.6	5647.3	5647.3	5647.3	5647.3	5647.3	5647.3	5647.3	5647.3
6	4987.4	4973.1	4973.1	4973.1	4974.4	4973.1	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4
7	4525.9	4496.9	4496.9	4496.9	4525.9	4486.5	4486.5	4486.5	4410.4	4402.0	4402.0	4402.0
8	3999.5	3927.1	3927.1	3927.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1
9	5866.3	5866.3	5866.3	5866.3	5529.2	5529.2	5529.2	5529.2	5166.0	4935.0	4935.0	4935.0
10	5572.6	5572.6	5572.6	5572.6	5161.3	5161.3	5161.3	5161.3	4904.2	4904.2	4904.2	4904.2
11	6205.2	6173.4	6173.4	6173.4	6177.2	6177.2	6177.2	6177.2	6177.2	6177.2	6177.2	6177.2
12	5858.9	5858.9	5858.9	5858.9	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6
13	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4453.6	4592.0	4592.0	4592.0	4592.0
14	6895.7	6885.0	6885.0	6885.0	6741.4	6613.7	6613.7	6613.7	6741.4	6613.7	6613.7	6613.7
15	3902.1	3853.6	3853.6	3853.6	3956.7	3956.7	3956.7	3956.7	3859.7	3859.7	3859.7	3859.7
16	4051.5	4027.1	4027.1	4027.1	3876.1	3869.2	3869.2	3869.2	3876.1	3869.2	3869.2	3869.2
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	3983.3	3920.8	3920.8	3920.8	3940.3	3920.1	3920.1	3920.1	3909.1	3909.1	3909.1	3909.1
19	4697.0	4697.0	4697.0	4697.0	4669.7	4669.7	4669.7	4669.7	4576.9	4576.9	4576.9	4576.9
20	4929.2	4839.4	4839.4	4839.4	4280.8	4260.0	4260.0	4260.0	4280.8	4260.0	4260.0	4260.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	3956.1	3956.1	3956.1	3956.1
2	7980.4	7979.3	7979.3	7979.3	7980.4	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15567.0	15567.0	15567.0	15567.0	15567.0	15567.0	15567.0	15567.0	15565.7	15565.7	15565.7	15565.7
4	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5
5	5808.2	5808.2	5808.2	5808.2	5648.9	5648.9	5648.9	5648.9	5643.1	5643.1	5643.1	5643.1
6	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4
7	4525.9	4496.9	4496.9	4496.9	4525.9	4486.5	4486.5	4486.5	4410.4	4402.0	4402.0	4402.0
8	3999.5	3927.1	3927.1	3927.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1
9	5884.5	5853.3	5853.3	5853.3	5166.0	5056.1	5056.1	5056.1	5852.0	5852.0	5852.0	5852.0
10	5572.6	5572.6	5572.6	5572.6	5161.3	5161.3	5161.3	5161.3	4904.2	4904.2	4904.2	4904.2
11	6205.2	6173.4	6173.4	6173.4	6177.2	6177.2	6177.2	6177.2	6177.2	6177.2	6177.2	6177.2
12	5858.9	5858.9	5858.9	5858.9	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6
13	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4520.4	4430.1	4430.1	4430.1
14	6863.8	6856.0	6856.0	6856.0	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3
15	3902.1	3853.6	3853.6	3853.6	3956.7	3956.7	3956.7	3956.7	3859.7	3859.7	3859.7	3859.7
16	4051.5	4027.1	4027.1	4027.1	3876.1	3869.2	3869.2	3869.2	3876.1	3869.2	3869.2	3869.2
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	3983.3	3920.8	3920.8	3920.8	3940.3	3920.1	3920.1	3920.1	3909.1	3909.1	3909.1	3909.1
19	4697.0	4697.0	4697.0	4697.0	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4929.2	4839.4	4839.4	4839.4	4280.8	4260.0	4260.0	4260.0	4280.8	4260.0	4260.0	4260.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 50,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	4030.9	3956.1	3956.1	3956.1	3956.1
2	7980.4	7979.3	7979.3	7979.3	7980.4	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3	7979.3
3	15555.8	15555.8	15555.8	15555.8	15551.6	15551.6	15551.6	15551.6	15550.3	15550.3	15550.3	15550.3
4	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5	10383.5
5	5808.2	5808.2	5808.2	5808.2	5648.9	5648.9	5648.9	5648.9	5643.1	5643.1	5643.1	5643.1
6	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4	4974.4
7	4525.9	4496.9	4496.9	4496.9	4525.9	4486.5	4486.5	4486.5	4410.4	4402.0	4402.0	4402.0
8	3999.5	3927.1	3927.1	3927.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1	3931.1
9	5166.0	5071.5	5071.5	5071.5	5864.9	5849.5	5849.5	5849.5	5166.0	4935.0	4935.0	4935.0
10	5572.6	5572.6	5572.6	5572.6	5161.3	5161.3	5161.3	5161.3	4910.9	4910.9	4900.6	4878.5
11	6205.2	6173.4	6173.4	6173.4	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0	6173.0
12	5858.9	5856.0	5856.0	5856.0	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6	5840.6
13	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4520.4	4430.1	4430.1	4430.1
14	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3	6845.3
15	3902.1	3853.6	3853.6	3853.6	3956.7	3956.7	3956.7	3956.7	3859.7	3859.7	3859.7	3859.7
16	4051.5	4027.1	4027.1	4027.1	3876.1	3869.2	3869.2	3869.2	3876.1	3869.2	3869.2	3869.2
17	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8	6258.8
18	3983.3	3920.8	3920.8	3920.8	3940.3	3920.1	3920.1	3920.1	3909.1	3909.1	3909.1	3909.1
19	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9	4576.9
20	4929.2	4839.4	4839.4	4839.4	4280.8	4260.0	4260.0	4260.0	4280.8	4260.0	4260.0	4260.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =8											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7652.2	7652.2	7652.2	7652.2	7674.9	7673.6	7673.6	7673.6	7674.9	7673.6	7673.6	7673.6
2	9102.3	9102.3	9102.3	9102.3	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2
3	15568.8	15568.8	15568.8	15568.8	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0
4	11007.3	11007.3	11007.3	11007.3	10444.8	10444.8	10444.8	10444.8	10294.3	10292.2	10292.2	10292.2
5	6938.7	6908.0	6908.0	6908.0	6470.0	6440.8	6440.8	6440.8	6464.9	6464.9	6464.9	6453.3
6	7989.5	7989.5	7989.5	7989.5	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4
7	7499.6	7439.4	7439.4	7439.4	7154.2	7154.2	7154.2	7087.5	7201.8	7139.3	7139.3	7139.3
8	6273.3	6273.3	6273.3	6273.3	6062.8	6051.1	6051.1	6051.1	6078.2	6061.6	6061.6	6061.6
9	9038.6	9034.4	9034.4	9034.4	9000.2	9000.2	9000.2	9000.2	8984.8	8550.9	8550.9	8550.9
10	7867.5	7860.3	7860.3	7860.3	7630.3	7630.3	7630.3	7630.3	7717.5	7692.9	7692.9	7683.3
11	9025.4	9025.4	9025.4	9025.4	8946.7	8946.7	8946.7	8946.7	8836.7	8651.6	8651.6	8651.6
12	8694.5	8694.5	8694.5	8694.5	8723.3	8698.3	8698.3	8698.3	8697.0	8697.0	8697.0	8697.0
13	4684.8	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	11217.7	11216.0	11216.0	11216.0	11234.5	10805.1	10805.1	10805.1	11234.5	10736.4	10736.4	10736.4
15	7488.8	7488.8	7488.8	7488.8	7585.4	7585.4	7585.4	7585.4	7488.8	7488.8	7488.8	7488.8
16	6317.9	5976.9	5976.9	5976.9	5663.0	5663.0	5663.0	5663.0	5663.0	5663.0	5663.0	5663.0
17	7640.7	6913.3	6913.3	6913.3	7188.9	6554.4	6554.4	6554.4	6605.3	6255.1	6255.1	6255.1
18	5518.6	5117.6	5117.6	5117.6	5055.3	4922.0	4922.0	4922.0	5055.3	4922.0	4922.0	4922.0
19	5929.0	5929.0	5929.0	5929.0	5351.6	5351.6	5351.6	5351.6	5371.1	5371.1	5371.1	5371.1
20	7205.7	7197.4	7197.4	7197.4	7133.1	7133.1	7133.1	7133.1	7133.1	7133.1	7133.1	7133.1

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7331.9	7331.9	7331.9	7331.9	7674.9	7673.6	7673.6	7673.6	7674.9	7673.6	7673.6	7673.6
2	9015.0	9015.0	9015.0	9015.0	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2
3	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0
4	10444.8	10444.8	10444.8	10444.8	10386.5	10386.5	10386.5	10386.5	10386.5	10386.5	10386.5	10386.5
5	6493.3	6451.3	6451.3	6451.3	6493.3	6451.3	6451.3	6451.3	6491.9	6442.8	6442.8	6442.8
6	8000.4	8000.4	8000.4	8000.4	7975.4	7975.4	7975.4	7975.4	7974.1	7498.6	7498.6	7498.6
7	7619.3	7614.9	7614.9	7614.9	7254.7	7201.7	7201.7	7201.7	7136.2	7107.4	7107.4	7107.4
8	6455.4	6098.1	6098.1	6098.1	6019.5	6019.5	6019.5	6019.5	6019.5	6019.5	6019.5	6019.5
9	9077.7	9000.2	9000.2	9000.2	9000.2	9000.2	9000.2	9000.2	8984.8	8550.9	8550.9	8550.9
10	8066.6	7792.4	7792.4	7792.4	7701.9	7224.7	7224.7	7224.7	7604.3	7594.7	7594.7	7594.7
11	8946.7	8946.7	8946.7	8946.7	8946.7	8946.7	8946.7	8946.7	8836.7	8651.6	8651.6	8515.6
12	8799.8	8799.8	8799.8	8799.8	8723.3	8698.3	8698.3	8698.3	8697.0	8697.0	8697.0	8697.0
13	4684.8	4684.8	4684.8	4684.8	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	11269.8	11234.5	11234.5	11234.5	11001.3	10943.4	10943.4	10943.4	11001.3	10943.4	10943.4	10943.4
15	7585.8	7585.8	7585.8	7585.8	7494.9	7494.9	7494.9	7494.9	7494.9	7494.9	7494.9	7494.9
16	6167.0	6040.7	6040.7	6040.7	5663.0	5663.0	5663.0	5663.0	5663.0	5663.0	5663.0	5663.0
17	8364.4	7228.0	7228.0	7228.0	7188.9	6554.4	6554.4	6554.4	6605.3	6255.1	6255.1	6255.1
18	5695.4	5360.1	5360.1	5360.1	5055.3	4922.0	4948.5	4948.5	5134.0	5134.0	5134.0	5134.0
19	5463.2	5171.4	5171.4	5171.4	5420.6	5389.3	5389.3	5389.3	5371.1	5371.1	5371.1	5371.1
20	7675.9	7599.0	7599.0	7599.0	7133.1	7118.6	7118.6	7118.6	7121.2	7090.5	7090.5	7090.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75, Construction Heuristics=SPT1, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =22											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7331.9	7331.9	7331.9	7331.9	7674.9	7673.6	7673.6	7673.6	7674.9	7673.6	7673.6	7673.6
2	9015.0	9015.0	9015.0	9015.0	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2	8995.2
3	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0
4	10579.0	10501.2	10501.2	10501.2	10386.5	10386.5	10386.5	10386.5	10386.5	10386.5	10386.5	10386.5
5	6951.5	6880.7	6880.7	6880.7	6507.6	6489.0	6489.0	6489.0	6491.9	6442.8	6442.8	6442.8
6	7999.1	7999.1	7999.1	7999.1	7974.1	7498.6	7498.6	7498.6	7974.1	7813.3	7813.3	7813.3
7	7619.3	7614.9	7614.9	7614.9	7254.7	7201.7	7201.7	7201.7	7136.2	7107.4	7107.4	7107.4
8	6109.8	6102.8	6102.8	6102.8	6019.5	6019.5	6019.5	6019.5	6019.5	6019.5	6019.5	6019.5
9	9077.7	9000.2	9000.2	9077.7	8999.1	8847.3	8847.3	8847.3	9009.8	8984.8	8984.8	8984.8
10	7701.9	7685.0	7685.0	7685.0	7701.9	7224.7	7224.7	7224.7	7604.3	7594.7	7594.7	7594.7
11	8950.5	8950.5	8950.5	8950.5	8833.9	8833.9	8833.9	8833.9	8833.9	8833.9	8833.9	8833.9
12	8799.8	8799.8	8799.8	8799.8	8723.3	8698.3	8698.3	8698.3	8697.0	8697.0	8697.0	8697.0
13	4684.8	4684.8	4684.8	4684.8	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	10943.7	10906.9	10906.9	10906.9	11217.3	11217.3	11217.3	11217.3	11217.3	11217.3	11217.3	11217.3
15	7494.9	7494.9	7494.9	7494.9	7585.4	7585.4	7585.4	7585.4	7502.1	7425.7	7425.7	7425.7
16	6394.8	6315.0	6315.0	6315.0	5824.2	5763.0	5763.0	5763.0	5744.3	5744.3	5744.3	5744.3
17	8364.4	7228.0	7228.0	7228.0	7188.9	6554.4	6554.4	6554.4	6605.3	6255.1	6605.3	6605.3
18	5398.0	5264.6	5264.6	5264.6	5134.0	5134.0	5134.0	5134.0	4901.7	4703.2	4703.2	4703.2
19	5463.2	5171.4	5171.4	5171.4	5420.6	5389.3	5389.3	5389.3	5371.1	5371.1	5371.1	5371.1
20	7278.5	7267.2	7267.2	7267.2	7169.2	7115.9	7115.9	7115.9	7522.9	7119.3	7119.3	7119.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =8											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8381.2	8379.5	8379.5	8379.5	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3
2	9015.0	9015.0	9015.0	9015.0	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7
3	15555.8	15555.8	15555.8	15555.8	15565.7	15564.6	15564.6	15564.6	15554.5	15554.5	15554.5	15554.5
4	10400.6	10356.3	10356.3	10356.3	10365.9	10187.5	10187.5	10187.5	10356.3	10356.3	10356.3	10356.3
5	6792.7	6679.1	6679.1	6679.1	6439.7	6437.9	6437.9	6437.9	6439.7	6437.9	6437.9	6437.9
6	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4
7	8740.4	8660.4	8660.4	8660.4	7172.4	7172.4	7172.4	7172.4	7172.4	7172.4	7076.8	7093.2
8	6152.5	6119.1	6119.1	6119.1	6133.8	6093.8	6133.8	6133.8	6104.4	6104.4	6104.4	6104.4
9	9039.9	9039.9	9039.9	9039.9	9000.8	8986.5	8986.5	8986.5	8813.3	8044.0	8044.0	8044.0
10	7625.9	7604.3	7604.3	7604.3	7604.3	7604.3	7604.3	7604.3	7822.5	7590.9	7590.9	7590.9
11	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5
12	8698.3	8698.3	8698.3	8698.3	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1
13	4819.6	4819.6	4819.6	4819.6	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5
15	7779.4	7779.4	7779.4	7779.4	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8
16	6820.1	6820.1	6820.1	6820.1	5755.6	5755.6	5755.6	5755.6	5670.2	5670.2	5670.2	5670.2
17	7274.8	7258.2	7258.2	7258.2	6904.3	6642.9	6642.9	6642.9	6618.3	6618.3	6618.3	6618.3
18	6837.9	6837.9	6837.9	6837.9	5204.6	5142.7	5142.7	5142.7	4917.1	4909.4	4909.4	4909.4
19	7306.3	6676.8	6676.8	6676.8	5141.7	5056.9	5056.9	5056.9	5469.8	5454.4	5454.4	5454.4
20	8574.0	7600.2	7600.2	7600.2	7646.8	7293.9	7293.9	7293.9	7221.7	7221.3	7221.3	7221.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7955.9	7865.9	7865.9	7865.9	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3
2	9015.0	9015.0	9015.0	9015.0	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7
3	15565.7	15564.6	15564.6	15564.6	15565.7	15564.6	15564.6	15564.6	15554.5	15554.5	15554.5	15554.5
4	10400.6	10356.3	10356.3	10356.3	10278.2	10057.8	10057.8	10057.8	10357.1	10357.1	10357.1	10357.1
5	6792.7	6679.1	6679.1	6615.1	6546.3	6474.6	6474.6	6474.6	6491.8	6468.8	6468.8	6468.8
6	8332.5	8201.1	8201.1	8201.1	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4
7	7632.0	7219.0	7219.0	7219.0	7172.4	7108.4	7108.4	7108.4	7034.4	7034.4	7034.4	7034.4
8	6308.5	6308.5	6308.5	6308.5	6179.6	6179.6	6179.6	6179.6	6104.4	6104.4	6104.4	6104.4
9	9039.9	9039.9	9039.9	9039.9	9000.8	8986.5	8986.5	8986.5	8813.3	8044.0	8044.0	8044.0
10	7625.9	7604.3	7604.3	7604.3	7594.7	7594.7	7594.7	7594.7	7594.7	7594.7	7594.7	7594.7
11	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5
12	8698.3	8698.3	8698.3	8698.3	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1	8694.1
13	4819.6	4819.6	4819.6	4819.6	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0
14	11338.0	11338.0	11338.0	11338.0	11217.7	11217.7	11217.7	11217.7	11234.5	11234.5	11234.5	11234.5
15	7779.4	7779.4	7779.4	7779.4	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8
16	6820.1	6820.1	6820.1	6820.1	5755.6	5755.6	5755.6	5755.6	5670.2	5670.2	5670.2	5670.2
17	7274.8	7258.2	7258.2	7258.2	6904.3	6642.9	6642.9	6642.9	6618.3	6618.3	6618.3	6618.3
18	6373.2	6280.4	6280.4	6280.4	5204.6	5142.7	5142.7	5142.7	4917.1	4909.4	4902.1	4902.1
19	5754.1	5754.1	5754.1	5754.1	5463.9	5267.5	5267.5	5267.5	5463.9	5267.5	5267.5	5267.5
20	8574.0	7600.2	7600.2	7600.2	7467.1	7310.6	7310.6	7310.6	7229.9	7175.9	7175.9	7175.9

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=SPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =22											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7955.9	7865.9	7865.9	7865.9	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3	7900.3
2	9015.0	9015.0	9015.0	9015.0	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7
3	15565.7	15564.6	15564.6	15564.6	15565.7	15564.6	15564.6	15564.6	15554.5	15554.5	15554.5	15554.5
4	10926.6	10391.4	10391.4	10391.4	10369.7	10369.7	10369.7	10369.7	10357.1	10357.1	10357.1	10357.1
5	7515.4	7396.0	7396.0	7396.0	6546.3	6474.6	6474.6	6474.6	6491.8	6468.8	6468.8	6468.8
6	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4
7	7632.0	7219.0	7219.0	7219.0	7096.7	7096.7	7096.7	7096.7	7096.7	7096.7	7096.7	7096.7
8	6308.5	6308.5	6308.5	6308.5	6179.6	6179.6	6179.6	6179.6	6104.4	6104.4	6104.4	6104.4
9	9039.9	9039.9	9039.9	9039.9	9000.8	8986.5	8986.5	8986.5	8813.3	8813.3	8813.3	8813.3
10	8932.0	8724.5	8724.5	8724.5	7594.7	7594.7	7594.7	7594.7	7594.7	7594.7	7594.7	7594.7
11	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8950.5	8981.0	8949.2	8949.2	8949.2
12	8713.7	8713.7	8713.7	8713.7	8694.1	8563.1	8563.1	8563.1	8694.1	8694.1	8694.1	8694.1
13	4819.6	4761.0	4761.0	4761.0	4240.3	4240.3	4240.3	4240.3	4240.3	4240.3	4240.3	4240.3
14	11338.0	11338.0	11338.0	11338.0	11217.7	11217.7	11217.7	11217.7	11216.0	11216.0	11216.0	11216.0
15	7779.4	7779.4	7779.4	7779.4	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8
16	6820.1	6820.1	6820.1	6416.9	6273.8	6004.0	6004.0	6004.0	5681.7	5681.7	5681.7	5681.7
17	7274.8	7258.2	7258.2	7258.2	6904.3	6642.9	6642.9	6642.9	6618.3	6618.3	6618.3	6618.3
18	5909.0	5909.0	5909.0	5909.0	5030.4	5020.5	5020.5	5020.5	4605.8	4605.8	4605.8	4605.8
19	5754.1	5754.1	5754.1	5754.1	5463.9	5267.5	5267.5	5267.5	5463.9	5267.5	5267.5	5267.5
20	8139.8	8052.9	8052.9	8052.9	7115.4	7099.3	7099.3	7099.3	7115.4	7099.3	7099.3	7099.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =8											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7883.5	7883.5	7883.5	7883.5	7930.3	7900.3	7900.3	7900.3	7930.3	7900.3	7900.3	7900.3
2	9028.0	9013.7	9013.7	9013.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7
3	15570.1	15570.1	15570.1	15570.1	15570.1	15570.1	15570.1	15570.1	15550.3	15550.3	15550.3	15550.3
4	10363.2	10363.2	10363.2	10363.2	10365.9	10365.9	10365.9	10365.9	10363.2	10363.2	10363.2	10363.2
5	6580.3	6580.3	6580.3	6580.3	6505.5	6463.7	6463.7	6463.7	6566.1	6444.8	6444.8	6444.8
6	8009.6	7924.2	7924.2	7924.2	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4
7	7274.9	7090.1	7090.1	7090.1	7076.8	7076.8	7076.8	7076.8	7040.5	7040.5	7040.5	7040.5
8	6673.4	6673.4	6673.4	6673.4	6201.4	6201.4	6201.4	6201.4	6031.2	6023.3	6023.3	6023.3
9	8913.6	8776.1	8776.1	8776.1	8913.6	8776.1	8776.1	8776.1	8913.6	8776.1	8776.1	8776.1
10	7566.4	7566.4	7566.4	7566.4	7286.3	7228.1	7228.1	7228.1	7607.3	7607.3	7607.3	7607.3
11	9016.0	9016.0	9016.0	9016.0	8939.1	8881.1	8881.1	8881.1	8939.1	8881.1	8881.1	8881.1
12	8712.4	8697.0	8697.0	8697.0	8477.4	8477.4	8477.4	8477.4	8477.4	8477.4	8477.4	8477.4
13	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1	4164.1
14	11245.2	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5
15	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8
16	5781.6	5781.6	5781.6	5781.6	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2
17	7299.7	6917.5	6917.5	6917.5	7038.2	6949.1	6949.1	6949.1	6544.2	6383.6	6383.6	6383.6
18	5019.3	5019.3	5019.3	5019.3	4987.1	4962.5	4962.5	4962.5	4979.1	4951.7	4951.7	4951.7
19	5870.4	5428.4	5428.4	5428.4	5469.8	5454.4	5454.4	5454.4	5392.2	5235.6	5235.6	5369.0
20	7196.5	7196.5	7196.5	7196.5	7096.8	7096.8	7096.8	7096.8	7096.8	7096.8	7096.8	7096.8

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7953.3	7936.9	7936.9	7936.9	7881.8	7881.8	7881.8	7881.8	7930.3	7900.3	7900.3	7900.3
2	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7
3	15604.3	15604.3	15604.3	15604.3	15590.0	15590.0	15590.0	15590.0	15568.8	15568.8	15568.8	15568.8
4	10363.2	10363.2	10363.2	10363.2	10363.2	10363.2	10363.2	10363.2	10363.2	10363.2	10363.2	10363.2
5	6689.5	6618.4	6618.4	6618.4	6566.1	6444.8	6444.8	6444.8	6518.7	6460.6	6460.6	6460.6
6	8003.8	8003.8	8003.8	8003.8	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4	7975.4
7	7292.0	7178.5	7178.5	7178.5	7178.5	7040.5	7040.5	7040.5	7102.8	7102.8	7102.8	7102.8
8	6406.6	6406.6	6406.6	6406.6	6109.8	6072.6	6072.6	6072.6	6031.2	6023.3	6023.3	6023.3
9	8913.6	8776.1	8776.1	8776.1	8913.6	8776.1	8776.1	8776.1	8913.6	8776.1	8776.1	8776.1
10	7566.4	7566.4	7566.4	7566.4	7286.3	7228.1	7160.2	7160.2	7600.1	7590.5	7590.5	7590.5
11	8946.3	8946.3	8946.3	8946.3	8946.3	8946.3	8946.3	8946.3	8939.1	8881.1	8881.1	8881.1
12	8477.4	8477.4	8477.4	8477.4	8677.4	8292.3	8292.3	8292.3	8477.4	8477.4	8477.4	8477.4
13	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2
14	11245.2	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5
15	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8
16	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2
17	8626.8	8511.3	8511.3	8511.3	6618.7	6499.7	6499.7	6499.7	6605.3	6605.3	6605.3	6605.3
18	4987.1	4962.5	4962.5	4962.5	4987.1	4962.5	4962.5	4962.5	4979.1	4951.7	4951.7	4951.7
19	5737.6	5737.6	5737.6	5737.6	5517.3	5504.0	5504.0	5504.0	5427.1	5427.1	5427.1	5427.1
20	7136.6	7095.1	7095.1	7095.1	7096.8	7096.8	7096.8	7096.8	7096.8	7096.8	7096.8	7090.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =22											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7953.3	7936.9	7936.9	7936.9	7881.8	7881.8	7881.8	7881.8	7930.3	7900.3	7900.3	7900.3
2	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7
3	15604.3	15604.3	15604.3	15604.3	15590.0	15590.0	15590.0	15590.0	15568.8	15568.8	15568.8	15568.8
4	10446.4	10446.4	10446.4	10446.4	10386.5	10386.5	10386.5	10386.5	10146.6	10146.6	10146.6	10146.6
5	6553.8	6547.1	6547.1	6547.1	6661.1	6645.2	6645.2	6645.2	6536.4	6529.7	6529.7	6529.7
6	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7988.4	7867.8	7818.2	7818.2	7818.2
7	7352.1	7352.1	7352.1	7352.1	7178.5	6978.6	6978.6	6978.6	7102.8	7102.8	7102.8	7102.8
8	6406.6	6406.6	6406.6	6406.6	6109.8	6072.6	6072.6	6072.6	6031.2	6023.3	6023.3	6023.3
9	8913.6	8776.1	8776.1	8776.1	8913.6	8776.1	8776.1	8776.1	8913.6	8776.1	8776.1	8776.1
10	8181.5	7957.8	7957.8	7957.8	7600.1	7590.5	7590.5	7590.5	7604.3	7604.3	7604.3	7604.3
11	8946.3	8946.3	8946.3	8946.3	8946.3	8946.3	8946.3	8946.3	8939.1	8155.7	8155.7	8155.7
12	8477.4	8477.4	8477.4	8477.4	8677.4	8292.3	8292.3	8292.3	8477.4	8477.4	8477.4	8477.4
13	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2	4511.2
14	11245.2	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5	11234.5
15	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8
16	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5670.2	5763.0	5750.4	5750.4	5750.4
17	7217.1	7133.1	7133.1	7133.1	7038.2	6949.1	6949.1	6949.1	6544.2	6383.6	6383.6	6383.6
18	4987.1	4987.1	4987.1	4987.1	5295.5	5295.5	5295.5	5295.5	4994.2	4943.8	4943.8	4943.8
19	5737.6	5737.6	5737.6	5737.6	5517.3	5504.0	5504.0	5504.0	5427.1	5427.1	5427.1	5427.1
20	7860.1	7342.8	7342.8	7342.8	7248.8	7242.1	7242.1	7242.1	7161.0	7160.3	7160.3	7160.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =8											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7953.3	7946.5	7946.5	7946.5	7883.5	7883.5	7883.5	7883.5	7897.4	7897.4	7897.4	7897.4
2	9015.0	9015.0	9015.0	9015.0	9000.7	9000.7	9000.7	9000.7	8995.2	8995.2	8995.2	8995.2
3	15663.3	15663.3	15663.3	15663.3	15604.1	15604.1	15604.1	15604.1	15568.8	15554.5	15554.5	15554.5
4	10399.1	10399.1	10399.1	10399.1	10399.1	10399.1	10399.1	10399.1	10363.2	10363.2	10363.2	10363.2
5	6818.2	6485.2	6485.2	6485.2	6478.4	6478.4	6478.4	6478.4	6467.5	6467.5	6467.5	6467.5
6	8267.1	8242.5	8242.5	8242.5	7988.4	7988.4	7988.4	7988.4	7986.0	7986.0	7986.0	7986.0
7	7178.5	7178.5	7178.5	7178.5	7071.7	7040.5	7040.5	7040.5	7071.7	7040.5	7040.5	7040.5
8	6109.8	6109.8	6109.8	6109.8	6079.4	6079.4	6079.4	6079.4	6079.4	6079.4	6079.4	6079.4
9	8426.9	8053.6	8053.6	8053.6	8663.4	8514.0	8514.0	8514.0	8663.4	8514.0	8514.0	8514.0
10	8825.8	8550.2	8550.2	8550.2	7720.3	7635.8	7635.8	7635.8	7542.3	7542.3	7542.3	7542.3
11	8827.7	8344.6	8344.6	8344.6	8623.2	8143.1	8143.1	8143.1	8827.7	7987.2	7987.2	7987.2
12	8485.7	8195.0	8195.0	8195.0	8485.7	8245.2	8245.2	8245.2	8694.1	8694.1	8694.1	8694.1
13	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4453.6	4592.0	4592.0	4592.0	4592.0
14	11436.1	10353.7	10353.7	10353.7	11216.0	11216.0	11216.0	11216.0	11150.6	11075.2	11075.2	11075.2
15	7494.9	7494.9	7494.9	7494.9	7488.8	7488.8	7488.8	7488.8	7494.9	7488.8	7488.8	7488.8
16	6239.2	6184.5	6184.5	6184.5	5805.5	5747.4	5747.4	5747.4	5750.1	5744.3	5744.3	5744.3
17	7140.5	7115.9	7115.9	7115.9	6830.5	6726.5	6659.9	6659.9	6642.9	6618.3	6618.3	6618.3
18	5398.4	5398.4	5398.4	5398.4	5025.4	5022.0	5022.0	5022.0	5025.4	5022.0	5022.0	5022.0
19	5790.1	5790.1	5790.1	5790.1	5428.4	5428.4	5428.4	5428.4	5428.4	5428.4	5428.4	5428.4
20	7997.3	7600.6	7600.6	7600.6	7191.5	7098.5	7098.5	7098.5	7193.2	7169.9	7169.9	7169.9

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =15											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7897.4	7897.4	7897.4	7897.4	7883.5	7883.5	7883.5	7883.5	7897.4	7897.4	7897.4	7897.4
2	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	8995.2	8995.2	8995.2	8995.2
3	15663.3	15663.3	15663.3	15663.3	15604.1	15604.1	15604.1	15604.1	15550.3	15550.3	15550.3	15550.3
4	10399.1	10399.1	10399.1	10399.1	10399.1	10399.1	10399.1	10399.1	10363.2	10363.2	10363.2	10363.2
5	6761.4	6568.4	6568.4	6568.4	6797.0	6554.2	6554.2	6554.2	6479.7	6457.6	6457.6	6457.6
6	8003.8	8003.8	8003.8	8003.8	8114.4	8114.4	8114.4	8114.4	7988.4	7988.4	7988.4	7988.4
7	7715.0	7417.6	7417.6	7417.6	7034.4	7034.4	7034.4	7034.4	7034.4	6928.6	6928.6	6928.6
8	6109.8	6109.8	6109.8	6098.1	6069.8	6069.8	6069.8	6069.8	6095.7	6077.0	6077.0	6077.0
9	9130.0	8759.6	8759.6	8759.6	8663.4	8514.0	8514.0	8514.0	8663.4	8514.0	8514.0	8514.0
10	7794.7	7632.3	7632.3	7632.3	7542.3	7542.3	7542.3	7542.3	7281.0	7281.0	6969.1	6969.1
11	9336.6	9336.6	9336.6	9336.6	8574.2	7755.6	7755.6	7755.6	8574.2	7755.6	7755.6	7755.6
12	8697.0	8697.0	8697.0	8697.0	8694.1	8694.1	8694.1	8694.1	8458.6	8162.7	8162.7	8162.7
13	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4520.4	4430.1	4430.1	4430.1
14	11436.1	10353.7	10353.7	10353.7	11216.0	11216.0	11216.0	11216.0	11150.6	11075.2	11075.2	11075.2
15	7494.9	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7494.9	7488.8	7488.8	7488.8
16	6239.2	6184.5	6184.5	6184.5	5805.5	5747.4	5747.4	5747.4	5750.1	5744.3	5744.3	5744.3
17	7016.5	7016.5	7016.5	7016.5	6909.5	6699.8	6699.8	6699.8	6829.4	6375.6	6375.6	6375.6
18	5398.4	5398.4	5398.4	5398.4	5025.4	5022.0	5022.0	5022.0	5025.4	5022.0	5022.0	5022.0
19	5521.2	5521.2	5521.2	5521.2	5428.4	5428.4	5428.4	5428.4	5573.2	5573.2	5573.2	5573.2
20	7563.1	7544.6	7544.6	7544.6	7404.3	7221.1	7221.1	7221.1	7193.2	7169.9	7169.9	7169.9

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 75,

Construction Heuristics=LPTcomp,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =22											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7897.4	7897.4	7897.4	7897.4	7883.5	7883.5	7883.5	7883.5	7897.4	7897.4	7897.4	7897.4
2	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	9000.7	8995.2	8995.2	8995.2	8995.2
3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3	15550.3
4	10399.1	10399.1	10399.1	10386.5	10069.2	10069.2	10069.2	10069.2	10069.2	10069.2	10069.2	10069.2
5	6761.4	6761.4	6761.4	6761.4	6622.9	6622.9	6622.9	6622.9	6455.3	6455.3	6455.3	6455.3
6	8003.8	8003.8	8003.8	8003.8	8114.4	8071.1	8071.1	8071.1	7988.4	7988.4	7988.4	7988.4
7	7172.4	7034.4	7034.4	7034.4	7048.4	7048.4	7048.4	7048.4	7163.0	7163.0	7163.0	7163.0
8	6151.0	6104.9	6104.9	6104.9	6069.8	6069.8	6069.8	6069.8	6095.7	6077.0	6077.0	6077.0
9	9130.0	8759.6	8759.6	8759.6	8663.4	8514.0	8514.0	8514.0	8663.4	8514.0	8514.0	8514.0
10	9027.0	8855.2	8855.2	8855.2	8074.3	7852.5	7852.5	7852.5	7406.5	7139.2	7139.2	7139.2
11	9336.6	9336.6	9336.6	9336.6	8574.2	7755.6	7755.6	7755.6	8574.2	7755.6	7755.6	7755.6
12	8694.5	8694.5	8694.5	8694.5	8694.1	8694.1	8694.1	8694.1	8458.6	8162.7	8162.7	8162.7
13	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4592.0	4520.4	4430.1	4430.1	4430.1
14	11436.1	10353.7	10353.7	10353.7	11216.0	11216.0	11216.0	11216.0	11150.6	11075.2	11075.2	11075.2
15	7494.9	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7488.8	7494.9	7488.8	7488.8	7488.8
16	6239.2	6184.5	6184.5	6184.5	5681.7	5681.7	5681.7	5681.7	5681.7	5681.7	5681.7	5681.7
17	7514.6	7504.5	7504.5	7504.5	6909.5	6699.8	6699.8	6699.8	6829.4	6375.6	6375.6	6375.6
18	5398.4	5398.4	5398.4	5031.7	4896.2	4896.2	4896.2	4896.2	5015.1	4999.7	4999.7	4999.7
19	6081.7	6081.7	6081.7	6081.7	5387.4	5372.0	5372.0	5372.0	5573.2	5573.2	5573.2	5573.2
20	7563.1	7544.6	7544.6	7544.6	7404.3	7221.1	7350.0	7350.0	7260.0	7260.0	7260.0	7260.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7850.8	7687.1	7687.1	7687.1	7891.9	7392.3	7392.3	7392.3	7842.1	7792.5	7792.5	7792.5
2	11398.3	11398.3	11398.3	11398.3	11412.0	11412.0	11412.0	11412.0	11412.0	11412.0	11412.0	11410.9
3	15614.7	15614.7	15614.7	15614.7	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8
4	11099.1	11099.1	11099.1	11099.1	10324.9	10280.6	10280.6	10280.6	10404.2	10396.0	10396.0	10396.0
5	7989.6	7811.7	7811.7	7811.7	7345.0	7345.0	7345.0	7345.0	7345.0	7345.0	7345.0	7345.0
6	9969.0	9207.2	9207.2	9207.2	9753.7	9753.7	9753.7	9753.7	9743.0	9743.0	9743.0	9743.0
7	8846.4	8846.4	8753.4	8753.4	8541.7	8541.7	8541.7	8541.7	8411.6	8411.6	8411.6	8411.6
8	7818.2	7818.2	7818.2	7818.2	7604.1	7604.1	7604.1	7604.1	7604.1	7604.1	7604.1	7604.1
9	11262.5	11262.5	11262.5	11262.5	11279.3	11279.3	11279.3	11279.3	10737.3	10737.3	10737.3	10737.3
10	10801.2	10801.2	10801.2	10801.2	10041.9	10041.9	10041.9	10041.9	10041.9	10041.9	10041.9	10041.9
11	11958.8	11574.9	11574.9	11574.9	11990.6	11990.6	11990.6	11990.6	11929.0	11929.0	11929.0	11929.0
12	11737.3	11574.7	11574.7	11574.7	11651.3	11650.9	11650.9	11650.9	11626.3	11625.9	11625.9	11625.9
13	10020.9	9596.8	9596.8	9160.7	9915.4	9412.9	9412.9	9412.9	9320.1	9174.8	9174.8	9174.8
14	14476.7	13728.8	13728.8	13728.8	14173.9	14173.9	14173.9	14173.9	14172.6	14172.6	14172.6	14172.6
15	9857.8	9857.8	9857.8	9857.8	9760.8	9760.8	9760.8	9760.8	9760.8	9760.8	9760.8	9760.8
16	8772.1	8760.9	8760.9	8760.9	7883.0	7883.0	7883.0	7883.0	7555.7	7555.7	7555.7	7555.7
17	9391.6	9109.5	9109.5	9109.5	9589.9	8813.6	8813.6	8813.6	8398.3	8317.2	8317.2	8317.2
18	8262.1	8103.9	8103.9	8103.9	7466.6	7458.1	7458.1	7458.1	7519.7	7152.3	7152.3	7152.3
19	8433.1	7763.8	7763.8	7763.8	7616.9	7616.9	7616.9	7616.9	6668.2	6668.2	6668.2	6668.2
20	9878.5	9110.0	9110.0	9110.0	9175.3	9175.3	9175.3	9175.3	8391.6	8368.3	8368.3	8368.3

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7891.9	7887.3	7887.3	7887.3	7697.8	7697.8	7697.8	7697.8	7823.7	6980.1	6980.1	6980.1
2	11412.6	11412.6	11412.6	11412.6	11416.4	11416.4	11416.4	11416.4	11416.4	11416.4	11416.4	11416.4
3	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8
4	10404.2	10404.2	10404.2	10404.2	10324.9	10280.6	10280.6	10280.6	10404.2	10396.0	10396.0	10396.0
5	8028.4	7143.8	7143.8	7143.8	7345.0	7345.0	7345.0	7345.0	7033.9	6937.1	6937.1	6937.1
6	9753.7	9753.7	9753.7	9753.7	9652.1	9598.6	9598.6	9598.6	9652.1	9598.6	9598.6	9598.6
7	10030.5	9417.3	9417.3	9417.3	8541.7	8541.7	8541.7	8541.7	8411.6	8411.6	8411.6	8411.6
8	7686.2	7686.2	7686.2	7686.2	7604.1	7604.1	7595.4	7595.4	7702.0	7702.0	7702.0	7702.0
9	11341.2	11341.2	11341.2	11341.2	11486.7	11486.7	11486.7	11486.7	10822.2	10507.4	10507.4	10507.4
10	10675.1	10532.0	10532.0	10532.0	10651.4	10511.6	10511.6	10511.6	9772.1	9581.2	9581.2	9581.2
11	12009.4	12009.4	12009.4	12009.4	11990.6	11990.6	11990.6	11990.6	11929.0	11929.0	11929.0	11929.0
12	12414.1	12413.7	12413.7	12413.7	11651.3	11651.3	11651.3	11651.3	11574.7	11574.7	11574.7	11574.7
13	10254.1	9614.7	9614.7	9614.7	8956.1	8803.7	8803.7	8803.7	9320.1	9174.8	9174.8	9174.8
14	14172.6	14172.6	14172.6	14172.6	14172.6	14172.6	14172.6	14172.6	14172.6	14172.6	14172.6	14172.6
15	9963.1	9944.0	9944.0	9760.8	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9
16	8330.5	7629.8	7629.8	7629.8	8421.9	7979.3	7979.3	7979.3	7583.6	7555.7	7555.7	7555.7
17	9844.3	9248.8	9248.8	9248.8	8398.3	8398.3	8398.3	8398.3	8398.3	8317.2	8317.2	8317.2
18	8330.0	8330.0	8330.0	8330.0	7519.7	7519.7	7519.7	7519.7	7466.6	7458.1	7466.6	7466.6
19	7226.1	7031.8	7031.8	7031.8	6917.3	6820.9	6820.9	6820.9	6917.3	6820.9	6820.9	6820.9
20	9016.5	9016.5	9016.5	9016.5	8729.7	8729.7	8729.7	8729.7	9083.5	9083.5	9083.5	9083.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=SPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7891.9	7891.9	7891.9	7891.9	7839.3	7839.3	7839.3	7839.3	7839.3	7839.3	7839.3	7839.3
2	11412.6	11412.6	11412.6	11412.6	11416.4	11416.4	11416.4	11416.4	11416.4	11416.4	11416.4	11416.4
3	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8	15555.8
4	10404.2	10404.2	10347.3	10347.3	10403.6	10400.5	10400.5	10400.5	10400.6	10400.5	10400.5	10400.5
5	7589.5	7428.6	7428.6	7428.6	7186.1	7070.7	7070.7	7070.7	7440.7	7337.9	7337.9	7337.9
6	9757.3	9753.7	9753.7	9753.7	9652.1	9598.6	9598.6	9598.6	9652.1	9598.6	9598.6	9598.6
7	10030.5	9417.3	9417.3	9417.3	8541.7	8541.7	8541.7	8541.7	8411.6	8411.6	8411.6	8411.6
8	7703.7	7653.4	7653.4	7653.4	7702.0	7702.0	7702.0	7702.0	7668.4	7624.0	7624.0	7624.0
9	11817.1	11349.5	11349.5	11349.5	11318.5	11079.0	11079.0	11079.0	10822.2	10507.4	10507.4	10507.4
10	11623.5	9825.3	9825.3	9825.3	9810.5	9810.5	9810.5	9810.5	9810.5	9810.5	9810.5	9810.5
11	12009.4	12009.4	11991.6	11991.6	11945.8	11945.8	11945.8	11945.8	11928.6	11433.9	11433.9	11433.9
12	11651.3	11651.3	11651.3	11651.3	11626.3	11626.3	11626.3	11626.3	11574.7	11574.7	11574.7	11574.7
13	10254.1	9614.7	9614.7	9614.7	8956.1	8803.7	8803.7	8803.7	9320.1	9320.1	9320.1	9320.1
14	14172.6	14172.6	14172.6	14172.6	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3
15	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9
16	9615.5	9100.8	9100.8	9100.8	8421.9	7979.3	7979.3	7979.3	7583.6	7555.7	7555.7	7555.7
17	9844.3	9248.8	9248.8	9844.3	8497.2	8448.9	8448.9	8448.9	8497.2	8448.9	8448.9	8448.9
18	8073.3	8073.3	8073.3	8073.3	7151.4	7151.4	7151.4	7151.4	7151.4	7151.4	7151.4	7151.4
19	7260.8	7150.4	7150.4	7150.4	6917.3	6820.9	6820.9	6820.9	6917.3	6820.9	6820.9	6820.9
20	9287.2	9287.2	9287.2	9287.2	9095.0	9095.0	9095.0	9095.0	8938.4	8907.7	8907.7	8907.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8125.1	8125.1	8125.1	8125.1	7932.1	7915.7	7915.7	7915.7	7883.1	7883.1	7883.1	7883.1
2	11451.7	11451.7	11451.7	11451.7	11415.1	11415.1	11415.1	11415.1	11402.1	11402.1	11402.1	11402.1
3	15570.1	15570.1	15570.1	15570.1	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5
4	10636.4	10542.2	10542.2	10542.2	10582.2	10569.6	10569.6	10569.6	10412.5	10412.5	10412.5	10412.5
5	8101.3	8030.2	8030.2	8030.2	7135.6	7110.2	7110.2	7110.2	6916.9	6804.7	6804.7	6803.0
6	11298.6	10379.4	10379.4	10424.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0
7	8784.3	8684.1	8684.1	8684.1	8497.8	8497.8	8497.8	8497.8	8500.3	8491.7	8491.7	8491.7
8	7725.3	7725.3	7725.3	7725.3	7672.3	7630.5	7630.5	7630.5	7672.3	7630.5	7630.5	7630.5
9	11435.5	10884.9	10884.9	10884.9	10799.3	10419.9	10419.9	10419.9	11280.6	11266.3	11266.3	10863.1
10	11756.9	9665.5	9665.5	9665.5	10422.1	9705.7	9705.7	9705.7	9820.1	9642.5	9642.5	9746.9
11	11956.5	11956.5	11956.5	11956.5	11932.8	11626.4	11626.4	11626.4	11932.8	11572.9	11572.9	11572.9
12	12659.7	12636.0	12636.0	12636.0	11156.0	11156.0	11156.0	11156.0	11569.3	11569.3	11569.3	11569.3
13	11352.5	11352.5	11352.5	11352.5	9471.5	9471.5	9471.5	9471.5	9396.3	9396.3	9396.3	9396.3
14	14283.9	14283.9	14283.9	14283.9	14212.3	14212.3	14212.3	14212.3	14212.3	14212.3	14212.3	14212.3
15	10160.7	10160.7	10160.7	10160.7	9995.8	9995.8	9995.8	9995.8	9766.9	9766.9	9766.9	9766.9
16	9748.4	9136.0	9136.0	9136.0	7712.8	7712.8	7712.8	7712.8	7678.4	7604.6	7604.6	7604.6
17	10669.3	10329.3	10329.3	10329.3	8851.6	8812.4	8812.4	8812.4	8677.1	8566.1	8566.1	8566.1
18	8724.4	8677.4	8677.4	8677.4	7922.5	7814.6	7814.6	7814.6	7742.9	7631.4	7631.4	7631.4
19	8053.2	8012.0	8012.0	8012.0	6715.1	6715.1	6715.1	6715.1	6989.9	6989.9	6989.9	6989.9
20	10417.9	10417.9	10417.9	10417.9	8969.0	8969.0	8969.0	8969.0	8969.0	8969.0	8969.0	8969.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	9545.2	9545.2	9545.2	9545.2	7932.1	7915.7	7915.7	7915.7	7898.5	7883.1	7883.1	7883.1
2	11451.7	11451.7	11451.7	11451.7	11402.1	11402.1	11402.1	11402.1	11402.1	11402.1	11402.1	11402.1
3	15555.8	15555.8	15555.8	15555.8	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5
4	10738.7	10611.0	10611.0	10611.0	10582.2	10569.6	10569.6	10569.6	10412.5	10412.5	10412.5	10412.5
5	8518.0	7311.0	7311.0	7311.0	7069.4	6845.7	6845.7	6845.7	7069.4	6845.7	6845.7	6845.7
6	10603.6	9898.0	9898.0	9898.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0
7	9315.8	9142.3	9142.3	9142.3	8500.3	8491.7	8491.7	8491.7	8497.8	8497.8	8497.8	8497.8
8	8004.9	8004.9	8004.9	8004.9	7675.1	7612.0	7612.0	7612.0	7564.0	7548.5	7548.5	7548.5
9	12480.1	11946.5	11946.5	11946.5	11324.7	11290.0	11290.0	11290.0	11096.2	11096.2	11096.2	11096.2
10	11855.9	11855.9	11855.9	11855.9	10581.7	10049.7	10049.7	10049.7	10222.7	10116.7	10116.7	10116.7
11	11956.5	11956.5	11956.5	11956.5	11932.8	11626.4	11626.4	11626.4	11932.8	11932.8	11932.8	11932.8
12	12585.8	12585.8	12585.8	12585.8	11953.2	11953.2	11953.2	11953.2	11577.6	11577.6	11577.6	11577.6
13	11352.5	11352.5	11352.5	11352.5	9471.5	9471.5	9471.5	9471.5	9396.3	9396.3	9396.3	9396.3
14	14283.9	14283.9	14283.9	14283.9	14212.3	14212.3	14212.3	14212.3	14212.3	14212.3	14212.3	14212.3
15	11664.9	11636.7	11636.7	11636.7	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4
16	10456.3	10307.0	10307.0	10307.0	7727.7	7632.5	7632.5	7632.5	7678.4	7604.6	7604.6	7604.6
17	9975.4	9593.0	9593.0	9593.0	8769.4	8707.3	8707.3	8707.3	8480.5	8480.5	8480.5	8480.5
18	8724.4	8677.4	8677.4	8677.4	7922.5	7906.1	7906.1	7906.1	8024.4	7795.4	7795.4	7795.4
19	8871.3	8871.3	8871.3	8871.3	6938.4	6906.5	6906.5	6906.5	6989.9	6989.9	6989.9	6989.9
20	10417.9	10417.9	10417.9	10355.9	9064.8	9034.3	9034.3	9034.3	8532.2	8141.6	8141.6	8141.6

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=SPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8888.9	8692.6	8692.6	8692.6	8886.2	8710.4	8710.4	8710.4	8006.1	8006.1	8006.1	8006.1
2	11451.7	11451.7	11451.7	11451.7	11402.1	11402.1	11402.1	11402.1	11402.1	11402.1	11402.1	11402.1
3	15555.8	15555.8	15555.8	15555.8	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5	15554.5
4	10810.8	10810.8	10810.8	10810.8	10310.0	10310.0	10310.0	10310.0	10310.0	10310.0	10310.0	10310.0
5	7428.5	7142.0	7142.0	7142.0	7069.4	6845.7	6845.7	6845.7	7069.4	6845.7	6845.7	6845.7
6	10603.6	9898.0	9898.0	9898.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0	9730.0
7	8784.3	8684.1	8684.1	8600.0	8785.7	8628.3	8628.3	8628.3	8541.7	8523.6	8523.6	8523.6
8	7966.8	7922.3	7922.3	7922.3	7719.2	7685.0	7685.0	7685.0	7564.0	7548.5	7548.5	7548.5
9	12480.1	11946.5	11946.5	11946.5	11324.7	11290.0	11290.0	11290.0	11096.2	11096.2	11096.2	11096.2
10	10896.9	10526.6	10526.6	10526.6	10479.4	10003.5	10003.5	10003.5	10222.7	10116.7	10116.7	10116.7
11	12827.8	12827.8	12827.8	12827.8	11945.8	11945.8	11945.8	11945.8	11945.8	11945.8	11945.8	11945.8
12	12585.8	12585.8	12585.8	12585.8	11953.2	11953.2	11953.2	11953.2	11577.6	11577.6	11577.6	11577.6
13	11352.5	11352.5	11352.5	11352.5	9471.5	9442.9	9442.9	9442.9	9396.3	9396.3	9396.3	9396.3
14	15340.6	15340.6	15340.6	15340.6	14191.8	13644.0	13644.0	13644.0	13320.0	13200.5	13200.5	13200.5
15	11664.9	11636.7	11636.7	11636.7	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4
16	10456.3	10307.0	10307.0	10307.0	7727.7	7632.5	7632.5	7632.5	7678.4	7604.6	7604.6	7604.6
17	9570.2	9271.1	9271.1	9271.1	8520.5	8520.5	8520.5	8520.5	8208.3	8185.0	8185.0	8185.0
18	9327.4	8592.6	8592.6	8592.6	8514.8	7843.5	7843.5	7843.5	8024.4	7795.4	7795.4	7795.4
19	8871.3	8871.3	8871.3	8871.3	6938.4	6906.5	6906.5	6906.5	6989.9	6989.9	6989.9	6989.9
20	10751.2	10706.3	10706.3	10706.3	9064.8	9034.3	9034.3	9034.3	8532.2	8141.6	8141.6	8141.6

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8227.4	8227.4	8227.4	8227.4	8140.8	8126.5	8126.5	8126.5	7642.2	7642.2	7642.2	7642.2
2	11413.7	11413.7	11413.7	11413.7	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1
3	15552.0	15552.0	15552.0	15552.0	15567.0	15567.0	15567.0	15567.0	15550.3	15550.3	15550.3	15550.3
4	10570.0	10570.0	10570.0	10570.0	10536.8	10536.8	10536.8	10536.8	10459.8	10459.8	10459.8	10459.8
5	7699.9	7276.2	7276.2	7276.2	7715.3	7576.6	7576.6	7715.3	7037.5	7014.2	7014.2	7014.2
6	9764.2	9764.2	9764.2	9764.2	9743.0	9743.0	9743.0	9743.0	9743.0	9743.0	9743.0	9743.0
7	8551.8	8411.6	8411.6	8411.6	8968.5	8813.1	8813.1	8813.1	8367.4	8303.4	8303.4	8303.4
8	8251.2	8198.6	8198.6	8198.6	7754.7	7647.2	7647.2	7647.2	7630.5	7600.3	7600.3	7600.3
9	10405.6	10405.6	10405.6	10405.6	10300.8	10233.6	10233.6	10280.7	10481.4	10383.1	10383.1	10383.1
10	11254.1	10975.6	10975.6	10975.6	10155.0	10145.6	10145.6	9920.8	10315.3	9759.1	9759.1	9759.1
11	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6
12	10504.8	10504.8	10504.8	10504.8	10504.8	10504.8	10504.8	10166.0	11502.7	11487.3	11487.3	11487.3
13	11989.6	11518.3	11518.3	11518.3	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1
14	14223.0	14223.0	14223.0	14223.0	14212.3	14212.3	14212.3	14212.3	14201.8	14191.1	14191.1	14191.1
15	10245.2	9965.8	9965.8	9965.8	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9
16	8821.9	8438.2	8438.2	8209.3	7750.1	7590.2	7590.2	7590.2	7581.4	7568.5	7568.5	7568.5
17	9212.9	9192.0	9192.0	9192.0	8612.6	8577.3	8577.3	8577.3	8591.0	8591.0	8591.0	8591.0
18	8052.9	8052.9	8052.9	8052.9	7503.0	7503.0	7503.0	7503.0	7799.2	7799.2	7799.2	7799.2
19	7605.7	6815.3	6815.3	6815.3	6972.2	6851.6	6851.6	6851.6	6972.2	6851.6	6851.6	6851.6
20	9956.7	9636.6	9636.6	9636.6	9335.0	8571.4	8571.4	8571.4	8824.5	8300.5	8818.0	8818.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8227.4	8227.4	8227.4	8227.4	8140.8	7990.2	7990.2	7990.2	8238.8	7719.2	7719.2	7719.2
2	11429.4	11429.4	11429.4	11429.4	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1
3	15552.0	15552.0	15552.0	15552.0	15567.0	15567.0	15567.0	15567.0	15550.3	15550.3	15550.3	15550.3
4	10570.0	10570.0	10570.0	10570.0	10536.8	10536.8	10512.0	10512.0	10488.7	10310.3	10310.3	10310.3
5	7867.2	7319.9	7319.9	7319.9	7260.3	7209.9	7209.9	7209.9	7095.3	7095.3	7095.3	7095.3
6	9764.2	9764.2	9764.2	9764.2	9743.0	9743.0	9743.0	9743.0	9743.0	9743.0	9743.0	9743.0
7	9343.9	9063.7	9063.7	9063.7	8968.5	8813.1	8813.1	8813.1	8367.4	8367.4	8367.4	8367.4
8	7947.5	7732.1	7732.1	7732.1	7613.9	7603.9	7603.9	7603.9	7828.9	7529.8	7529.8	7529.8
9	10481.4	10383.1	10383.1	10383.1	10481.4	10383.1	10383.1	10383.1	10481.4	10383.1	10383.1	10383.1
10	10812.0	10765.1	10765.1	10765.1	9897.3	9897.3	9897.3	9897.3	9772.1	9772.1	9772.1	9772.1
11	11458.6	11458.6	11458.6	11458.6	11458.6	11458.6	11148.6	11148.6	11466.3	11323.3	11323.3	11323.3
12	11618.7	11593.7	11593.7	11593.7	11588.1	11588.1	11588.1	11588.1	11549.7	11549.7	11549.7	11549.7
13	9367.3	9367.3	9367.3	9367.3	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1
14	14223.0	14223.0	14223.0	14223.0	14212.3	14212.3	14212.3	14212.3	14174.3	14174.3	14174.3	14174.3
15	10543.1	10349.1	10349.1	10349.1	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9
16	8917.8	8096.1	8096.1	8096.1	7974.6	7581.4	7581.4	7581.4	7581.4	7568.5	7568.5	7568.5
17	9537.5	9287.8	9287.8	9287.8	8650.6	8618.7	8618.7	8618.7	8348.7	8348.7	8348.7	8348.7
18	7926.0	7926.0	7926.0	7926.0	7793.7	7793.7	7793.7	7793.7	7795.4	7795.4	7795.4	7795.4
19	8894.9	8203.6	8203.6	8203.6	7459.9	6848.3	6848.3	6848.3	7009.8	7009.8	7009.8	7009.8
20	8736.0	8687.5	8687.5	8687.5	8736.0	8687.5	8687.5	8687.5	8736.0	8687.5	8687.5	8687.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100,

Construction Heuristics=LPT1,

Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8701.8	8499.7	8499.7	8499.7	8617.6	8334.3	8334.3	8334.3	8238.8	7719.2	7719.2	7719.2
2	11429.4	11429.4	11429.4	11429.4	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1	11415.1
3	15552.0	15552.0	15552.0	15552.0	15567.0	15567.0	15567.0	15567.0	15554.5	15554.5	15554.5	15554.5
4	10474.5	10474.5	10474.5	10474.5	10474.5	10471.5	10471.5	10471.5	10474.5	10334.1	10334.1	10334.1
5	7867.2	7319.9	7319.9	7319.9	7000.6	6936.9	6936.9	6936.9	6929.9	6802.4	6802.4	6802.4
6	9764.2	9764.2	9764.2	9764.2	9743.0	9743.0	9743.0	9730.0	9730.0	9730.0	9730.0	9730.0
7	8916.2	8916.2	8916.2	8916.2	8565.0	8565.0	8565.0	8565.0	8565.0	8565.0	8565.0	8565.0
8	8900.1	8354.1	8354.1	8354.1	7613.9	7603.9	7603.9	7603.9	7751.6	7574.9	7574.9	7574.9
9	10481.4	10383.1	10383.1	10383.1	10481.4	10383.1	10383.1	10383.1	10481.4	10383.1	10383.1	10383.1
10	10651.2	10482.6	10482.6	10482.6	9897.3	9897.3	9897.3	9897.3	9772.1	9772.1	9772.1	9772.1
11	11945.6	11704.9	11704.9	11704.9	11928.6	11928.6	11928.6	11928.6	11453.0	11453.0	11453.0	11453.0
12	11618.7	11593.7	11593.7	11593.7	11588.1	11588.1	11588.1	11588.1	11549.7	11549.7	11549.7	11549.7
13	9376.1	9376.1	9376.1	9376.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1
14	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3	14174.3
15	10543.1	10349.1	10349.1	10349.1	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9	9766.9
16	8917.8	8096.1	8096.1	8096.1	7974.6	7581.4	7581.4	7581.4	7581.4	7568.5	7568.5	7581.4
17	9505.4	8409.7	8409.7	8409.7	8849.5	8482.3	8482.3	8482.3	8386.6	8386.6	8386.6	8386.6
18	8645.8	8632.4	8632.4	8632.4	7793.7	7793.7	7793.7	7793.7	7795.4	7795.4	7795.4	7795.4
19	8894.9	8203.6	8203.6	8203.6	7459.9	6848.3	7459.9	7459.9	6910.8	6910.8	6910.8	6910.8
20	10263.5	9824.6	9824.6	9824.6	8815.7	8518.6	8518.6	8518.6	8688.3	8573.5	8573.5	8573.5

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =10											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8678.8	8195.7	8195.7	8195.7	8008.5	8008.5	8008.5	8008.5	7991.3	7900.7	7900.7	7991.3
2	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11428.1	11428.1	11428.1	11428.1
3	15720.4	15705.0	15705.0	15705.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0
4	10433.8	10243.6	10243.6	10243.6	10386.5	10386.5	10386.5	10386.5	10357.1	10357.1	10357.1	10357.1
5	8693.9	8076.1	8495.1	8495.1	7234.1	7234.1	7234.1	7234.1	7114.2	6894.2	6894.2	6894.2
6	10143.3	9419.9	9419.9	9419.9	9681.5	8940.9	8940.9	8940.9	9730.0	9728.7	9728.7	9728.7
7	9471.5	9023.2	9023.2	9023.2	7719.0	7719.0	7719.0	7719.0	7719.0	7719.0	7719.0	7719.0
8	7854.5	7854.5	7759.8	7759.8	7632.2	7608.8	7608.8	7608.8	7632.2	7608.8	7608.8	7608.8
9	11825.1	11793.3	11825.1	11825.1	11052.1	10857.9	10857.9	10857.9	11052.1	10857.9	10857.9	10857.9
10	12491.5	12437.5	12437.5	12437.5	10548.2	10324.7	10324.7	10324.7	9781.7	9781.7	9781.7	9781.7
11	13599.5	13236.5	13236.5	13236.5	11938.4	11938.4	11938.4	11938.4	11931.5	11931.5	11931.5	11931.5
12	12580.3	12548.5	11688.0	11688.0	11457.5	9614.3	9614.3	9614.3	11457.5	9614.3	9614.3	9614.3
13	10196.9	8574.2	8574.2	8574.2	9320.1	9320.1	9320.1	9320.1	9412.9	9412.9	9412.9	9412.9
14	14783.6	14783.6	14783.6	14783.6	14334.6	14334.6	14334.6	14334.6	14173.9	14173.9	14173.9	14173.9
15	10780.6	10696.0	10696.0	10696.0	9863.5	9863.5	9863.5	9863.5	9857.4	9857.4	9857.4	9857.4
16	9609.1	9609.1	9609.1	9609.1	8463.5	8429.3	8429.3	8429.3	8061.0	8061.0	8061.0	8061.0
17	9291.7	8721.3	8721.3	8721.3	9211.5	8575.9	8575.9	8575.9	9192.2	8894.5	8894.5	9050.4
18	9520.8	9498.5	9498.5	9498.5	8080.2	8076.4	8064.8	8064.8	7699.2	7699.2	7699.2	7699.2
19	8954.8	8905.2	8905.2	8905.2	7506.3	7456.7	7456.7	7456.7	6542.8	6542.8	6542.8	6542.8
20	10403.2	10372.5	10372.5	10372.5	9495.9	9495.9	9495.9	9495.9	9366.3	9322.7	9322.7	9322.7

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =20											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	8281.8	8266.4	8266.4	8266.4	7883.5	7883.5	7883.5	7883.5	7575.7	7560.3	7560.3	7560.3
2	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11428.1	11428.1	11428.1	11428.1
3	15720.4	15705.0	15705.0	15705.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0	15552.0
4	10433.8	10011.3	10011.3	10011.3	10151.8	9951.5	9951.5	9951.5	10433.8	10410.5	10410.5	10410.5
5	7400.3	7330.6	7330.6	7330.6	7228.3	7134.9	7134.9	7134.9	6874.3	6768.4	6768.4	6768.4
6	10143.3	9419.9	9419.9	9419.9	9681.5	8940.9	8940.9	8940.9	9730.0	9728.7	9728.7	9728.7
7	8808.1	8708.5	8708.5	8645.1	8982.4	8982.4	8982.4	8982.4	8632.2	8508.9	8508.9	8508.9
8	8384.6	7933.4	7933.4	7933.4	7632.2	7608.8	7608.8	7608.8	7632.2	7608.8	7608.8	7608.8
9	13655.9	13655.9	13655.9	13655.9	11052.1	10857.9	10857.9	10857.9	11052.1	10857.9	10857.9	10857.9
10	11141.3	11141.3	11141.3	11141.3	10548.2	10324.7	10324.7	10324.7	9781.7	9781.7	9781.7	9781.7
11	13263.5	13230.7	11804.5	11804.5	11745.7	11745.7	11745.7	11745.7	11745.7	11745.7	11745.7	11745.7
12	9909.3	9909.3	9909.3	9909.3	11457.5	9614.3	9614.3	9614.3	11457.5	9614.3	9614.3	9614.3
13	10196.9	8574.2	8574.2	8574.2	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1
14	14783.6	14783.6	14765.1	14765.1	14004.7	13994.0	13994.0	13994.0	14004.7	13994.0	13994.0	13994.0
15	10447.0	9634.1	9634.1	9634.1	9863.5	9863.5	9863.5	9863.5	9857.4	9857.4	9857.4	9857.4
16	9609.1	9609.1	9609.1	9609.1	8463.5	8429.3	8429.3	8429.3	8061.0	8061.0	8061.0	8061.0
17	9812.9	9365.6	9365.6	9365.6	8987.5	8854.4	8854.4	8854.4	8528.8	8480.5	8480.5	8480.5
18	9412.7	8979.6	8979.6	8979.6	7875.4	7875.4	7875.4	7875.4	7699.2	7699.2	7699.2	7699.2
19	8954.8	8905.2	8905.2	8905.2	7506.3	7456.7	7456.7	7456.7	6542.8	6542.8	6542.8	6542.8
20	10712.5	10139.0	10139.0	10139.0	8673.0	8673.0	8673.0	8673.0	8673.0	8673.0	8673.0	8673.0

APPENDIX 8 - SOLUTIONS OF REAL PROBLEMS WITH COUPLING OF HEURISTICS (CONTINUED)

Number of Jobs = 100, Construction Heuristics=LPTcomp, Improvement Heuristic: TS-SA

Problem #	Tabu Search											
	Tabu =30											
	MI=50				MI=100				MI=150			
	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$	No SA	SA with $\alpha=0.8$	SA with $\alpha=0.9$	SA with $\alpha=0.99$
1	7864.2	7864.2	7864.2	7864.2	7883.5	7883.5	7883.5	7883.5	7575.7	7560.3	7560.3	7560.3
2	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11397.9	11398.3	11398.3	11398.3	11398.3
3	15720.4	15720.4	15720.4	15720.4	15567.4	15567.4	15567.4	15567.4	15552.0	15552.0	15552.0	15552.0
4	11099.4	11099.4	11099.4	11099.4	10151.8	9951.5	9951.5	9951.5	10433.8	10410.5	10410.5	10410.5
5	7400.3	7330.6	7330.6	7330.6	7228.3	7134.9	7134.9	7134.9	6943.1	6824.7	6943.1	6943.1
6	10143.3	9419.9	9419.9	9953.6	9809.4	9384.0	9384.0	9384.0	9040.1	8977.8	8977.8	8977.8
7	9385.9	9247.9	9247.9	9247.9	8982.4	8982.4	8982.4	8982.4	8632.2	8508.9	8508.9	8508.9
8	8384.6	7933.4	7933.4	7933.4	7632.2	7608.8	7608.8	7608.8	7632.2	7632.2	7632.2	7632.2
9	13655.9	13655.9	13655.9	13655.9	11052.1	10857.9	10857.9	10857.9	11052.1	10857.9	10857.9	10899.3
10	11141.3	11141.3	11141.3	11141.3	10548.2	10324.7	10324.7	10324.7	9781.7	9781.7	9781.7	9781.7
11	11852.0	11852.0	11852.0	11852.0	11799.1	11718.3	11718.3	11718.3	10442.1	10017.2	10017.2	10017.2
12	9909.3	9909.3	9909.3	9909.3	11457.5	9614.3	9614.3	9614.3	11457.5	9614.3	11098.5	11098.5
13	9619.1	9533.2	9533.2	9533.2	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1	9320.1
14	14401.5	14384.0	14384.0	14384.0	14004.7	13994.0	13994.0	13994.0	14172.6	14172.6	14172.6	14172.6
15	10089.6	10089.6	10089.6	10089.6	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4	9857.4
16	9609.1	9609.1	9609.1	9609.1	8463.5	8429.3	8429.3	8429.3	8061.0	8061.0	8061.0	8061.0
17	9480.5	9174.3	9174.3	9174.3	8987.5	8854.4	8854.4	8854.4	8528.8	8480.5	8480.5	8480.5
18	9412.7	8979.6	8979.6	8979.6	7875.4	7875.4	7875.4	7875.4	7699.2	7699.2	7699.2	7699.2
19	8954.8	8793.9	8683.7	8683.7	7397.2	7397.2	7397.2	7397.2	7020.2	7020.2	7020.2	7020.2
20	9684.2	9452.0	9452.0	9452.0	8673.0	8673.0	8673.0	8673.0	8673.0	8673.0	8673.0	8673.0