A VARIABLE NEIGHBOURHOOD SEARCH ALGORITHM FOR IDENTICAL PARALLEL MACHINE PROBLEM

by

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APPROVAL PAGE

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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M. S. Thesis - Industrial Engineering
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ABSTRACT

Variable Neighbourhood Search (VNS) is one of the most recent metaheuristics used for solving combinatorial optimization problems in which a systematic change of neighbourhood within a local search is carried out. In this thesis, an investigation of VNS algorithm is proposed for the Identical Parallel Machine Scheduling (IPMS) problem with makespan criterion. 150 IPMS benchmark suites are generated randomly which is uniformly distributed between (1,100). In addition, Longest Processing Time (LPT) Rule is used for the worst case analysis as an upperbound theorem. The results gained by VNS algorithm are presented for each configuration. The solution quality was evaluated and compared according to the LPT solutions. It is concluded that the VNS algorithms improved 92 out of the 150 instances of LPT results in a reasonable computing time.

Keywords: Scheduling, Identical Parallel Machine, Makespan, Variable Neighbourhood Search

ÖZDEŞ PARALEL MAKİNE PROBLEMLERİ İÇİN BİR DEĞİŞKEN KOMŞU ARAMA ALGORİTMASI

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ÖZ

Değişken komşu araması (VNS), yerel bir aramanın içinde komşuların sistematik bir değişikliğinin tamamlandığı kombinatoryel optimization problemlerini çözmek için kullanılan yeni bir metasezgisel yöntemlerden biridir. Bu tezde, bir VNS algoritması araştırması, toplam üretim zamanı kriteriyle özdeş paralel makine çizelgelemesi (IPMS) problemi için önerildi. 150 IPMS test problemi (1,100) arasında düzgün dağılımlı olacak şekilde rasgele oluşturuldu. Ayrıca, En Uzun İşlem Zamanı (LPT) Kuralı, bir üst sınır teoremi olarak en kötü olay analizi için kullanıldı. VNS algoritması ile elde edilen sonuçlar, her konfigürasyon için sunuldu. Sonuç kalitesi LPT sonuçlarına göre değerlendirildi ve kıyaslandı. Sonuç olarak, VNS algoritmaları kabul edilebilir işlem zamanı içinde LPT sonuçlarının 150 örneğinden 92 tanesini iyileştirdi.

Anahtar Kelimeler: Çizelgeleme, Özdeş Paralel Makine, Toplam Üretim Zamanı, Değişken Komşu Araması

To my family,

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION

p_j	: Processing time of job j
C_{max}	: Makespan
PMS	: Parallel Machine Scheduling
IPMS	: Identical Parallel Machine Scheduling
$Pm\|\|C_{max}$	: Parallel Machine Scheduling with Criterion of Makespan
VNS	: Variable Neighbourhood Search
LPT	: Longest Processing Time Rule
CPU	: Central Processing Unit
n x m	: n Number of Jobs through m Number of Machine

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Scheduling is a study that concerns the allocation of limited resources to the tasks, which can be in several forms, from service industry to manufacturing systems, or information processes (Pinedo, 1995). To be competitive, effective scheduling has a great importance for improving the productivity, utilization of resources and profitability of production lines. In this study, we deal with the parallel machine environment.

PMS is one of the most studied areas in the scheduling literature. The only way to secure optimal solutions is by enumerative techniques. Dynamic programming, cutting-plane based approaches, lagrangian and branch and bound (B&B) techniques have been used to find optimal solutions.

Metaheuristics are applied to PMS problems; since they give the optimal or near-optimal solutions in a shorter time than exact algorithms do. Tabular Search (TS), Genetic Algorithms (GA), Particle Swarm Optimization (PSO) and Simulated Annealing (SA) are used to generate satisfactory solutions.

IPMS problem for minimizing the makespan has been proved to be a NP problem. It is solved in pseudopolynomial time via operational methods such as dynamic programming, integer programming and etc. (Pinedo, 1995).

We will apply the VNS Algorithm to the $Pm| |C_{\max}$ problem.

Our study is organized as follows. Chapter 2 gives an overview of PMS problems with notation, classification, complexity and solution procedures. This chapter also includes the literature on the scheduling of PMS problems with the minimum makespan objective. In Chapter 3, the VNS method and its methodology are introduced respectively. In Chapter 4, experimental design of the study is presented and computational results of the study are summarized. Finally, Chapter 5 makes the conclusions from results.

CHAPTER 2

PARALLEL MACHINE SCHEDULING

2.1 INTRODUCTION

This chapter surveys the literature related to our research. In the second sub-section, PMS problems are discussed around the makespan minimization objective. Also literature on PMS problems with the minimum makespan objective is given.

2.2 PARALLEL MACHINE SCHEDULING

2.2.1 Overview

In the general PMS problem, a set of independent jobs is to be scheduled on a number of parallel machines (processors) to meet an objective related to machine completion times. The most common objective is the minimization of the makespan.

The scheduling process involves two kinds of decisions: sequencing (the order in which jobs are processed), and job-machine assignment. Single machine problems ask just to find optimal job sequencing, but in the multiple machines case it is necessary to find an optimal job-machine assignment as well. The complexity usually grows exponentially with the number m of machines making the problem intractable. This problem, like all deterministic scheduling problems, belongs to the wide class of Combinatorial Optimization problems, many of which are known to be NP-hard (Mokotoff, 2001).

2.2.2 Parallel Machine Environments

In PMS problem we have n jobs and m machines. The machines can be identical, uniform or unrelated:

- On identical machines, the processing time of a job, p_i (i=1,…,n), is the same on any machine.
- On uniform machines, each machine has a different processing speed. There is a trend among the processing times of the jobs on different machines.
- On unrelated machines, processing times of jobs vary arbitrarily from one machine to another. So, a matrix p_{ij} (i=1,…,n; j=1,…,m) is needed.

2.2.3 Performance Measures

The objective is to find a suitable allocation of jobs to machines, and a sequence for each machine which would optimize a performance measure. There are many performance measures for scheduling problems. (French, 1982)'s classification of performance measures:

- Completion time based performance measures:
    - Minimize the maximum flow time, $F_{\max}$
    - Minimize the maximum completion time (makespan), $C_{\max}$
    - Minimize mean flow time or total flow time, $\sum F_i / n$ or $\sum F_i$
    - Minimize mean completion time or total completion time, $\sum C_i / n$ or $\sum C_i$
    - Minimize weighted flow time, $\sum w_i F_i$
    - Minimize weighted completion time, $\sum w_i C_i$
- Due date based performance measures:
    - Minimize maximum lateness, $L_{\max}$
    - Minimize maximum tardiness, $T_{\max}$
    - Minimize mean lateness or total lateness, $\sum L_i / n$ or $\sum L_i$
    - Minimize mean tardiness or total tardiness, $\sum T_i / n$ or $\sum T_i$
    - Minimize weighted lateness, $\sum w_i L_i$

    - Minimize weighted tardiness, $\sum w_i T_i$
- Utilization based performance measures:
    - Minimize idle time
    - Maximize utilization of manpower
    - Maximize machine utilization

In real life scheduling problems, performance of a schedule is measured with more than one criterion. (Nagar, 1995) presented a survey of multi and bi-criteria scheduling.

In this study we deal with minimizing the maximum completion time (makespan), $C_{\max}$, criteria in IPMS problem.

2.2.4 Assumptions

(French, 1982) presented following assumptions which characterize parallel machine models.

- Each job is an entity composed of a single operation that cannot be processed on more than one machine simultaneously.
- No preemption is allowed.
- No cancellation.
- Processing times are independent of sequencing.
- Job accumulation is allowed.
- Machine idle time is allowed.
- No machine can process more than one job at a time.
- Machines never break down and are available throughout the scheduling period.
- Ready times are zero for all the jobs.
- There is no randomness:
    - The number of jobs, n, is known and fixed;
    - The number of machines, m, is known and fixed;
    - The processing times, p_i (i=1,…,n), are known and fixed;
    - The ready times, r_i (i=1,…,n), are known and fixed;

- All other specifications needed to define a particular problem are known and fixed.

2.2.5 NP-hardness of $Pm||C_{\max}$

In the general job shop problem each job has a sequence of m operations and each machine has a sequence of n jobs to process. So, it is a resource allocation and sequencing problem. Even 3 jobs on 3 machines problem is NP-hard (Sotskov, Shaklevich, 1995). The $Pm||C_{\max}$ problem is seems easier than general job shop problem because it is only a resource allocation or sequencing problem.

PMS can be solved by finding an optimal sequence of jobs as a sequencing problem. Then we assign jobs according to this sequence, on the free machine. As a resource allocation problem, if we find out the optimum assignment of jobs to machines our problem is solved. The processing order of the assigned jobs on machines has no effect on the performance.

PMS is easier than general job shop but even the most simplified versions of PMS problems are NP-hard in this sense (Pinedo, 1995). According to (Baker, 1998), if we are faced with the need to solve large versions of an NP-hard problem, we know in advance that we may not be able to find optimal solutions with available techniques. Consequently, current studies focus on new ways in determining near optimum solutions. Other ways for solving these hard problems are:

- Simplifiying problem and solving them with exact polynomial solutions
- Applying exact algorithms
- Developing approximation algorithms

2.3 LITERATURE REVIEW

Due to the importance of PMS, their solution have been studied and examined extensively by various approaches. All important approaches relevant to PMS problems can be classified into two main categories: exact algorithms such as dynamic programming, cutting-plane based approaches, lagrangian and branch and bound (B&B)

techniques; and approximate algorithms such as Simulated Annealing, Genetic Algortihms and Tabular Search.

2.3.1 Exact Algorithms

For finite size problems a straightforward exact algorithm is to simply enumerate the full solution space. Yet, such an algorithm is infeasible due to the exponential size of the solution space. To increase efficiency, all modern exact methods use pruning rules to discard parts of the search space in which the (optimal) solution cannot be found. These approaches are doing an implicit enumeration of the search space (Stützle, 1998).

Mixedinteger programming is one of the most widely used techniques to formulate PMS models. Using mixed integer linear programming, as opposed to approximation algorithms, may not give the optimum solution in polynomial time. A mixed-integer programming formulation for the $Pm| |C_{\max}$ is as follows:

$$\text{Min } C_{\max} \tag{2.2}$$

$$\text{s.t. } C_{\max} - \sum_{i=1}^{n} p_i x_{ij} \geq 0 \text{ for all j=1,….,m} \tag{2.3}$$

$$\sum_{j=1}^{m} x_{ij} = 1 \text{ for all i=1,….,n} \tag{2.4}$$

$$x_{ij} \in \{0,1\} \text{ for all i=1,….,n; for all j=1,….,m} \tag{2.5}$$

where; $x_{ij} = 1$ if job i is assigned to machine j,

$x_{ij} = 0$ if job i is not assigned to machine j.

Constraint (2.3) ensures that maximum completion time of jobs on any machine m cannot exceed the makespan value $C_{\max}$. Constraint (2.4) guarantees that each job is processed on one and only one machine.

(Dell'Amico, Martello, 1995) presented an effective branch and bound based procedure for minimizing makespan on identical parallel machines. For unrelated parallel machines, B&B algorithms were proposed by (Stern, 1976), (Martello, 1997).

(Rothkopf, 1966), (Lawler, Moore, 1969), (Sahni, 1976), (Graham, 1979), (Lenstra, Rinnoy Kan, 1980), and (Leung, 1982) have proposed general dynamic programming approaches. The time and memory required to run those makes these formulations inefficient.

2.3.2 Approximation Algorithms

Approximation algorithms try to find a satisfactory solution within an acceptable amount of time, based on a heuristic rule. They cannot guarantee to find optimal solutions but they can find near optimal solutions much faster than exact algorithms. Approximation algorithms are divided to two classes: constructive and local search algorithms.

2.3.2.1 Constructive Algorithms

Constructive algorithms generate solutions starting from the input data, following a set of rules. List scheduling (LS) (Graham, 1966) and MultiFit (Coffman, 1984) constructive algorithms are applied to the PMS problem.

In LS, firstly make a list of the jobs, in some order. Then remove the first job from the list and assign it to the first available machine. Repeat this step until all the jobs on the list have been assigned to some machine (Graham, 1966). However, there is no obvious way to order the list. The accuracy of the LS is depends on the list-making rule. Any simple dispatching rule (e.g., LPT, SPT) will sometimes produce suboptimal results.

(De, Morton, 1980) suggested that in order to minimize makespan, overloading at the end of the list must be avoided. This can be avoided by not assigning the jobs with the LPT, on the last positions of the list. After making a list with LPT rule, we can apply any LS algorithm. Satisfactory results of worst case and probability case analysis have shown that LPT is asymptotically an excellent approximation algorithm (Frenk, Rinnony Kan, 1986).

In the next theorem, an upperbound is presented for $\frac{C_{\max}(LPT)}{C_{\max}(OPT)}$, where $C_{\max}(LPT)$ denotes the makespan of the LPT schedule and $C_{\max}(OPT)$ denotes the makespan of the (possibly unknown) optimal schedule. This type of worst case analysis is of interest as it gives an indication of how well the heuristic is guaranteed to perform as well as the type of instances for which the heuristic performs badly (Pinedo, 1995).

Upperbound Theorem: For $Pm||C_{\max}$,

$$\frac{C_{\max}(LPT)}{C_{\max}(OPT)} \leq \frac{4}{3} - \frac{1}{3 \times m}$$

This theorem shows that, if there is one machine, LPT gives the optimum result. When the number of machines increase, the worst case ratio reaches to $1.\overline{33}$.

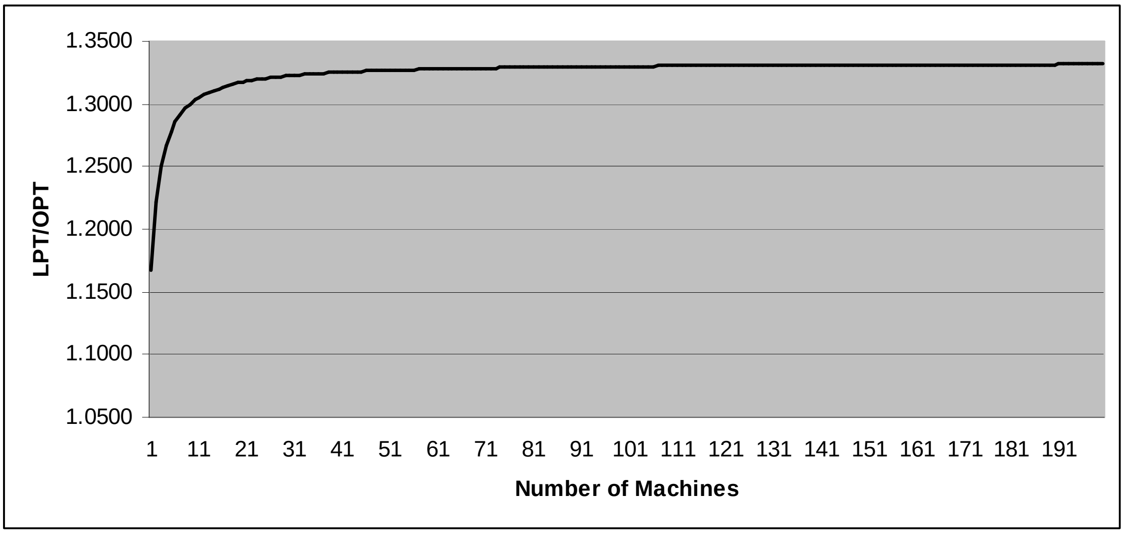


Figure 2.1 The worst case ratio graph according to the number of machines

2.3.2.2 Local Search Algorithms

The most effective approximate algorithms today are local search algorithms (alternatively called neighbourhood search algorithms). Local search algorithms start from some initial solution and iteratively try to replace the current solution by a better solution in an appropriately defined neighborhood of the current solution.

The most basic local search algorithm is iterative improvement which only replaces the current solution with a better one and stops as soon as no better, neighbored solutions can be found anymore (Stützle, 1998).

First applications of local search have been presented in the late fifties and the early sixties (Croes, 1958), (Lin, 1965). They have become very popular in the last twenty years and that they are applied to many problems but there are a few applications to PMS problems.

(Hübscher, Glover, 1994) presented a Tabular Search (TS) approach to the $Pm||C_{\max}$ problem. They introduced a diversification strategy based on selecting influential moves, which improves the behavior and quality of the solutions obtained by general TS.

(Jozefowska, 1998) considered the discrete-continuous identical PMS problem where the optimization criterion is the makespan. In order to solve this NP-hard problem, they combined linear programming and local search methods (TS, SA, and GA). By comparing the performance of the three metaheuristics, they showed that TS is preferable, finding the largest number of optimal solutions and showing the smallest deviation for all problem sizes.

CHAPTER 3

VARIABLE NEIGHBOURHOOD SEARCH ALGORITHM

3.1 AN OVERVIEW

In recent years, several general heuristics (or metaheuristics) have been proposed which extend local search in various ways and avoid being trapped in local optima with a poor value. The purpose of this note is to show that a simple and effective metaheuristic may be obtained by proceeding to a systematic change of neighborhood within a local search algorithm. (Mladenovi´c, Hansen, 1997) call this approach Variable Neighborhood Search (VNS). The diffrerence of VNS from most other local search methods is VNS does not follow a trajectory, but explores increasingly distant neighborhoods of the current solution, and jumps from there to a new one if and only if a better solution is optained.

3.2 NEIGHBOURHOOD STRUCTURES

The performance of the metaheuristic algorithm significantly depends on the efficiency of the neighbourhood structure. The solutions are determined to move with the neighbourhood structure. In this study, the following two neighbourhood structures are employed:

Exchange is a function used to move around in which any two randomly selected operations are simply swapped. In Figure 3.1, B and E are selected randomly and swapped.

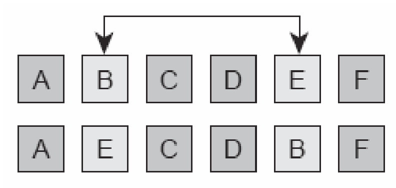


Figure 3.1 Exchange Function

Insert is another fine-tuning function that inserts a randomly chosen gene in front or back of another randomly chosen gene. In Figure 3.2, B and E are selected randomly. B is inserted in front (or back) of E.

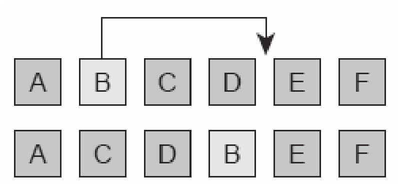


Figure 3.2 Insert Function

There are many neighbourhood structures reported in the literature but we preferred these two due to the simplicity, ease of use and a reasonable efficiency.

3.3 VNS ALGORITHM

VNS is one of the most recent metaheuristics developed for problem solving in an easier way. It is known as one of very well-known local search methods. VNS gets more attention day-by-day due to its ease of use and accomplishments in solving combinatorial optimisation problems.

The VNS is a simple and effective search procedure that proceeds to a systematic change of neighbourhood. An ordinary VNS algorithm gets an initial solution $x \in S$, where S is the whole set of search space, than manipulates it through a two nested loop in which the core one alters and explores via two main functions so called shake and local search. The outer loop works as a refresher reiterating the inner loop, while the inner loop carries the major search. Local search explores an improved solution within the local neighbourhood, while shake diversifies the solution by switching to another local neighbourhood.

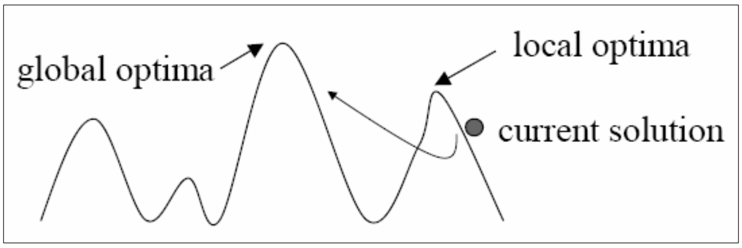


Figure 3.3 Diversification by shake function

The inner loop iterates as long as it keeps improving the solutions, where an integer, k, controls the length of the loop. Once an inner loop is completed, the outer loop re-iterates until the termination condition is met. Since the complementariness of neighbourhood functions is the key idea behind VNS, the neighbourhood structure should be chosen very rigorously in order to achieve an efficient VNS.

In order to develop an effective VNS algorithm, one needs two kinds of neighbourhood functions: shake functions ($N_k^s(x)$) and local search functions ($N_l^{LS}(x)$). Each neighbourhood function has a particular neighbourhood structure. The neighbourhood structures may be used more than one for each function (shake and local search) so as to achieve a valuable neighbourhood change. For that purpose, the counters k ($1 \le k \le k_{\max}$) and l ($1 \le l \le l_{\max}$) are used for shake and local search functions respectively in order to ease switching from one to another neighbourhood.

Steps of the VNS procedure are as follows:

1. Initialization: Find an initial solution x.
2. Repeat the following steps until the stopping condition is met:
   - **a.** Shake Procedure: Generate at random a starting solution $x' \in N_k^S(x)$.
   - **b.** Local Search: Apply a local search from the starting solution x' using the base neighborhood structure $N_l^{LS}(x)$ until a local minimum $x'' \in N_l^{LS}(x)$ is found.
   - **c.** Improve or not: If x" is better than x, do x ← x'.

The stopping condition may be a maximum CPU time allowed, a maximum number of iterations, or maximum number of iterations between two improvements.

CHAPTER 4

EXPERIMENTAL RESULTS

4.1 AN OVERVIEW

In this chapter, VNS configurations for PMS are developed, which is a recently proposed metaheuristic for solving combinatorial problems. As explained in chapter 3, Metaheuristics (or modern heuristic techniques) present near optimal solutions for real problems. In addition, LPT Rule is used for the worst case analysis as an upperbound theorem.

4.2 VNS TO PMS

Variable Neighborhood Search is a recently proposed metaheuristic for solving combinatorial problems (Mladenovic, 1995). The basic idea is to proceed to a systematic change of neighborhood within a local search algorithm. Exploration of these neighborhoods can be done in two ways. The smallest ones, i.e. those closest to the current solution, may be explored systematically until a solution better than the incumbent is found. The largest ones, i.e. those far from the current solution, may be explored partially by drawing a solution at random and beginning a (variable neighborhood) local search from there. The algorithm remains at the same solution until another solution better than the incumbent is found and then jumps there. Neighborhoods are usually ranked in such a way that solutions are explored increasingly far from the current one. In this way, intensification of the search around the current solution is followed naturally by diversification. The level of intensification or diversification can be controlled through a few easy to set parameters. We may view

Variable Neighborhood Search as a 'shaking' process, where movement to a neighborhood further from the current solution corresponds to a harder shake. Unlike random restart, Variable Neighborhood Search allows a controlled increase in the level of the shake (Mladenovic and Hansen, 1997).

```
function Modified VNS
        generate initial solution, x∈S
        while termination condition not met do
                k←1
                x'∈S←shake function(x)
                while k≤k_max do
                        if(k=1) then x" ∈S←local search function 1(x')
                        if(k=2) then x" ∈S←local search function 2(x')
                        if  f(x")<f(x') then
                                x'←x"
                        else k←k+1
                        end-if
                end-while
        if  f(x')<f(x) then x←x'
        end-while
end-function
```

Figure 4.1 the pseudocode of the VNS algorithm

4.2.1 Experimentation with VNS Algorithm

This section describes our experiment to test the efficiency of the VNS algorithm. The VNS algorithm was coded in Borland C and implemented on an Intel P4 1.33GHz PC with 256 MB memory. We have applied three different VNS implementations with different configurations of shake and local search functions. Our aim is to develop efficient implementation. The list of three VNS algorithms provided with their configurations is in the following.

Table 4.1 VNS implementations

VNS-I	No Shake Local Search ← Exchange + Insert
VNS-II	Shake ← Exchange + Insert + Exchange Local Search ← Exchange + Insert
VNS-III	Shake ← Exchange + Insert + Exchange Local Search ← Exchange

Test problems were generated for varying sizes of m = 2, 5, 10 or 20 machines and n = 20, 50, 100 or 200 jobs. We generate, for each job, an integer processing time p_i using a uniform distribution [1,100]. We generate 10 instances for each pair of (n, m). 10 replications of 10 instances were run for 2x20, 2x50, 2x100, 2x200, 5x20, 5x50, 5x100, 5x200, 10x20, 10x50, 10x100, 10x200, 20x50, 20x100 and 20x200 problem sets, e.g., in 2x20 problem, 2 corresponds to the number of jobs and 20 corresponds to the number of machines. Since all the data require about 50 pages to be shown, only 8 of them were chosen to show to the data pattern as presented in Appendix A. Results obtained from VNS algorithms for m=2, 5, 10 and 20 with respect to makespan and CPU values are given in Appendix B. The statistics of these two performance metrics such as the average, standard deviation, minimum and the maximum values are calculated in MS Excel file.

We have applied LPT rule to our problem instances. Their makespan values are given in Appendix D. According to upperbound theorem, $\frac{C_{\max}(LPT)}{C_{\max}(OPT)} \le \frac{4}{3} - \frac{1}{3 \times m}$. So from this equation we can obtain upperbounds for problems. In Table 4.2 we can see upperbounds for our 2, 5, 10 and 20 machine problems. By using these obtained upperbound values we can obtain lowerbound values from $\frac{C_{\max}(LPT)}{U.B.} \le C_{\max}(OPT)$. Our problem lowerbound values are given in Appendix C.

Table 4.2 Upperbounds for 2, 5, 10 and 20 machine problems

# Machine	LPT / OPT
2	1.1667
5	1.2667
10	1.3000
20	1.3167

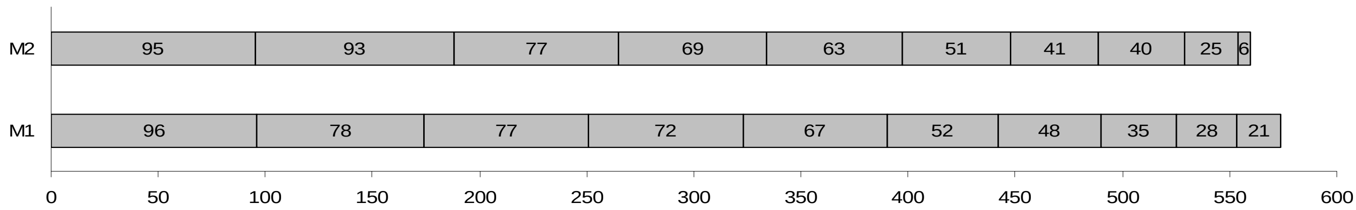
4.2.1.1 Problem Representation

Consider first instance of our 2x20 problem.

Ji	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pi	67	48	96	77	69	41	6	63	35	52	21	51	28	40	95	77	93	25	72	78

LPT Schedule:

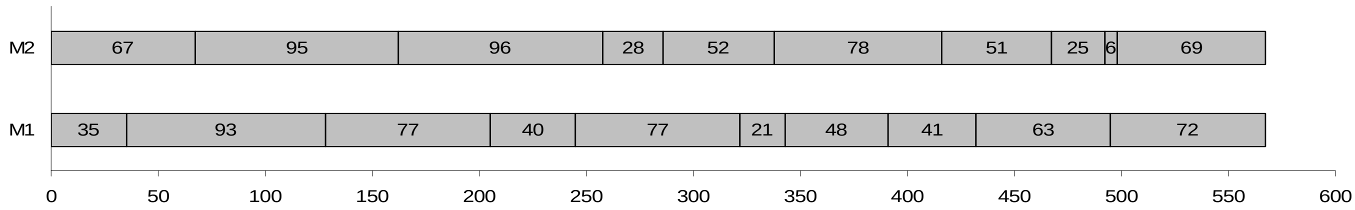
Ji	3	15	17	20	4	16	19	5	1	8	10	12	2	6	14	9	13	18	11	7
Pi	96	95	93	78	77	77	72	69	67	63	52	51	48	41	40	35	28	25	21	6



$$C_{\max}(LPT) = 574 \qquad \frac{C_{\max}(LPT)}{C_{\max}(OPT)} \leq 1.1667$$

VNS Schedule:

Ji	9	1	17	15	16	3	14	4	13	10	11	20	2	6	12	8	18	7	19	5
Pi	35	67	93	95	77	96	40	77	28	52	21	78	48	41	51	63	25	6	72	69



$$C_{\max}(VNS) = 567 \qquad \frac{C_{\max}(VNS)}{C_{\max}(OPT)} \leq 1.1524$$

In the following section, experimental study has been completed in two stages; first, we compared the LPT rule and the VNS algorithm with respect to their makespan values then the LPT rule worst case ratio (LPT / OPT) and the VNS algorithm worst case ratio (VNS / OPT). Experimental results are in the following Table 4.3. In fisrt column we can see problem instance number. In the next five columns, optimum, LPT, VNS-I, VNS-II and VNS-III makespans are given. Then in the next three columns we can see how much VNS results the LPT rule and the VNS algorithm with respect to their makespan values then the LPT rule worst case ratio and the VNS algorithm worst case ratio.

4.2.1.2 Results of the $P2||C_{\max}$ problem

The performance of VNS algorithm looks very impressive as the results produced. As seen from the tables, the worst case ratios of VNS algorithm are less than or equal to those of LPT for all problem sets. VNS gives good results for 2x20. Eight of ten LPT results are improved. When job size increased, the performance decreased but still it results in the same values with LPT.

Table 4.3.a $P2||C_{\max}$ problem for 20 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
2-20-01	492	574	567	567	567	1.0123	1.0123	1.0123	1.1667	1.1524	1.1524	1.1524
2-20-02	429	501	500	500	500	1.0020	1.0020	1.0020	1.1667	1.1643	1.1643	1.1643
2-20-03	401	468	468	468	468	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-20-04	477	557	553	553	553	1.0072	1.0072	1.0072	1.1667	1.1583	1.1583	1.1583
2-20-05	411	479	476	476	476	1.0063	1.0063	1.0063	1.1667	1.1594	1.1594	1.1594
2-20-06	458	534	530	530	530	1.0075	1.0075	1.0075	1.1667	1.1579	1.1579	1.1579
2-20-07	507	592	591	591	591	1.0017	1.0017	1.0017	1.1667	1.1647	1.1647	1.1647
2-20-08	369	431	431	431	431	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-20-09	560	653	652	652	652	1.0015	1.0015	1.0015	1.1667	1.1649	1.1649	1.1649
2-20-10	439	512	509	509	509	1.0059	1.0059	1.0059	1.1667	1.1598	1.1598	1.1598
improved			8	8	8							

Table 4.3.b $P2||C_{\max}$ problem for 50 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
2-50-01	977	1140	1139	1139	1139	1.0009	1.0009	1.0009	1.1667	1.1656	1.1656	1.1656
2-50-02	1089	1270	1270	1270	1270	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-50-03	1119	1306	1306	1306	1306	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-50-04	1147	1338	1335	1335	1335	1.0022	1.0022	1.0022	1.1667	1.1641	1.1641	1.1641
2-50-05	1111	1296	1296	1296	1296	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-50-06	1039	1212	1212	1212	1212	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-50-07	1043	1217	1216	1216	1216	1.0008	1.0008	1.0008	1.1667	1.1657	1.1657	1.1657
2-50-08	1053	1229	1229	1229	1229	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-50-09	1030	1202	1202	1202	1202	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-50-10	892	1041	1041	1041	1041	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
improved			3	3	3							

Table 4.3.c $P2||C_{\max}$ problem for 100 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
2-100-01	2338	2728	2728	2728	2728	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-02	2087	2435	2435	2435	2435	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-03	1781	2078	2078	2078	2078	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-04	2037	2377	2377	2377	2377	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-05	2305	2689	2689	2689	2689	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-06	2187	2552	2552	2552	2552	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-07	2074	2420	2420	2420	2420	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-08	2314	2700	2700	2700	2700	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-100-09	2199	2565	2564	2564	2564	1.0004	1.0004	1.0004	1.1667	1.1662	1.1662	1.1662
2-100-10	2309	2694	2694	2694	2694	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
improved			1	1	1							

Table 4.3.d $P2||C_{\max}$ problem for 200 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
2-200-01	4308	5026	5026	5026	5026	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-02	4052	4727	4727	4727	4727	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-03	4334	5056	5056	5056	5056	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-04	4105	4789	4789	4789	4789	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-05	3993	4659	4659	4659	4659	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-06	4269	4981	4981	4981	4981	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-07	4289	5004	5004	5004	5004	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-08	4300	5017	5017	5017	5017	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-09	4307	5025	5025	5025	5025	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
2-200-10	4110	4795	4795	4795	4795	1.0000	1.0000	1.0000	1.1667	1.1667	1.1667	1.1667
improved			0	0	0							

4.2.1.3 Results of the $P5||C_{\max}$ *problem*

The performance of VNS algorithm looks very impressive as the results produced. As seen from the tables, the worst case ratios of VNS algorithm are less than or equal to those of LPT for all problem sets. VNS gives excellent results for 5x20; it improves LPT results for all instances. Eight of ten LPT results are improved in 5x50. When job size increased to 100 or 200, the number of improvement decreased to 4.

Table 4.4.a $P5||C_{\max}$ problem for 20 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
5-20-01	128	162	157	157	157	1.0318	1.0318	1.0318	1.2667	1.2276	1.2276	1.2276
5-20-02	173	219	214	214	214	1.0234	1.0234	1.0234	1.2667	1.2377	1.2377	1.2377
5-20-03	148	188	183	183	183	1.0273	1.0273	1.0273	1.2667	1.2330	1.2330	1.2330
5-20-04	176	223	216	216	216	1.0324	1.0324	1.0324	1.2667	1.2269	1.2269	1.2269
5-20-05	144	183	182	182	182	1.0055	1.0055	1.0055	1.2667	1.2597	1.2597	1.2597
5-20-06	164	208	206	206	206	1.0097	1.0097	1.0097	1.2667	1.2545	1.2545	1.2545
5-20-07	184	233	231	231	231	1.0087	1.0087	1.0087	1.2667	1.2558	1.2558	1.2558
5-20-08	171	217	206	206	206	1.0534	1.0534	1.0534	1.2667	1.2025	1.2025	1.2025
5-20-09	194	246	239	239	239	1.0293	1.0293	1.0293	1.2667	1.2306	1.2306	1.2306
5-20-10	168	213	210	210	210	1.0143	1.0143	1.0143	1.2667	1.2488	1.2488	1.2488
		improved	10	10	10							

Table 4.4.b $P5||C_{\max}$ problem for 50 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
5-50-01	420	532	527	527	527	1.0095	1.0095	1.0095	1.2667	1.2548	1.2548	1.2548
5-50-02	395	500	497	497	497	1.0060	1.0060	1.0060	1.2667	1.2591	1.2591	1.2591
5-50-03	395	500	499	499	499	1.0020	1.0020	1.0020	1.2667	1.2641	1.2641	1.2641
5-50-04	413	523	518	518	518	1.0097	1.0097	1.0097	1.2667	1.2546	1.2546	1.2546
5-50-05	468	593	592	592	592	1.0017	1.0017	1.0017	1.2667	1.2645	1.2645	1.2645
5-50-06	459	581	578	578	578	1.0052	1.0052	1.0052	1.2667	1.2601	1.2601	1.2601
5-50-07	364	461	461	461	461	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-50-08	365	462	462	462	462	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-50-09	374	474	473	473	473	1.0021	1.0021	1.0021	1.2667	1.2640	1.2640	1.2640
5-50-10	382	484	480	480	480	1.0083	1.0083	1.0083	1.2667	1.2562	1.2562	1.2562
		improved	8	8	8							

Table 4.4.c $P5\|C_{\max}$ problem for 100 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
5-100-01	872	1104	1099	1099	1099	1.0045	1.0045	1.0045	1.2667	1.2609	1.2609	1.2609
5-100-02	806	1021	1021	1021	1021	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-100-03	671	850	850	850	850	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-100-04	863	1093	1093	1093	1093	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-100-05	767	971	970	970	970	1.0010	1.0010	1.0010	1.2667	1.2654	1.2654	1.2654
5-100-06	764	968	968	968	968	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-100-07	741	939	939	939	939	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-100-08	814	1031	1031	1031	1031	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-100-09	769	974	973	973	973	1.0010	1.0010	1.0010	1.2667	1.2654	1.2654	1.2654
5-100-10	739	936	935	935	935	1.0011	1.0011	1.0011	1.2667	1.2653	1.2653	1.2653
improved			4	4	4							

Table 4.4.d $P5\|C_{\max}$ problem for 200 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
5-200-01	1745	2210	2209	2209	2209	1.0005	1.0005	1.0005	1.2667	1.2661	1.2661	1.2661
5-200-02	1573	1993	1993	1993	1993	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-200-03	1569	1988	1988	1988	1988	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-200-04	1472	1864	1863	1863	1863	1.0005	1.0005	1.0005	1.2667	1.2660	1.2660	1.2660
5-200-05	1655	2096	2095	2095	2095	1.0005	1.0005	1.0005	1.2667	1.2661	1.2661	1.2661
5-200-06	1592	2016	2016	2016	2016	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-200-07	1600	2027	2025	2025	2025	1.0010	1.0010	1.0010	1.2667	1.2654	1.2654	1.2654
5-200-08	1569	1987	1987	1987	1987	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-200-09	1605	2033	2033	2033	2033	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
5-200-10	1563	1980	1980	1980	1980	1.0000	1.0000	1.0000	1.2667	1.2667	1.2667	1.2667
improved			4	4	4							

4.2.1.4 Results of the $P10\|C_{\max}$ *problem*

The performance of VNS algorithm looks very impressive as the results produced. As seen from the tables, the worst case ratios of VNS algorithm are less than or equal to those of LPT for all problem sets. VNS gives excellent results for 10x50; it improves LPT results for all instances. But it can improve two of ten LPT results in 10x20.

Table 4.5.a $P10\|\|C_{max}$ problem for 20 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
10-20-01	87	113	113	113	113	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-20-02	79	103	100	100	100	1.0300	1.0300	1.0300	1.3000	1.2621	1.2621	1.2621
10-20-03	82	106	106	106	106	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-20-04	75	98	96	96	96	1.0208	1.0208	1.0208	1.3000	1.2735	1.2735	1.2735
10-20-05	76	99	99	99	99	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-20-06	88	114	114	114	114	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-20-07	81	105	105	105	105	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-20-08	88	115	115	115	115	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-20-09	91	118	118	118	118	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-20-10	98	127	127	127	127	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
improved			2	2	2							

Table 4.5.b $P10\|\|C_{max}$ problem for 50 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
10-50-01	246	320	312	312	312	1.0256	1.0256	1.0256	1.3000	1.2675	1.2675	1.2675
10-50-02	202	263	259	259	259	1.0154	1.0154	1.0154	1.3000	1.2802	1.2802	1.2802
10-50-03	184	239	235	235	235	1.0170	1.0170	1.0170	1.3000	1.2782	1.2782	1.2782
10-50-04	179	233	231	231	231	1.0087	1.0087	1.0087	1.3000	1.2888	1.2888	1.2888
10-50-05	217	282	279	279	279	1.0108	1.0108	1.0108	1.3000	1.2862	1.2862	1.2862
10-50-06	202	263	259	259	259	1.0154	1.0154	1.0154	1.3000	1.2802	1.2802	1.2802
10-50-07	207	269	262	262	262	1.0267	1.0267	1.0267	1.3000	1.2662	1.2662	1.2662
10-50-08	225	292	290	290	290	1.0069	1.0069	1.0069	1.3000	1.2911	1.2911	1.2911
10-50-09	200	260	257	257	257	1.0117	1.0117	1.0117	1.3000	1.2850	1.2850	1.2850
10-50-10	183	238	236	237	237	1.0085	1.0042	1.0042	1.3000	1.2891	1.2945	1.2945
improved			10	10	10							

Table 4.5.c $P10\|\|C_{max}$ problem for 100 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
10-100-01	353	459	459	459	459	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-100-02	410	533	532	532	532	1.0019	1.0019	1.0019	1.3000	1.2976	1.2976	1.2976
10-100-03	397	516	510	510	510	1.0118	1.0118	1.0118	1.3000	1.2849	1.2849	1.2849
10-100-04	360	468	467	467	467	1.0021	1.0021	1.0021	1.3000	1.2972	1.2972	1.2972
10-100-05	398	518	517	517	517	1.0019	1.0019	1.0019	1.3000	1.2975	1.2975	1.2975
10-100-06	382	496	493	493	493	1.0061	1.0061	1.0061	1.3000	1.2921	1.2921	1.2921
10-100-07	370	481	478	478	478	1.0063	1.0063	1.0063	1.3000	1.2919	1.2919	1.2919
10-100-08	378	491	489	489	489	1.0041	1.0041	1.0041	1.3000	1.2947	1.2947	1.2947
10-100-09	368	479	477	477	477	1.0042	1.0042	1.0042	1.3000	1.2946	1.2946	1.2946
10-100-10	388	505	504	504	504	1.0020	1.0020	1.0020	1.3000	1.2974	1.2974	1.2974
improved			9	9	9							

Table 4.5.d $P10\| \|C_{\max}$ problem for 200 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
10-200-01	774	1006	1003	1003	1003	1.0030	1.0030	1.0030	1.3000	1.2961	1.2961	1.2961
10-200-02	784	1019	1019	1019	1019	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-200-03	739	961	961	961	961	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-200-04	780	1014	1014	1014	1014	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-200-05	778	1012	1011	1011	1011	1.0010	1.0010	1.0010	1.3000	1.2987	1.2987	1.2987
10-200-06	811	1054	1053	1053	1053	1.0009	1.0009	1.0009	1.3000	1.2988	1.2988	1.2988
10-200-07	732	951	949	949	949	1.0021	1.0021	1.0021	1.3000	1.2973	1.2973	1.2973
10-200-08	798	1038	1037	1037	1037	1.0010	1.0010	1.0010	1.3000	1.2987	1.2987	1.2987
10-200-09	786	1022	1022	1022	1022	1.0000	1.0000	1.0000	1.3000	1.3000	1.3000	1.3000
10-200-10	772	1003	1002	1002	1002	1.0010	1.0010	1.0010	1.3000	1.2987	1.2987	1.2987
		improved	6	6	6							

4.2.1.5 Results of the $P20\| \|C_{\max}$ *problem*

The performance of VNS algorithm looks very impressive as the results produced. As seen from the tables, the worst case ratios of VNS algorithm are less than or equal to those of LPT for all problem sets. VNS gives excellent results for 20 machine problem sets. The improvement performance is very high for all instances.

Table 4.6.a $P20\| \|C_{\max}$ problem for 50 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
20-50-01	103	136	130	130	131	1.0462	1.0462	1.0382	1.3167	1.2586	1.2586	1.2683
20-50-02	99	131	131	131	131	1.0000	1.0000	1.0000	1.3167	1.3167	1.3167	1.3167
20-50-03	106	140	129	130	131	1.0853	1.0769	1.0687	1.3167	1.2132	1.2226	1.2320
20-50-04	106	140	131	130	131	1.0687	1.0769	1.0687	1.3167	1.2320	1.2226	1.2320
20-50-05	95	125	121	122	122	1.0331	1.0246	1.0246	1.3167	1.2745	1.2851	1.2851
20-50-06	99	131	123	124	124	1.0650	1.0565	1.0565	1.3167	1.2363	1.2463	1.2463
20-50-07	115	151	139	139	139	1.0863	1.0863	1.0863	1.3167	1.2120	1.2120	1.2120
20-50-08	96	127	122	122	122	1.0410	1.0410	1.0410	1.3167	1.2648	1.2648	1.2648
20-50-09	116	153	137	137	138	1.1168	1.1168	1.1087	1.3167	1.1790	1.1790	1.1876
20-50-10	83	109	106	106	106	1.0283	1.0283	1.0283	1.3167	1.2804	1.2804	1.2804
		improved	9	9	9							

Table 4.6.b $P20||C_{max}$ problem for 100 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
20-100-01	194	256	252	252	252	1.0159	1.0159	1.0159	1.3167	1.2961	1.2961	1.2961
20-100-02	202	266	262	261	262	1.0153	1.0192	1.0153	1.3167	1.2969	1.2919	1.2969
20-100-03	201	265	261	261	261	1.0153	1.0153	1.0153	1.3167	1.2968	1.2968	1.2968
20-100-04	192	253	251	251	251	1.0080	1.0080	1.0080	1.3167	1.3063	1.3063	1.3063
20-100-05	186	245	243	243	243	1.0082	1.0082	1.0082	1.3167	1.3059	1.3059	1.3059
20-100-06	197	259	253	253	253	1.0237	1.0237	1.0237	1.3167	1.2862	1.2862	1.2862
20-100-07	208	274	264	264	264	1.0379	1.0379	1.0379	1.3167	1.2686	1.2686	1.2686
20-100-08	207	272	268	268	268	1.0149	1.0149	1.0149	1.3167	1.2973	1.2973	1.2973
20-100-09	197	260	258	258	258	1.0078	1.0078	1.0078	1.3167	1.3065	1.3065	1.3065
20-100-10	191	251	250	250	250	1.0040	1.0040	1.0040	1.3167	1.3114	1.3114	1.3114
		improved	10	10	10							

Table 4.6.c $P20||C_{max}$ problem for 200 jobs results with respect to makespan

Problem Name	OPT≥	LPT	VNS-I	VNS-II	VNS-III	LPT / VNS-I	LPT / VNS-II	LPT / VNS-III	LPT / OPT	VNS-I / OPT	VNS-II / OPT	VNS-III / OPT
20-200-01	380	500	498	498	499	1.0040	1.0040	1.0020	1.3167	1.3114	1.3114	1.3140
20-200-02	365	480	479	479	479	1.0021	1.0021	1.0021	1.3167	1.3139	1.3139	1.3139
20-200-03	392	516	513	513	513	1.0058	1.0058	1.0058	1.3167	1.3090	1.3090	1.3090
20-200-04	373	491	491	491	491	1.0000	1.0000	1.0000	1.3167	1.3167	1.3167	1.3167
20-200-05	377	496	495	495	495	1.0020	1.0020	1.0020	1.3167	1.3140	1.3140	1.3140
20-200-06	383	504	503	503	503	1.0020	1.0020	1.0020	1.3167	1.3141	1.3141	1.3141
20-200-07	375	494	491	491	492	1.0061	1.0061	1.0041	1.3167	1.3087	1.3087	1.3113
20-200-08	406	534	533	533	534	1.0019	1.0019	1.0000	1.3167	1.3142	1.3142	1.3167
20-200-09	400	527	523	523	523	1.0076	1.0076	1.0076	1.3167	1.3067	1.3067	1.3067
20-200-10	376	495	495	495	495	1.0000	1.0000	1.0000	1.3167	1.3167	1.3167	1.3167
		improved	8	8	7							

If we look over the results, we can see that VNS gives much better results than LPT. It is concluded that the VNS algorithms improved 92 out of the 150 instances of LPT results in a reasonable computing time.

CHAPTER 5

CONCLUSION

The objective of our study is to determine a sequence of n jobs to be processed through m identical parallel machines. The sequence should be arranged in order to minimize makespan. The problem is denoted as $Pm||C_{\max}$ in scheduling.

The LPT is asymptotically an excellent approximation algorithm. LPT rule assigns at t=0 the m largest jobs to the m machines. After that, whenever a machine is freed, the longest job among those not yet processed is put on the machine. This heuristic tires to place the shorter jobs toward the end of the schedule, where they can be used for balancing the loads (Pinedo, 1995).

Since the problem is known to be NP-hard, we may not be able to find optimal solutions to large versions of an NP-hard problem with available techniques such as branch & bound or dynamic programming algorithms. Current studies focus on new ways in determining near optimum solutions. It is better to develop metaheuristic algorithms.

Metaheuristics (or modern heuristic techniques) present near optimal solutions for real problems. VNS is a recently proposed metaheuristic for solving combinatorial problems. The basic idea of VNS is to proceed to a systematic change of neighborhood within a local search algorithm. We designed three different VNS implementations with different configurations of shake and local search functions.

In this thesis, an investigation of VNS algorithm is proposed for the IPMS problem with makespan criterion. LPT Rule is used for the worst case analysis as an upperbound theorem. Two metrics are measured as the performance criteria: the makespan and the execution time (CPU). The results gained by VNS algorithm are presented for each configuration. The solution quality was evaluated and compared according to the LPT solutions. It is concluded that the VNS algorithms improved 92 out of the 150 instances of LPT results in a reasonable computing time.

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APPENDIX A

DATASET

2-20-01

2

20

67	48	96	77	69	41	6	63	35	52	21
51	28	40	95	77	93	25	72	78		

2-20-02

2

20

68	8	77	77	14	47	58	88	14	11	35
3	40	18	86	62	69	35	95	95		

2-50-01

2

50

53	15	1	53	19	58	43	13	74	42	31
81	4	59	6	8	89	57	81	89	11	12
66	57	63	11	30	30	41	42	19	59	65
87	66	5	90	85	30	80	16	14	45	33
80	58	76	12	54	65					

2-50-02

2

50

8	37	44	57	63	71	75	99	91	88	18
69	60	52	36	41	53	51	53	62	14	79
32	83	8	86	13	85	43	27	82	28	71
73	31	63	43	84	11	45	17	2	37	89
4	67	40	25	58	72					

2-100-01

2

100

87	36	94	90	92	78	83	7	83	3	31
94	9	85	1	6	22	90	78	65	85	68
86	32	29	50	85	86	71	16	100	1	3
2	29	55	52	18	31	68	69	32	69	24
84	19	92	30	82	84	53	55	75	23	77
66	10	67	19	66	59	5	86	88	76	80
76	56	84	2	95	99	84	9	8	83	53
42	36	91	45	97	38	36	51	74	37	31
7	13	80	37	11	62	80	81	49	48	93
76										

2-100-02

2

100

51	49	83	64	22	11	48	67	15	92	62
29	55	26	56	15	10	39	92	99	90	24
13	100	18	35	59	37	15	49	68	52	90
84	30	55	97	96	50	79	62	77	47	43
38	4	10	35	38	35	73	90	82	42	57
72	76	62	17	61	34	50	20	25	87	28
64	16	83	9	59	23	100	68	4	32	27
94	17	40	23	22	10	54	20	87	51	48
34	82	31	35	63	53	31	27	60	10	25
77										

2-200-01

2
200

44	100	40	31	15	60	35	3	18	43	71
64	54	42	78	75	64	2	6	17	60	23
34	23	76	48	49	66	93	44	10	21	33
71	92	82	41	17	10	95	77	38	56	100
5	3	45	16	6	15	24	30	79	91	33
65	98	79	67	61	54	7	80	95	48	78
68	20	67	62	17	48	13	79	80	62	52
33	48	37	34	58	67	99	55	80	61	43
13	76	56	18	30	53	93	74	85	69	89
58	51	42	35	98	76	13	70	13	35	71
90	88	7	12	57	37	24	48	21	85	7
56	91	9	34	19	69	70	92	24	53	84
26	99	17	5	25	81	77	55	55	84	27
32	62	98	25	39	46	10	75	7	22	63
61	71	99	67	67	11	86	64	75	43	70
60	62	25	68	100	26	45	78	50	48	45
6	58	78	3	65	13	4	77	45	86	78
79	15	90	27	4	32	16	28	5	44	44
96	30									

2-200-02

2
200

49	57	35	47	52	64	92	72	62	99	34
70	3	73	31	83	47	84	60	39	72	95
15	28	72	1	13	29	83	70	69	41	26
36	85	26	53	36	47	26	92	42	79	89
13	71	95	13	97	1	92	26	38	27	37
27	23	20	84	31	49	7	77	62	99	8
99	18	32	55	36	4	23	58	28	14	42
23	10	14	53	54	96	66	9	38	38	16
90	52	39	99	21	96	97	69	10	25	49
89	92	8	44	40	6	33	38	39	2	88
22	43	20	51	3	3	7	24	5	67	79
88	29	50	73	61	9	99	75	55	80	65
28	26	56	60	33	7	9	82	68	80	51
9	78	42	46	85	53	83	38	22	49	65
1	37	91	62	47	60	64	65	29	32	93
20	47	21	50	21	53	14	56	29	46	67
90	40	56	93	51	33	8	67	33	23	32
15	85	69	29	64	4	50	1	98	2	4
30	66									

APPENDIX B

RESULTS FOR VNS

Table A.1.a Results of Makespan for VNS-I for m=2

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
2-20-01	567	567	567	567	567	567	567	567	567	567	567	567	567	0.00	0.00
2-20-02	500	500	500	500	500	500	500	500	500	500	500	500	500	0.00	0.00
2-20-03	468	468	468	468	468	468	468	468	468	468	468	468	468	0.00	0.00
2-20-04	553	553	553	553	553	553	553	553	553	553	553	553	553	0.00	0.00
2-20-05	476	476	476	476	476	476	476	476	476	476	476	476	476	0.00	0.00
2-20-06	530	530	530	530	530	530	530	530	530	530	530	530	530	0.00	0.00
2-20-07	591	591	591	591	591	591	591	591	591	591	591	591	591	0.00	0.00
2-20-08	431	431	431	431	431	431	431	431	431	431	431	431	431	0.00	0.00
2-20-09	652	652	652	652	652	652	652	652	652	652	652	652	652	0.00	0.00
2-20-10	509	509	509	509	509	509	509	509	509	509	509	509	509	0.00	0.00
2-50-01	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	0.00	0.00
2-50-02	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	0.00	0.00
2-50-03	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	0.00	0.00
2-50-04	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	0.00	0.00
2-50-05	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	0.00	0.00
2-50-06	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	0.00	0.00
2-50-07	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	0.00	0.00
2-50-08	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	0.00	0.00
2-50-09	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	0.00	0.00
2-50-10	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	0.00	0.00
2-100-01	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	0.00	0.00
2-100-02	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	0.00	0.00
2-100-03	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	0.00	0.00
2-100-04	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	0.00	0.00
2-100-05	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	0.00	0.00
2-100-06	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	0.00	0.00
2-100-07	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	0.00	0.00
2-100-08	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	0.00	0.00
2-100-09	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	0.00	0.00
2-100-10	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	0.00	0.00
2-200-01	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	0.00	0.00
2-200-02	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	0.00	0.00
2-200-03	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	0.00	0.00
2-200-04	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	0.00	0.00
2-200-05	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	0.00	0.00
2-200-06	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	0.00	0.00
2-200-07	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	0.00	0.00
2-200-08	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	0.00	0.00
2-200-09	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	0.00	0.00
2-200-10	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	0.00	0.00

Table A.1.b Results of CPU for VNS-I for m=2

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
2-20-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-06	0.0000	0.0000	0.0000	0.0000	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.01	0.02	0.00	0.01
2-20-07	0.0150	0.0150	0.0150	0.0150	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-20-08	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-20-09	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-20-10	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-01	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-02	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-03	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-04	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-05	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-06	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-07	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-08	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-09	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-50-10	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-100-01	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.02	0.02	0.02	0.00
2-100-02	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0620	0.0620	0.03	0.06	0.02	0.02
2-100-03	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-04	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-05	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-06	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0470	0.0470	0.0630	0.0630	0.06	0.06	0.05	0.01
2-100-07	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.06	0.06	0.06	0.00
2-100-08	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.06	0.06	0.06	0.00
2-100-09	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.06	0.06	0.06	0.00
2-100-10	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.0630	0.06	0.06	0.06	0.00
2-200-01	0.0630	0.0630	0.0630	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.36	0.48	0.06	0.20
2-200-02	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-03	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-04	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-05	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-06	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-07	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-08	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.5308	0.5308	0.5308	0.5310	0.50	0.53	0.48	0.02
2-200-09	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.53	0.53	0.53	0.00
2-200-10	0.5310	0.5310	0.5310	0.5310	0.5322	0.5322	0.5322	0.5322	0.5322	0.5322	0.53	0.53	0.53	0.00

Table A.1.c Results of Makespan for VNS-II for m=2

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
2-20-01	567	567	567	567	567	567	567	567	567	567	567	567	567	0.00	0.00
2-20-02	500	500	500	500	500	500	500	500	500	500	500	500	500	0.00	0.00
2-20-03	468	468	468	468	468	468	468	468	468	468	468	468	468	0.00	0.00
2-20-04	553	553	553	553	553	553	553	553	553	553	553	553	553	0.00	0.00
2-20-05	476	476	476	476	476	476	476	476	476	476	476	476	476	0.00	0.00
2-20-06	530	530	530	530	530	530	530	530	530	530	530	530	530	0.00	0.00
2-20-07	591	591	591	591	591	591	591	591	591	591	591	591	591	0.00	0.00
2-20-08	431	431	431	431	431	431	431	431	431	431	431	431	431	0.00	0.00
2-20-09	652	652	652	652	652	652	652	652	652	652	652	652	652	0.00	0.00
2-20-10	509	509	509	509	509	509	509	509	509	509	509	509	509	0.00	0.00
2-50-01	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	0.00	0.00
2-50-02	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	0.00	0.00
2-50-03	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	0.00	0.00
2-50-04	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	0.00	0.00
2-50-05	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	0.00	0.00
2-50-06	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	0.00	0.00
2-50-07	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	0.00	0.00
2-50-08	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	0.00	0.00
2-50-09	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	0.00	0.00
2-50-10	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	0.00	0.00
2-100-01	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	0.00	0.00
2-100-02	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	0.00	0.00
2-100-03	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	0.00	0.00
2-100-04	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	0.00	0.00
2-100-05	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	0.00	0.00
2-100-06	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	0.00	0.00
2-100-07	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	0.00	0.00
2-100-08	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	0.00	0.00
2-100-09	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	0.00	0.00
2-100-10	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	0.00	0.00
2-200-01	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	0.00	0.00
2-200-02	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	0.00	0.00
2-200-03	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	0.00	0.00
2-200-04	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	0.00	0.00
2-200-05	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	0.00	0.00
2-200-06	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	0.00	0.00
2-200-07	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	0.00	0.00
2-200-08	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	0.00	0.00
2-200-09	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	0.00	0.00
2-200-10	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	0.00	0.00

Table A.1.d Results of CPU for VNS-II for m=2

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
2-20-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-100-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-100-02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0620	0.0620	0.01	0.06	0.00	0.03
2-100-03	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-04	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-05	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-06	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0460	0.0460	0.0620	0.0620	0.06	0.06	0.05	0.01
2-100-07	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-08	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-09	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-100-10	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.0620	0.06	0.06	0.06	0.00
2-200-01	0.0620	0.0620	0.0620	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.36	0.48	0.06	0.20
2-200-02	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-03	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-04	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-05	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-06	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-07	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.48	0.48	0.48	0.00
2-200-08	0.4840	0.4840	0.4840	0.4840	0.4840	0.4840	0.5000	0.5000	0.5000	0.5310	0.49	0.53	0.48	0.02
2-200-09	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.5310	0.53	0.53	0.53	0.00
2-200-10	0.5310	0.5310	0.5310	0.5310	0.5308	0.5308	0.5308	0.5308	0.5308	0.5308	0.53	0.53	0.53	0.00

Table A.1.e Results of Makespan for VNS-III for m=2

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
2-20-01	567	567	567	567	567	567	567	567	567	567	567	567	567	0.00	0.00
2-20-02	500	500	500	500	500	500	500	500	500	500	500	500	500	0.00	0.00
2-20-03	468	468	468	468	468	468	468	468	468	468	468	468	468	0.00	0.00
2-20-04	553	553	553	553	553	553	553	553	553	553	553	553	553	0.00	0.00
2-20-05	476	476	476	476	476	476	476	476	476	476	476	476	476	0.00	0.00
2-20-06	530	530	530	530	530	530	530	530	530	530	530	530	530	0.00	0.00
2-20-07	591	591	591	591	591	591	591	591	591	591	591	591	591	0.00	0.00
2-20-08	431	431	431	431	431	431	431	431	431	431	431	431	431	0.00	0.00
2-20-09	652	652	652	652	652	652	652	652	652	652	652	652	652	0.00	0.00
2-20-10	509	509	509	509	509	509	509	509	509	509	509	509	509	0.00	0.00
2-50-01	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	1139	0.00	0.00
2-50-02	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	0.00	0.00
2-50-03	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	1306	0.00	0.00
2-50-04	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	1335	0.00	0.00
2-50-05	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	1296	0.00	0.00
2-50-06	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212	0.00	0.00
2-50-07	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	0.00	0.00
2-50-08	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	1229	0.00	0.00
2-50-09	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	1202	0.00	0.00
2-50-10	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	0.00	0.00
2-100-01	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	2728	0.00	0.00
2-100-02	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	2435	0.00	0.00
2-100-03	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	0.00	0.00
2-100-04	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	2377	0.00	0.00
2-100-05	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	2689	0.00	0.00
2-100-06	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	2552	0.00	0.00
2-100-07	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	2420	0.00	0.00
2-100-08	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	2700	0.00	0.00
2-100-09	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	0.00	0.00
2-100-10	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	2694	0.00	0.00
2-200-01	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	5026	0.00	0.00
2-200-02	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	4727	0.00	0.00
2-200-03	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	0.00	0.00
2-200-04	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	4789	0.00	0.00
2-200-05	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	4659	0.00	0.00
2-200-06	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	0.00	0.00
2-200-07	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	5004	0.00	0.00
2-200-08	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	5017	0.00	0.00
2-200-09	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	0.00	0.00
2-200-10	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	4795	0.00	0.00

Table A.1.f Results of CPU for VNS-III for m=2

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
2-20-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-20-10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-50-10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-100-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
2-100-02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0310	0.0310	0.01	0.03	0.00	0.01
2-100-03	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.03	0.03	0.03	0.00
2-100-04	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.03	0.03	0.03	0.00
2-100-05	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.03	0.03	0.03	0.00
2-100-06	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0150	0.0150	0.0150	0.0150	0.02	0.03	0.02	0.01
2-100-07	0.0150	0.0150	0.0150	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.03	0.03	0.02	0.01
2-100-08	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.03	0.03	0.03	0.00
2-100-09	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.03	0.03	0.03	0.00
2-100-10	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310	0.03	0.03	0.03	0.00
2-200-01	0.0310	0.0310	0.0310	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.18	0.25	0.03	0.11
2-200-02	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.25	0.25	0.25	0.00
2-200-03	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.25	0.25	0.25	0.00
2-200-04	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.25	0.25	0.25	0.00
2-200-05	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.25	0.25	0.25	0.00
2-200-06	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.25	0.25	0.25	0.00
2-200-07	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.25	0.25	0.25	0.00
2-200-08	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2650	0.2650	0.2650	0.2340	0.25	0.27	0.23	0.01
2-200-09	0.2340	0.2340	0.2340	0.2340	0.2340	0.2340	0.2340	0.2340	0.2340	0.2340	0.23	0.23	0.23	0.00
2-200-10	0.2340	0.2340	0.2340	0.2340	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.24	0.25	0.23	0.01

Table A.2.a Results of Makespan for VNS-I for m=5

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
5-20-01	157	157	157	157	157	157	157	157	157	157	157	157	157	0.00	0.00
5-20-02	214	214	214	214	214	214	214	214	214	214	214	214	214	0.00	0.00
5-20-03	183	183	183	183	183	183	183	183	183	183	183	183	183	0.00	0.00
5-20-04	216	216	216	216	216	216	216	216	216	216	216	216	216	0.00	0.00
5-20-05	182	182	182	182	182	182	182	182	182	182	182	182	182	0.00	0.00
5-20-06	206	206	206	206	206	206	206	206	206	206	206	206	206	0.00	0.00
5-20-07	231	231	231	231	231	231	231	231	231	231	231	231	231	0.00	0.00
5-20-08	206	206	206	206	206	206	206	206	206	206	206	206	206	0.00	0.00
5-20-09	239	239	239	239	239	239	239	239	239	239	239	239	239	0.00	0.00
5-20-10	210	210	210	210	210	210	210	210	210	210	210	210	210	0.00	0.00
5-50-01	527	527	527	527	527	527	527	527	527	527	527	527	527	0.00	0.00
5-50-02	497	497	497	497	497	497	497	497	497	497	497	497	497	0.00	0.00
5-50-03	499	499	499	499	499	499	499	499	499	499	499	499	499	0.00	0.00
5-50-04	518	518	518	518	518	518	518	518	518	518	518	518	518	0.00	0.00
5-50-05	592	592	592	592	592	592	592	592	592	592	592	592	592	0.00	0.00
5-50-06	578	578	578	578	578	578	578	578	578	578	578	578	578	0.00	0.00
5-50-07	461	461	461	461	461	461	461	461	461	461	461	461	461	0.00	0.00
5-50-08	462	462	462	462	462	462	462	462	462	462	462	462	462	0.00	0.00
5-50-09	473	473	473	473	473	473	473	473	473	473	473	473	473	0.00	0.00
5-50-10	480	480	480	480	480	480	480	480	480	480	480	480	480	0.00	0.00
5-100-01	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	0.00	0.00
5-100-02	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	0.00	0.00
5-100-03	850	850	850	850	850	850	850	850	850	850	850	850	850	0.00	0.00
5-100-04	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	0.00	0.00
5-100-05	970	970	970	970	970	970	970	970	970	970	970	970	970	0.00	0.00
5-100-06	968	968	968	968	968	968	968	968	968	968	968	968	968	0.00	0.00
5-100-07	939	939	939	939	939	939	939	939	939	939	939	939	939	0.00	0.00
5-100-08	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	0.00	0.00
5-100-09	973	973	973	973	973	973	973	973	973	973	973	973	973	0.00	0.00
5-100-10	935	935	935	935	935	935	935	935	935	935	935	935	935	0.00	0.00
5-200-01	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	0.00	0.00
5-200-02	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	0.00	0.00
5-200-03	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	0.00	0.00
5-200-04	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	0.00	0.00
5-200-05	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	0.00	0.00
5-200-06	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	0.00	0.00
5-200-07	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	0.00	0.00
5-200-08	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	0.00	0.00
5-200-09	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	0.00	0.00
5-200-10	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	0.00	0.00

Table A.2.b Results of CPU for VNS-I for m=5

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
5-20-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0151	0.0000	0.00	0.02	0.00	0.00
5-20-02	0.0151	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.00
5-20-03	0.0161	0.0000	0.0000	0.0000	0.0000	0.0159	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
5-20-04	0.0000	0.0161	0.0161	0.0161	0.0149	0.0159	0.0151	0.0000	0.0000	0.0000	0.01	0.02	0.00	0.01
5-20-05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
5-20-06	0.0000	0.0000	0.0000	0.0149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.00	0.02	0.00	0.01
5-20-07	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
5-20-08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0149	0.0000	0.00	0.01	0.00	0.00
5-20-09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
5-20-10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0159	0.0000	0.0000	0.00	0.02	0.00	0.01
5-50-01	0.0159	0.0161	0.0000	0.0161	0.0000	0.0161	0.0000	0.0000	0.0161	0.0161	0.01	0.02	0.00	0.01
5-50-02	0.0161	0.0161	0.0151	0.0000	0.0000	0.0000	0.0149	0.0161	0.0000	0.0149	0.01	0.02	0.00	0.01
5-50-03	0.0161	0.0161	0.0161	0.0000	0.0159	0.0159	0.0149	0.0161	0.0161	0.0161	0.01	0.02	0.00	0.01
5-50-04	0.0000	0.0159	0.0000	0.0151	0.0151	0.0000	0.0161	0.0159	0.0000	0.0000	0.01	0.02	0.00	0.01
5-50-05	0.0000	0.0161	0.0161	0.0000	0.0149	0.0000	0.0161	0.0161	0.0149	0.0000	0.01	0.02	0.00	0.01
5-50-06	0.0159	0.0161	0.0149	0.0161	0.0000	0.0151	0.0149	0.0159	0.0151	0.0159	0.01	0.02	0.00	0.00
5-50-07	0.0149	0.0149	0.0000	0.0000	0.0161	0.0149	0.0161	0.0159	0.0000	0.0159	0.01	0.02	0.00	0.01
5-50-08	0.0000	0.0000	0.0159	0.0159	0.0161	0.0149	0.0161	0.0161	0.0159	0.0159	0.01	0.02	0.00	0.01
5-50-09	0.0000	0.0149	0.0149	0.0159	0.0159	0.0159	0.0000	0.0161	0.0149	0.0161	0.01	0.02	0.00	0.01
5-50-10	0.0000	0.0159	0.0149	0.0310	0.0000	0.0149	0.0308	0.0149	0.0159	0.0149	0.02	0.03	0.00	0.01
5-100-01	0.0942	0.0781	0.0940	0.0779	0.0940	0.0940	0.0942	0.0779	0.0779	0.0781	0.09	0.09	0.08	0.01
5-100-02	0.0940	0.0940	0.0781	0.0940	0.0781	0.0779	0.0940	0.0940	0.0940	0.0779	0.09	0.09	0.08	0.01
5-100-03	0.0928	0.0942	0.0940	0.0940	0.0942	0.0781	0.0940	0.0791	0.0940	0.0930	0.09	0.09	0.08	0.01
5-100-04	0.0779	0.0940	0.0781	0.0781	0.0942	0.0930	0.0940	0.0781	0.0779	0.0791	0.08	0.09	0.08	0.01
5-100-05	0.1250	0.0779	0.0940	0.0779	0.0779	0.0779	0.0940	0.0779	0.0630	0.0779	0.08	0.13	0.06	0.02
5-100-06	0.0940	0.0781	0.0942	0.0942	0.0781	0.0781	0.0940	0.0781	0.0781	0.0779	0.08	0.09	0.08	0.01
5-100-07	0.0940	0.0781	0.0928	0.0940	0.0940	0.0930	0.0942	0.0940	0.0940	0.0928	0.09	0.09	0.08	0.00
5-100-08	0.0781	0.0779	0.0779	0.0928	0.0940	0.0930	0.0930	0.1101	0.0791	0.0940	0.09	0.11	0.08	0.01
5-100-09	0.0779	0.0779	0.0930	0.0779	0.0940	0.0930	0.0942	0.0940	0.0620	0.0928	0.09	0.09	0.06	0.01
5-100-10	0.0779	0.0779	0.0781	0.0779	0.0781	0.0779	0.0791	0.0781	0.0781	0.0791	0.08	0.08	0.08	0.00
5-200-01	0.6094	0.6411	0.6401	0.6411	0.6719	0.6099	0.5933	0.6089	0.6094	0.5938	0.62	0.67	0.59	0.03
5-200-02	0.5942	0.5933	0.5938	0.5942	0.6099	0.5938	0.5781	0.6089	0.5942	0.5928	0.60	0.61	0.58	0.01
5-200-03	0.5630	0.5620	0.5630	0.5791	0.5630	0.5630	0.5781	0.5469	0.5781	0.5630	0.57	0.58	0.55	0.01
5-200-04	0.6724	0.6250	0.7031	0.6562	0.7188	0.6562	0.7500	0.6724	0.6709	0.6567	0.68	0.75	0.63	0.04
5-200-05	0.5459	0.5317	0.5620	0.6396	0.5474	0.5469	0.5474	0.5469	0.5620	0.5942	0.56	0.64	0.53	0.03
5-200-06	0.6719	0.6724	0.7500	0.7500	0.6719	0.6880	0.6724	0.7354	0.6558	0.6719	0.69	0.75	0.66	0.04
5-200-07	0.5469	0.5308	0.5781	0.5469	0.5630	0.6880	0.5776	0.5942	0.5630	0.5630	0.58	0.69	0.53	0.04
5-200-08	0.5942	0.6250	0.6572	0.5791	0.5776	0.6250	0.6089	0.5942	0.5781	0.6411	0.61	0.66	0.58	0.03
5-200-09	0.6870	0.6719	0.6719	0.6724	0.6724	0.6719	0.7026	0.6562	0.6719	0.6724	0.68	0.70	0.66	0.01
5-200-10	0.6709	0.7188	0.6880	0.6870	0.6870	0.6719	0.7026	0.6562	0.6719	0.6558	0.68	0.72	0.66	0.02

Table A.2.c Results of Makespan for VNS-II for m=5

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
5-20-01	157	157	157	157	157	157	157	157	157	157	157	157	157	0.00	0.00
5-20-02	214	214	214	214	214	214	214	214	214	214	214	214	214	0.00	0.00
5-20-03	183	183	183	183	183	183	183	183	183	183	183	183	183	0.00	0.00
5-20-04	216	216	216	216	216	216	216	216	216	216	216	216	216	0.00	0.00
5-20-05	182	182	182	182	182	182	182	182	182	182	182	182	182	0.00	0.00
5-20-06	206	206	206	206	206	206	206	206	206	206	206	206	206	0.00	0.00
5-20-07	231	231	231	231	231	231	231	231	231	231	231	231	231	0.00	0.00
5-20-08	206	206	206	206	206	206	206	206	206	206	206	206	206	0.00	0.00
5-20-09	239	239	239	239	239	239	239	239	239	239	239	239	239	0.00	0.00
5-20-10	210	210	210	210	210	210	210	210	210	210	210	210	210	0.00	0.00
5-50-01	527	527	527	527	527	527	527	527	527	527	527	527	527	0.00	0.00
5-50-02	497	497	497	497	497	497	497	497	497	497	497	497	497	0.00	0.00
5-50-03	499	499	499	499	499	499	499	499	499	499	499	499	499	0.00	0.00
5-50-04	518	518	518	518	518	518	518	518	518	518	518	518	518	0.00	0.00
5-50-05	592	592	592	592	592	592	592	592	592	592	592	592	592	0.00	0.00
5-50-06	578	578	578	578	578	578	578	578	578	578	578	578	578	0.00	0.00
5-50-07	461	461	461	461	461	461	461	461	461	461	461	461	461	0.00	0.00
5-50-08	462	462	462	462	462	462	462	462	462	462	462	462	462	0.00	0.00
5-50-09	473	473	473	473	473	473	473	473	473	473	473	473	473	0.00	0.00
5-50-10	480	480	480	480	480	480	480	480	480	480	480	480	480	0.00	0.00
5-100-01	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	0.00	0.00
5-100-02	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	0.00	0.00
5-100-03	850	850	850	850	850	850	850	850	850	850	850	850	850	0.00	0.00
5-100-04	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	0.00	0.00
5-100-05	970	970	970	970	970	970	970	970	970	970	970	970	970	0.00	0.00
5-100-06	968	968	968	968	968	968	968	968	968	968	968	968	968	0.00	0.00
5-100-07	939	939	939	939	939	939	939	939	939	939	939	939	939	0.00	0.00
5-100-08	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	0.00	0.00
5-100-09	973	973	973	973	973	973	973	973	973	973	973	973	973	0.00	0.00
5-100-10	935	935	935	935	935	935	935	935	935	935	935	935	935	0.00	0.00
5-200-01	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	0.00	0.00
5-200-02	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	0.00	0.00
5-200-03	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	0.00	0.00
5-200-04	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	0.00	0.00
5-200-05	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	0.00	0.00
5-200-06	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	0.00	0.00
5-200-07	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	0.00	0.00
5-200-08	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	0.00	0.00
5-200-09	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	0.00	0.00
5-200-10	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	0.00	0.00

Table A.2.d Results of CPU for VNS-II for m=5

1"	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
5-20-01	0.0000	0.0469	0.0630	0.0161	0.0000	0.0159	0.0000	0.0000	0.0459	0.0159	0.02	0.06	0.00	0.02
5-20-02	0.0000	0.0310	0.0161	0.0151	0.0000	0.0000	0.0310	0.0149	0.0000	0.0000	0.01	0.03	0.00	0.01
5-20-03	0.0000	0.0149	0.0000	0.0159	0.0159	0.0000	0.0161	0.0000	0.0000	0.0000	0.01	0.02	0.00	0.01
5-20-04	0.0000	0.0159	0.0149	0.0000	0.0000	0.0000	0.0000	0.0161	0.0161	0.0149	0.01	0.02	0.00	0.01
5-20-05	0.0151	0.0159	0.0000	0.0149	0.0000	0.0000	0.0149	0.0000	0.0149	0.0000	0.01	0.02	0.00	0.01
5-20-06	0.0161	0.0000	0.0308	0.0000	0.0000	0.0000	0.0159	0.0000	0.0000	0.0149	0.01	0.03	0.00	0.01
5-20-07	0.0149	0.0159	0.0000	0.0000	0.0000	0.0322	0.0000	0.0161	0.0161	0.0000	0.01	0.03	0.00	0.01
5-20-08	0.0149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0159	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
5-20-09	0.0000	0.0151	0.0161	0.0310	0.0310	0.0161	0.0161	0.0000	0.0000	0.0000	0.01	0.03	0.00	0.01
5-20-10	0.0310	0.0000	0.0000	0.0000	0.0161	0.0000	0.0310	0.0159	0.0151	0.0151	0.01	0.03	0.00	0.01
5-50-01	0.0149	0.0159	0.0159	0.0161	0.0000	0.0149	0.0149	0.0310	0.0310	0.0151	0.02	0.03	0.00	0.01
5-50-02	0.0161	0.0161	0.0159	0.0000	0.0322	0.0149	0.0159	0.0161	0.0161	0.0149	0.02	0.03	0.00	0.01
5-50-03	0.0000	0.0151	0.0149	0.0322	0.0151	0.0149	0.0151	0.0161	0.0149	0.0149	0.02	0.03	0.00	0.01
5-50-04	0.0161	0.0151	0.0159	0.0149	0.0000	0.0161	0.0159	0.0149	0.0000	0.0161	0.01	0.02	0.00	0.01
5-50-05	0.0161	0.0149	0.0161	0.0000	0.0161	0.0149	0.0159	0.0161	0.0322	0.0161	0.02	0.03	0.00	0.01
5-50-06	0.0000	0.0000	0.0149	0.0149	0.0161	0.0159	0.0159	0.0000	0.0161	0.0000	0.01	0.02	0.00	0.01
5-50-07	0.0149	0.0161	0.0161	0.0161	0.0159	0.0308	0.0161	0.0161	0.0310	0.0149	0.02	0.03	0.01	0.01
5-50-08	0.0161	0.0149	0.0151	0.0149	0.0159	0.0000	0.0151	0.0322	0.0161	0.0159	0.02	0.03	0.00	0.01
5-50-09	0.0161	0.0149	0.0151	0.0161	0.0310	0.0149	0.0149	0.0310	0.0159	0.0149	0.02	0.03	0.01	0.01
5-50-10	0.0149	0.0149	0.0149	0.0151	0.0310	0.0159	0.0161	0.0159	0.0000	0.0159	0.02	0.03	0.00	0.01
5-100-01	0.0618	0.0779	0.0781	0.0781	0.0630	0.0781	0.0942	0.0779	0.0779	0.0781	0.08	0.09	0.06	0.01
5-100-02	0.0779	0.0940	0.0781	0.0779	0.0781	0.0940	0.0930	0.0940	0.0940	0.0620	0.08	0.09	0.06	0.01
5-100-03	0.0779	0.0928	0.0791	0.0930	0.0940	0.1089	0.0942	0.0940	0.0940	0.0791	0.09	0.11	0.08	0.01
5-100-04	0.0791	0.0930	0.0779	0.0779	0.0781	0.0781	0.0779	0.0940	0.0940	0.0781	0.08	0.09	0.08	0.01
5-100-05	0.0779	0.0779	0.0940	0.0779	0.0781	0.0791	0.0781	0.0620	0.0779	0.0791	0.08	0.09	0.06	0.01
5-100-06	0.0781	0.0620	0.0779	0.0791	0.0779	0.0940	0.0781	0.0630	0.0620	0.0779	0.08	0.09	0.06	0.01
5-100-07	0.0781	0.0632	0.0779	0.0781	0.0779	0.0779	0.0791	0.0928	0.0779	0.0781	0.08	0.09	0.06	0.01
5-100-08	0.0781	0.0620	0.0781	0.0781	0.0781	0.0781	0.0781	0.0781	0.0779	0.0791	0.08	0.08	0.06	0.01
5-100-09	0.0781	0.0940	0.0779	0.0630	0.0791	0.0779	0.0781	0.0781	0.0781	0.0620	0.08	0.09	0.06	0.01
5-100-10	0.0781	0.0781	0.0781	0.0620	0.0791	0.0791	0.0779	0.0779	0.0620	0.0781	0.08	0.08	0.06	0.01
5-200-01	0.5938	0.5776	0.6089	0.6089	0.5933	0.6250	0.5942	0.5942	0.6089	0.5928	0.60	0.63	0.58	0.01
5-200-02	0.5938	0.5938	0.5781	0.5776	0.5781	0.5938	0.5781	0.7183	0.5942	0.5781	0.60	0.72	0.58	0.04
5-200-03	0.5791	0.5630	0.5474	0.5474	0.5781	0.5942	0.5474	0.5312	0.5469	0.6401	0.57	0.64	0.53	0.03
5-200-04	0.6411	0.6401	0.6250	0.6250	0.6104	0.6562	0.6089	0.7349	0.6411	0.6558	0.64	0.73	0.61	0.04
5-200-05	0.5308	0.5630	0.5781	0.5928	0.5312	0.5474	0.5781	0.5469	0.6401	0.5308	0.56	0.64	0.53	0.03
5-200-06	0.7817	0.6406	0.6719	0.6880	0.7183	0.6870	0.6558	0.6406	0.6562	0.6724	0.68	0.78	0.64	0.04
5-200-07	0.5620	0.5469	0.5308	0.5938	0.6104	0.5317	0.5474	0.5620	0.5474	0.5459	0.56	0.61	0.53	0.03
5-200-08	0.5791	0.5776	0.5928	0.5776	0.5776	0.5781	0.5942	0.5781	0.5938	0.5781	0.58	0.59	0.58	0.01
5-200-09	0.6567	0.6719	0.6719	0.6719	0.6880	0.6572	0.6558	0.6406	0.6406	0.6411	0.66	0.69	0.64	0.02
5-200-10	0.6562	0.7349	0.6411	0.7031	0.6870	0.6709	0.7031	0.6880	0.6880	0.6870	0.69	0.73	0.64	0.03

Table A.2.e Results of Makespan for VNS-III for m=5

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
5-20-01	157	157	157	157	157	157	157	157	157	157	157	157	157	0.00	0.00
5-20-02	214	214	214	214	214	214	214	214	214	214	214	214	214	0.00	0.00
5-20-03	183	183	183	183	183	183	183	183	183	183	183	183	183	0.00	0.00
5-20-04	216	216	216	216	216	216	216	216	216	216	216	216	216	0.00	0.00
5-20-05	182	182	182	182	182	182	182	182	182	182	182	182	182	0.00	0.00
5-20-06	206	206	206	206	206	206	206	206	206	206	206	206	206	0.00	0.00
5-20-07	231	231	231	231	231	231	231	231	231	231	231	231	231	0.00	0.00
5-20-08	206	206	206	206	206	206	206	206	206	206	206	206	206	0.00	0.00
5-20-09	239	239	239	239	239	239	239	239	239	239	239	239	239	0.00	0.00
5-20-10	210	210	210	210	210	210	210	210	210	210	210	210	210	0.00	0.00
5-50-01	527	527	527	527	527	527	527	527	527	527	527	527	527	0.00	0.00
5-50-02	497	497	497	497	497	497	497	497	497	497	497	497	497	0.00	0.00
5-50-03	499	499	499	499	499	499	499	499	499	499	499	499	499	0.00	0.00
5-50-04	518	518	518	518	518	518	518	518	518	518	518	518	518	0.00	0.00
5-50-05	592	592	592	592	592	592	592	592	592	592	592	592	592	0.00	0.00
5-50-06	578	578	578	578	578	578	578	578	578	578	578	578	578	0.00	0.00
5-50-07	461	461	461	461	461	461	461	461	461	461	461	461	461	0.00	0.00
5-50-08	462	462	462	462	462	462	462	462	462	462	462	462	462	0.00	0.00
5-50-09	473	473	473	473	473	473	473	473	473	473	473	473	473	0.00	0.00
5-50-10	480	480	480	480	480	480	480	480	480	480	480	480	480	0.00	0.00
5-100-01	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	0.00	0.00
5-100-02	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	0.00	0.00
5-100-03	850	850	850	850	850	850	850	850	850	850	850	850	850	0.00	0.00
5-100-04	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	1093	0.00	0.00
5-100-05	970	970	970	970	970	970	970	970	970	970	970	970	970	0.00	0.00
5-100-06	968	968	968	968	968	968	968	968	968	968	968	968	968	0.00	0.00
5-100-07	939	939	939	939	939	939	939	939	939	939	939	939	939	0.00	0.00
5-100-08	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	1031	0.00	0.00
5-100-09	973	973	973	973	973	973	973	973	973	973	973	973	973	0.00	0.00
5-100-10	935	935	935	935	935	935	935	935	935	935	935	935	935	0.00	0.00
5-200-01	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	0.00	0.00
5-200-02	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993	0.00	0.00
5-200-03	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	1988	0.00	0.00
5-200-04	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	0.00	0.00
5-200-05	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	2095	0.00	0.00
5-200-06	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	0.00	0.00
5-200-07	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	0.00	0.00
5-200-08	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	1987	0.00	0.00
5-200-09	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	2033	0.00	0.00
5-200-10	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	0.00	0.00

Table A.2.f Results of CPU for VNS-III for m=5

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
5-20-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.00
5-20-02	0.0000	0.0160	0.0160	0.0310	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.01	0.03	0.00	0.01
5-20-03	0.0150	0.0000	0.0150	0.0000	0.0000	0.0000	0.0150	0.0000	0.0150	0.0000	0.01	0.02	0.00	0.01
5-20-04	0.0000	0.0150	0.0000	0.0000	0.0150	0.0000	0.0150	0.0160	0.0000	0.0000	0.01	0.02	0.00	0.01
5-20-05	0.0000	0.0150	0.0000	0.0150	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.00	0.02	0.00	0.01
5-20-06	0.0320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.0150	0.0000	0.01	0.03	0.00	0.01
5-20-07	0.0150	0.0000	0.0150	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0160	0.00	0.02	0.00	0.01
5-20-08	0.0160	0.0000	0.0000	0.0000	0.0150	0.0000	0.0160	0.0000	0.0150	0.0000	0.01	0.02	0.00	0.01
5-20-09	0.0000	0.0000	0.0160	0.0000	0.0000	0.0000	0.0160	0.0000	0.0000	0.0150	0.00	0.02	0.00	0.01
5-20-10	0.0000	0.0000	0.0160	0.0150	0.0000	0.0000	0.0160	0.0160	0.0000	0.0000	0.01	0.02	0.00	0.01
5-50-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.0000	0.0150	0.0000	0.00	0.02	0.00	0.01
5-50-02	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.0160	0.0000	0.0160	0.0000	0.00	0.02	0.00	0.01
5-50-03	0.0000	0.0000	0.0310	0.0000	0.0000	0.0310	0.0160	0.0150	0.0000	0.0150	0.01	0.03	0.00	0.01
5-50-04	0.0000	0.0160	0.0000	0.0000	0.0000	0.0000	0.0000	0.0160	0.0150	0.0000	0.00	0.02	0.00	0.01
5-50-05	0.0160	0.0310	0.0160	0.0160	0.0150	0.0150	0.0000	0.0150	0.0310	0.0150	0.02	0.03	0.00	0.01
5-50-06	0.0160	0.0160	0.0000	0.0160	0.0000	0.0310	0.0160	0.0150	0.0150	0.0000	0.01	0.03	0.00	0.01
5-50-07	0.0000	0.0000	0.0150	0.0150	0.0150	0.0000	0.0000	0.0000	0.0000	0.0160	0.01	0.02	0.00	0.01
5-50-08	0.0000	0.0000	0.0160	0.0000	0.0000	0.0160	0.0160	0.0160	0.0000	0.0000	0.01	0.02	0.00	0.01
5-50-09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0160	0.0000	0.0150	0.00	0.02	0.00	0.01
5-50-10	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.0000	0.0160	0.0150	0.0000	0.00	0.02	0.00	0.01
5-100-01	0.0320	0.0320	0.0470	0.0320	0.0470	0.0470	0.0470	0.0310	0.0470	0.0470	0.04	0.05	0.03	0.01
5-100-02	0.0310	0.0310	0.0310	0.0470	0.0470	0.0310	0.0470	0.0310	0.0470	0.0460	0.04	0.05	0.03	0.01
5-100-03	0.0310	0.0310	0.0460	0.0470	0.0320	0.0320	0.0470	0.0470	0.0470	0.0310	0.04	0.05	0.03	0.01
5-100-04	0.0310	0.0470	0.0470	0.0320	0.0310	0.0310	0.0310	0.0310	0.0320	0.0470	0.04	0.05	0.03	0.01
5-100-05	0.0320	0.0310	0.0470	0.0470	0.0310	0.0470	0.0320	0.0310	0.0320	0.0310	0.04	0.05	0.03	0.01
5-100-06	0.0470	0.0310	0.0310	0.0310	0.0470	0.0470	0.0310	0.0310	0.0470	0.0310	0.04	0.05	0.03	0.01
5-100-07	0.0320	0.0460	0.0470	0.0470	0.0310	0.0460	0.0310	0.0460	0.0470	0.0460	0.04	0.05	0.03	0.01
5-100-08	0.0310	0.0310	0.0470	0.0470	0.0470	0.0320	0.0310	0.0320	0.0310	0.0310	0.04	0.05	0.03	0.01
5-100-09	0.0470	0.0470	0.0320	0.0470	0.0310	0.0310	0.0310	0.0310	0.0320	0.0470	0.04	0.05	0.03	0.01
5-100-10	0.0470	0.0460	0.0320	0.0310	0.0310	0.0310	0.0310	0.0320	0.0470	0.0320	0.04	0.05	0.03	0.01
5-200-01	0.2970	0.2810	0.2970	0.2820	0.2970	0.2971	0.2971	0.2969	0.3130	0.2810	0.29	0.31	0.28	0.01
5-200-02	0.2661	0.3132	0.3291	0.3118	0.3281	0.3132	0.3120	0.3440	0.3120	0.3430	0.32	0.34	0.27	0.02
5-200-03	0.3279	0.2969	0.3120	0.2971	0.2969	0.2822	0.3132	0.3120	0.2969	0.2810	0.30	0.33	0.28	0.01
5-200-04	0.3440	0.3601	0.3440	0.3601	0.3750	0.3440	0.3440	0.3132	0.3279	0.3279	0.34	0.38	0.31	0.02
5-200-05	0.2661	0.2810	0.2649	0.2649	0.2808	0.2659	0.2810	0.2659	0.2661	0.2971	0.27	0.30	0.26	0.01
5-200-06	0.3442	0.3281	0.3291	0.3279	0.3440	0.3279	0.3279	0.3291	0.3281	0.3279	0.33	0.34	0.33	0.01
5-200-07	0.2810	0.2661	0.2661	0.2808	0.2820	0.2810	0.2661	0.2810	0.2810	0.2500	0.27	0.28	0.25	0.01
5-200-08	0.2810	0.2810	0.2969	0.2810	0.2969	0.2969	0.2969	0.2822	0.2810	0.2820	0.29	0.30	0.28	0.01
5-200-09	0.3281	0.3279	0.3440	0.3440	0.3279	0.3279	0.3442	0.3440	0.3281	0.3440	0.34	0.34	0.33	0.01
5-200-10	0.3279	0.3281	0.3440	0.3589	0.3440	0.3601	0.3428	0.3279	0.3440	0.3440	0.34	0.36	0.33	0.01

Table A.3.a Results of Makespan for VNS-I for m=10

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
10-20-01	113	113	113	113	113	113	113	113	113	113	113	113	113	0.00	0.00
10-20-02	100	100	100	100	100	100	100	100	100	100	100	100	100	0.00	0.00
10-20-03	106	106	106	106	106	106	106	106	106	106	106	106	106	0.00	0.00
10-20-04	96	96	96	96	96	96	96	96	96	96	96	96	96	0.00	0.00
10-20-05	99	99	99	99	99	99	99	99	99	99	99	99	99	0.00	0.00
10-20-06	114	114	114	114	114	114	114	114	114	114	114	114	114	0.00	0.00
10-20-07	105	105	105	105	105	105	105	105	105	105	105	105	105	0.00	0.00
10-20-08	115	115	115	115	115	115	115	115	115	115	115	115	115	0.00	0.00
10-20-09	118	118	118	118	118	118	118	118	118	118	118	118	118	0.00	0.00
10-20-10	127	127	127	127	127	127	127	127	127	127	127	127	127	0.00	0.00
10-50-01	312	312	312	312	312	312	312	312	312	312	312	312	312	0.00	0.00
10-50-02	259	259	259	259	259	259	259	259	259	259	259	259	259	0.00	0.00
10-50-03	235	235	235	235	235	235	235	235	235	235	235	235	235	0.00	0.00
10-50-04	231	231	231	231	231	231	231	231	231	231	231	231	231	0.00	0.00
10-50-05	279	279	279	279	280	279	279	279	279	279	279.1	280	279	0.32	0.04
10-50-06	259	259	259	259	259	259	259	259	259	259	259	259	259	0.00	0.00
10-50-07	262	262	262	262	262	262	262	262	262	262	262	262	262	0.00	0.00
10-50-08	290	290	290	290	290	290	290	290	290	290	290	290	290	0.00	0.00
10-50-09	257	257	257	257	257	257	257	257	257	257	257	257	257	0.00	0.00
10-50-10	237	237	236	237	237	237	237	237	237	237	236.9	237	236	0.32	0.38
10-100-01	459	459	459	459	459	459	459	459	459	459	459	459	459	0.00	0.00
10-100-02	532	532	532	532	532	532	532	532	532	532	532	532	532	0.00	0.00
10-100-03	510	510	510	510	510	510	510	510	510	510	510	510	510	0.00	0.00
10-100-04	467	467	467	467	467	467	467	467	467	467	467	467	467	0.00	0.00
10-100-05	517	517	517	517	517	517	517	517	517	517	517	517	517	0.00	0.00
10-100-06	493	493	493	493	493	493	493	493	493	493	493	493	493	0.00	0.00
10-100-07	478	478	478	478	478	478	478	478	478	478	478	478	478	0.00	0.00
10-100-08	489	489	489	489	489	489	489	489	489	489	489	489	489	0.00	0.00
10-100-09	477	477	477	477	477	477	477	477	477	477	477	477	477	0.00	0.00
10-100-10	504	504	504	504	504	504	504	504	504	504	504	504	504	0.00	0.00
10-200-01	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	0.00	0.00
10-200-02	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	0.00	0.00
10-200-03	961	961	961	961	961	961	961	961	961	961	961	961	961	0.00	0.00
10-200-04	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	0.00	0.00
10-200-05	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	0.00	0.00
10-200-06	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	0.00	0.00
10-200-07	949	949	949	949	949	949	949	949	949	949	949	949	949	0.00	0.00
10-200-08	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	0.00	0.00
10-200-09	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	0.00	0.00
10-200-10	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	0.00	0.00

Table A.3.b Results of CPU for VNS-I for m=10

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
10-20-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
10-20-02	0.0161	0.0156	0.0000	0.0000	0.0000	0.0000	0.0151	0.0000	0.0000	0.0161	0.01	0.02	0.00	0.01
10-20-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00
10-20-04	0.0161	0.0146	0.0000	0.0000	0.0308	0.0000	0.0000	0.0000	0.0151	0.0317	0.01	0.03	0.00	0.01
10-20-05	0.0000	0.0000	0.0161	0.0156	0.0000	0.0161	0.0000	0.0161	0.0161	0.0161	0.01	0.02	0.00	0.01
10-20-06	0.0000	0.0000	0.0151	0.0000	0.0146	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
10-20-07	0.0161	0.0161	0.0000	0.0312	0.0161	0.0161	0.0000	0.0000	0.0000	0.0000	0.01	0.03	0.00	0.01
10-20-08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0151	0.0000	0.0000	0.0000	0.0161	0.00	0.02	0.00	0.01
10-20-09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.00	0.02	0.00	0.01
10-20-10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.0156	0.0000	0.0161	0.00	0.02	0.00	0.01
10-50-01	0.0469	0.0469	0.0151	0.0161	0.0156	0.0474	0.0161	0.0146	0.0161	0.0146	0.02	0.05	0.01	0.02
10-50-02	0.0146	0.0312	0.0781	0.0151	0.0308	0.1099	0.0312	0.0781	0.0620	0.0630	0.05	0.11	0.01	0.03
10-50-03	0.0161	0.0308	0.0308	0.0161	0.0146	0.0151	0.0317	0.0161	0.0469	0.0161	0.02	0.05	0.01	0.01
10-50-04	0.2812	0.0791	0.0161	0.3438	0.1250	0.2959	0.1250	0.3276	0.2183	0.7192	0.25	0.72	0.02	0.20
10-50-05	0.1250	0.0161	0.4692	0.0469	0.0161	0.4849	0.2500	0.0781	0.5312	0.0933	0.21	0.53	0.02	0.21
10-50-06	0.2661	0.3750	0.3120	0.7031	0.1250	0.0781	0.0938	0.1089	0.2026	0.2661	0.25	0.70	0.08	0.19
10-50-07	0.0161	0.0312	0.0156	0.0620	0.2500	0.0474	0.0928	0.0474	0.0161	0.0308	0.06	0.25	0.02	0.07
10-50-08	0.1411	0.3750	0.0933	0.1411	0.0620	0.0776	0.0469	0.6562	0.1719	0.3281	0.21	0.66	0.05	0.19
10-50-09	0.0469	0.1250	0.1099	0.1104	0.0151	0.0317	0.0317	0.0791	0.0469	0.3120	0.09	0.31	0.02	0.09
10-50-10	0.0151	0.0156	0.2031	0.0161	0.0312	0.0161	0.0469	0.0308	0.0469	0.0322	0.05	0.20	0.02	0.06
10-100-01	0.1411	0.1411	0.1250	0.1250	0.1401	0.1411	0.1411	0.1250	0.1411	0.1406	0.14	0.14	0.13	0.01
10-100-02	0.1250	0.1250	0.1406	0.1250	0.1406	0.1250	0.1411	0.1250	0.1411	0.1250	0.13	0.14	0.13	0.01
10-100-03	0.1250	0.1250	0.1411	0.1411	0.1406	0.1401	0.1250	0.1411	0.1396	0.1250	0.13	0.14	0.13	0.01
10-100-04	0.2500	0.1411	0.1406	0.1250	0.1411	0.1250	0.2651	0.1401	0.1250	0.1411	0.16	0.27	0.13	0.05
10-100-05	0.1250	0.1567	0.1401	0.1411	0.1411	0.1406	0.1558	0.1411	0.2041	0.1401	0.15	0.20	0.13	0.02
10-100-06	0.1411	0.1401	0.1411	0.1401	0.1401	0.1406	0.1411	0.1396	0.1250	0.1411	0.14	0.14	0.13	0.00
10-100-07	0.2812	0.1401	0.4219	0.2812	0.2500	0.4058	0.8442	0.2812	0.2661	0.1401	0.33	0.84	0.14	0.20
10-100-08	0.1411	0.1411	0.1250	0.1250	0.1406	0.1411	0.1411	0.1411	0.1406	0.1411	0.14	0.14	0.13	0.01
10-100-09	0.8120	0.4219	0.8906	2.5469	0.4526	0.2651	0.2661	0.5620	0.1411	0.5630	0.69	2.55	0.14	0.69
10-100-10	0.1250	0.1411	0.2969	0.1396	0.1406	0.1250	0.1401	0.1401	0.1250	0.2817	0.17	0.30	0.13	0.07
10-200-01	1.0469	1.0630	1.0312	1.0469	1.0781	1.0469	1.0312	2.2656	1.0938	1.1396	1.18	2.27	1.03	0.38
10-200-02	1.1250	1.0791	1.1084	1.0938	1.1094	1.0781	1.0781	1.1104	1.0928	1.0938	1.10	1.13	1.08	0.02
10-200-03	1.0303	1.0312	1.0312	1.0312	1.0322	1.0166	1.0469	1.0479	1.0625	1.0469	1.04	1.06	1.02	0.01
10-200-04	1.0791	1.0947	1.0625	1.1084	1.0781	1.0938	1.0928	1.0781	1.0771	1.0635	1.08	1.11	1.06	0.01
10-200-05	1.0312	1.0469	1.0615	1.0469	1.0459	1.0781	1.0459	1.0312	1.0635	1.0469	1.05	1.08	1.03	0.01
10-200-06	2.1562	1.0938	1.3281	1.0625	1.1104	1.1250	2.1416	3.4072	1.0781	1.0791	1.56	3.41	1.06	0.78
10-200-07	1.0312	1.0625	1.0781	1.3584	1.0469	1.0781	1.1719	1.0781	1.0469	2.2031	1.22	2.20	1.03	0.36
10-200-08	1.1406	1.0938	1.0791	1.0625	1.0947	1.5781	1.0781	1.0781	1.0781	1.0791	1.14	1.58	1.06	0.16
10-200-09	1.5146	1.4697	1.1729	1.0928	1.0947	1.1250	1.0781	1.0928	1.0947	1.0938	1.18	1.51	1.08	0.17
10-200-10	1.0469	1.1865	1.0479	1.5615	1.0781	1.2197	1.2354	1.2178	1.0312	2.1416	1.28	2.14	1.03	0.34

Table A.3.c Results of Makespan for VNS-II for m=10

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
10-20-01	113	113	113	113	113	113	113	113	113	113	113	113	113	0.00	0.00
10-20-02	100	100	100	100	100	100	100	100	100	100	100	100	100	0.00	0.00
10-20-03	106	106	106	106	106	106	106	106	106	106	106	106	106	0.00	0.00
10-20-04	96	96	96	96	96	96	96	96	96	96	96	96	96	0.00	0.00
10-20-05	99	99	99	99	99	99	99	99	99	99	99	99	99	0.00	0.00
10-20-06	114	114	114	114	114	114	114	114	114	114	114	114	114	0.00	0.00
10-20-07	105	105	105	105	105	105	105	105	105	105	105	105	105	0.00	0.00
10-20-08	115	115	115	115	115	115	115	115	115	115	115	115	115	0.00	0.00
10-20-09	118	118	118	118	118	118	118	118	118	118	118	118	118	0.00	0.00
10-20-10	127	127	127	127	127	127	127	127	127	127	127	127	127	0.00	0.00
10-50-01	312	312	312	312	312	312	312	312	312	312	312	312	312	0.00	0.00
10-50-02	259	259	259	259	259	259	259	259	259	259	259	259	259	0.00	0.00
10-50-03	235	235	235	235	235	235	235	235	235	235	235	235	235	0.00	0.00
10-50-04	231	231	232	231	231	231	231	232	232	231	231.3	232	231	0.48	0.13
10-50-05	279	279	279	279	280	280	279	280	280	279	279.4	280	279	0.52	0.14
10-50-06	259	259	259	259	259	259	259	259	259	259	259	259	259	0.00	0.00
10-50-07	262	262	262	262	262	262	262	262	262	262	262	262	262	0.00	0.00
10-50-08	290	290	290	290	290	290	290	290	290	290	290	290	290	0.00	0.00
10-50-09	257	257	257	257	257	257	257	257	257	257	257	257	257	0.00	0.00
10-50-10	237	237	237	237	237	237	237	237	237	237	237	237	237	0.00	0.00
10-100-01	459	459	459	459	459	459	459	459	459	459	459	459	459	0.00	0.00
10-100-02	532	532	532	532	532	532	532	532	532	532	532	532	532	0.00	0.00
10-100-03	510	510	510	510	510	510	510	510	510	510	510	510	510	0.00	0.00
10-100-04	467	467	467	467	467	467	467	467	467	467	467	467	467	0.00	0.00
10-100-05	517	517	517	517	517	517	517	517	517	517	517	517	517	0.00	0.00
10-100-06	493	493	493	493	493	493	493	493	493	493	493	493	493	0.00	0.00
10-100-07	478	478	478	478	478	478	478	478	478	478	478	478	478	0.00	0.00
10-100-08	489	489	489	489	489	489	489	489	489	489	489	489	489	0.00	0.00
10-100-09	477	477	477	477	477	477	477	477	477	477	477	477	477	0.00	0.00
10-100-10	504	504	504	504	504	504	504	504	504	504	504	504	504	0.00	0.00
10-200-01	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	0.00	0.00
10-200-02	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	0.00	0.00
10-200-03	961	961	961	961	961	961	961	961	961	961	961	961	961	0.00	0.00
10-200-04	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	0.00	0.00
10-200-05	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	0.00	0.00
10-200-06	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	0.00	0.00
10-200-07	949	949	949	949	949	949	949	949	949	949	949	949	949	0.00	0.00
10-200-08	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	0.00	0.00
10-200-09	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	0.00	0.00
10-200-10	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	0.00	0.00

Table A.3.d Results of CPU for VNS-II for m=10

1"	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
10-20-01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
10-20-02	0.0156	0.0161	0.0000	0.0161	0.0161	0.0000	0.0161	0.0000	0.0000	0.0000	0.01	0.02	0.00	0.01
10-20-03	0.0000	0.0000	0.0000	0.0000	0.0156	0.0000	0.0000	0.0161	0.0156	0.0000	0.00	0.02	0.00	0.01
10-20-04	0.0161	0.0161	0.0000	0.0000	0.0161	0.0161	0.0000	0.0000	0.0000	0.0000	0.01	0.02	0.00	0.01
10-20-05	0.0000	0.0000	0.0151	0.0000	0.0000	0.0000	0.0000	0.0156	0.0156	0.0156	0.01	0.02	0.00	0.01
10-20-06	0.0000	0.0161	0.0000	0.0000	0.0000	0.0161	0.0000	0.0156	0.0000	0.0000	0.00	0.02	0.00	0.01
10-20-07	0.0000	0.0000	0.0161	0.0161	0.0161	0.0000	0.0000	0.0000	0.0151	0.0000	0.01	0.02	0.00	0.01
10-20-08	0.0000	0.0161	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0161	0.0000	0.00	0.02	0.00	0.01
10-20-09	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0000	0.0000	0.0151	0.00	0.02	0.00	0.01
10-20-10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
10-50-01	0.0161	0.0151	0.0151	0.0322	0.0161	0.0308	0.0161	0.0317	0.0156	0.0146	0.02	0.03	0.01	0.01
10-50-02	0.0620	0.0151	0.0161	0.0312	0.0151	0.0620	0.0312	0.0161	0.0317	0.0156	0.03	0.06	0.02	0.02
10-50-03	0.0312	0.0312	0.0151	0.0317	0.0161	0.0469	0.0161	0.0161	0.0146	0.0317	0.03	0.05	0.01	0.01
10-50-04	0.0469	0.5474	0.0151	0.7812	0.1562	0.7031	0.1089	0.0161	0.0151	0.1724	0.26	0.78	0.02	0.30
10-50-05	0.1250	0.4531	0.0942	0.0630	0.0469	0.0161	0.3750	0.0161	0.0474	0.2817	0.15	0.45	0.02	0.16
10-50-06	0.0781	0.3281	0.2500	0.1870	0.3750	0.4688	0.0620	0.7808	0.1719	0.2500	0.30	0.78	0.06	0.21
10-50-07	0.0776	0.1880	0.0781	0.0630	0.0322	0.0469	0.1724	0.0781	0.0791	0.0781	0.09	0.19	0.03	0.05
10-50-08	0.0469	0.0781	0.2969	0.2661	0.0312	0.2651	0.0781	0.0151	0.1089	0.1099	0.13	0.30	0.02	0.11
10-50-09	0.0161	0.0151	0.0161	0.2026	0.1099	0.2031	0.0469	0.4067	0.0469	0.0312	0.11	0.41	0.02	0.13
10-50-10	0.0151	0.0317	0.0161	0.0161	0.0151	0.0312	0.0151	0.0161	0.0308	0.0151	0.02	0.03	0.02	0.01
10-100-01	0.1411	0.1396	0.1411	0.1411	0.1719	0.1562	0.1396	0.1411	0.1411	0.1406	0.15	0.17	0.14	0.01
10-100-02	0.1411	0.1406	0.1562	0.1562	0.1406	0.1396	0.1411	0.1562	0.1411	0.1401	0.15	0.16	0.14	0.01
10-100-03	0.1411	0.1411	0.1411	0.1396	0.1411	0.1406	0.1411	0.1411	0.1401	0.1411	0.14	0.14	0.14	0.00
10-100-04	0.1558	0.2969	0.1401	0.1396	0.1250	0.1411	0.4370	0.1401	0.1411	0.2959	0.20	0.44	0.13	0.11
10-100-05	0.1250	0.1562	0.1411	0.1411	0.1558	0.1401	0.1411	0.1406	0.1411	0.1401	0.14	0.16	0.13	0.01
10-100-06	0.1396	0.1406	0.1411	0.1250	0.1406	0.2808	0.1719	0.1401	0.1562	0.3130	0.17	0.31	0.13	0.07
10-100-07	0.2974	0.1401	0.1411	0.1411	0.2969	1.0161	0.5781	0.2651	0.5620	0.1406	0.36	1.02	0.14	0.28
10-100-08	0.1411	0.1401	0.1411	0.1406	0.1411	0.1396	0.1401	0.2188	0.1401	0.1724	0.15	0.22	0.14	0.03
10-100-09	0.2808	1.2354	0.3120	1.7339	0.8438	0.1411	0.6250	0.7192	1.5781	0.2651	0.77	1.73	0.14	0.57
10-100-10	0.2808	0.1406	0.1411	0.1401	0.2812	0.1401	0.1411	0.1558	0.2822	0.1411	0.18	0.28	0.14	0.07
10-200-01	1.0630	1.1719	1.2026	1.1089	1.0781	1.1250	1.1104	1.0928	1.1084	1.0928	1.12	1.20	1.06	0.04
10-200-02	1.1562	1.1719	1.1885	1.1396	1.1416	1.1572	1.1719	1.1250	1.1553	1.1250	1.15	1.19	1.13	0.02
10-200-03	1.0791	1.0938	1.0781	1.0938	1.0635	1.0947	1.1250	1.0625	1.0928	1.0938	1.09	1.13	1.06	0.02
10-200-04	1.1572	1.1416	1.1572	1.1719	1.1729	1.1084	1.1250	1.1084	1.1416	1.3584	1.16	1.36	1.11	0.07
10-200-05	1.0928	1.0625	1.1562	1.1084	1.1562	1.0781	1.0938	1.2031	1.0771	1.0928	1.11	1.20	1.06	0.04
10-200-06	1.0938	1.0947	1.0928	1.0781	3.3584	1.0781	3.4531	1.0791	1.4844	1.2500	1.61	3.45	1.08	0.96
10-200-07	1.2334	1.2041	1.1094	1.1406	1.0928	1.1729	1.1084	1.1104	1.0947	1.1416	1.14	1.23	1.09	0.05
10-200-08	1.1875	1.1250	1.1396	1.1416	1.1572	1.1553	1.1406	1.1406	1.1250	1.1719	1.15	1.19	1.13	0.02
10-200-09	1.0938	1.1094	1.0615	1.1094	1.0625	1.0791	1.1250	1.0781	1.1104	1.0938	1.09	1.13	1.06	0.02
10-200-10	1.0469	1.0303	1.0469	1.0469	1.0781	1.0469	1.0771	1.0615	1.0615	1.0928	1.06	1.09	1.03	0.02

Table A.3.e Results of Makespan for VNS-III for m=10

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
10-20-01	113	113	113	113	113	113	113	113	113	113	113	113	113	0.00	0.00
10-20-02	100	100	100	100	100	100	100	100	100	100	100	100	100	0.00	0.00
10-20-03	106	106	106	106	106	106	106	106	106	106	106	106	106	0.00	0.00
10-20-04	96	96	96	96	96	96	96	96	96	96	96	96	96	0.00	0.00
10-20-05	99	99	99	99	99	99	99	99	99	99	99	99	99	0.00	0.00
10-20-06	114	114	114	114	114	114	114	114	114	114	114	114	114	0.00	0.00
10-20-07	105	105	105	105	105	105	105	105	105	105	105	105	105	0.00	0.00
10-20-08	115	115	115	115	115	115	115	115	115	115	115	115	115	0.00	0.00
10-20-09	118	118	118	118	118	118	118	118	118	118	118	118	118	0.00	0.00
10-20-10	127	127	127	127	127	127	127	127	127	127	127	127	127	0.00	0.00
10-50-01	312	312	312	312	312	312	312	312	312	312	312	312	312	0.00	0.00
10-50-02	259	259	259	259	259	259	259	259	259	259	259	259	259	0.00	0.00
10-50-03	235	235	235	235	235	235	235	235	235	235	235	235	235	0.00	0.00
10-50-04	232	232	231	232	231	232	231	232	231	232	231.6	232	231	0.52	0.26
10-50-05	280	279	279	280	280	280	279	280	279	279	279.5	280	279	0.53	0.18
10-50-06	259	259	260	260	259	260	260	260	260	259	259.6	260	259	0.52	0.23
10-50-07	262	262	262	262	262	262	262	262	262	262	262	262	262	0.00	0.00
10-50-08	290	290	290	290	290	290	290	290	290	290	290	290	290	0.00	0.00
10-50-09	257	257	257	257	257	257	257	257	257	257	257	257	257	0.00	0.00
10-50-10	237	237	237	237	237	237	237	237	237	237	237	237	237	0.00	0.00
10-100-01	459	459	459	459	459	459	459	459	459	459	459	459	459	0.00	0.00
10-100-02	532	532	532	532	532	532	532	532	532	532	532	532	532	0.00	0.00
10-100-03	510	510	510	510	510	510	510	510	510	510	510	510	510	0.00	0.00
10-100-04	467	467	467	467	467	467	467	467	467	467	467	467	467	0.00	0.00
10-100-05	517	517	517	517	517	517	517	517	517	517	517	517	517	0.00	0.00
10-100-06	493	493	493	493	493	493	493	493	493	493	493	493	493	0.00	0.00
10-100-07	478	478	478	478	478	478	478	478	478	478	478	478	478	0.00	0.00
10-100-08	489	489	489	489	489	489	489	489	489	489	489	489	489	0.00	0.00
10-100-09	477	477	477	477	477	477	477	477	477	477	477	477	477	0.00	0.00
10-100-10	504	504	504	504	504	504	504	504	504	504	504	504	504	0.00	0.00
10-200-01	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	1003	0.00	0.00
10-200-02	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	0.00	0.00
10-200-03	961	961	961	961	961	961	961	961	961	961	961	961	961	0.00	0.00
10-200-04	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	1014	0.00	0.00
10-200-05	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	1011	0.00	0.00
10-200-06	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	0.00	0.00
10-200-07	949	949	949	949	949	949	949	949	949	949	949	949	949	0.00	0.00
10-200-08	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	1037	0.00	0.00
10-200-09	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	1022	0.00	0.00
10-200-10	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	1002	0.00	0.00

Table A.3.f Results of CPU for VNS-III for m=10

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
10-20-01	0.0000	0.0000	0.0149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.00	0.02	0.00	0.01
10-20-02	0.0161	0.0310	0.0942	0.0310	0.0310	0.0310	0.0320	0.0322	0.0000	0.0000	0.03	0.09	0.00	0.03
10-20-03	0.0149	0.0161	0.0000	0.0149	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.01	0.02	0.00	0.01
10-20-04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.00	0.02	0.00	0.01
10-20-05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0159	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
10-20-06	0.0161	0.0149	0.0161	0.0000	0.0149	0.0149	0.0000	0.0000	0.0000	0.0000	0.01	0.02	0.00	0.01
10-20-07	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
10-20-08	0.0000	0.0000	0.0161	0.0161	0.0000	0.0000	0.0000	0.0000	0.0000	0.0149	0.00	0.02	0.00	0.01
10-20-09	0.0000	0.0000	0.0000	0.0000	0.0161	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
10-20-10	0.0000	0.0000	0.0149	0.0161	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.02	0.00	0.01
10-50-01	0.0161	0.0320	0.0149	0.0161	0.0161	0.0149	0.0310	0.0149	0.0159	0.0159	0.02	0.03	0.01	0.01
10-50-02	0.0940	0.0469	0.0161	0.0322	0.0000	0.0149	0.0159	0.0940	0.0930	0.0620	0.05	0.09	0.00	0.04
10-50-03	0.0308	0.0161	0.0159	0.0000	0.0159	0.0161	0.0161	0.0159	0.0308	0.0000	0.02	0.03	0.00	0.01
10-50-04	0.0159	0.0159	0.4060	0.0000	0.3750	0.0149	0.3750	0.0000	0.0000	0.0161	0.12	0.41	0.00	0.18
10-50-05	0.0161	0.1560	0.4368	0.0149	0.0161	0.0469	0.0781	0.0149	0.0000	0.1411	0.09	0.44	0.00	0.13
10-50-06	0.4531	0.1399	0.0000	0.0000	0.4221	0.0000	0.0161	0.0161	0.0149	0.1882	0.13	0.45	0.00	0.18
10-50-07	0.2500	0.0310	0.0471	0.0471	0.0471	0.1250	0.0149	0.0791	0.0471	0.0322	0.07	0.25	0.01	0.07
10-50-08	0.0940	0.2190	0.4529	0.2029	0.3428	0.0149	0.0618	0.2969	0.0940	0.1250	0.19	0.45	0.01	0.14
10-50-09	0.0471	0.0161	0.0322	0.1250	0.1721	0.1101	0.3291	0.0471	0.0471	0.0942	0.10	0.33	0.02	0.09
10-50-10	0.0149	0.0000	0.0149	0.0000	0.0161	0.0310	0.0000	0.0161	0.0000	0.0149	0.01	0.03	0.00	0.01
10-100-01	0.0618	0.0630	0.0779	0.0618	0.0630	0.0779	0.0620	0.0781	0.0620	0.0781	0.07	0.08	0.06	0.01
10-100-02	0.0618	0.0620	0.1411	0.0779	0.0618	0.0630	0.0630	0.0618	0.0630	0.0632	0.07	0.14	0.06	0.02
10-100-03	0.0620	0.0781	0.0781	0.0632	0.0779	0.0618	0.0630	0.0630	0.0779	0.0618	0.07	0.08	0.06	0.01
10-100-04	0.1250	0.0620	0.1250	0.2029	0.0632	0.2029	0.1250	0.0632	0.3430	0.0632	0.14	0.34	0.06	0.09
10-100-05	0.0630	0.0781	0.0632	0.0630	0.0779	0.0630	0.0620	0.0781	0.0620	0.0632	0.07	0.08	0.06	0.01
10-100-06	0.0620	0.2810	0.0620	0.0632	0.4060	0.1399	0.0620	0.5469	0.4060	0.0632	0.21	0.55	0.06	0.19
10-100-07	0.2661	0.0632	0.0632	0.1882	0.1560	0.2500	0.7500	1.1089	0.5630	0.2500	0.37	1.11	0.06	0.34
10-100-08	0.0618	0.0779	0.0779	0.0779	0.0791	0.0791	0.0781	0.0632	0.0779	0.0940	0.08	0.09	0.06	0.01
10-100-09	1.3601	2.8750	2.5310	0.8279	0.4221	1.6870	1.4839	1.4690	2.7820	0.6091	1.60	2.88	0.42	0.88
10-100-10	0.0618	0.1560	0.2500	0.0781	0.0781	0.1411	0.0781	0.2500	0.1409	0.0630	0.13	0.25	0.06	0.07
10-200-01	0.5320	0.5310	0.5322	0.5161	0.5308	0.5471	1.1252	0.5161	0.5161	0.5322	0.59	1.13	0.52	0.19
10-200-02	0.5322	0.5308	0.5469	0.5308	0.5469	0.5312	0.6250	0.5308	0.5308	0.5474	0.55	0.63	0.53	0.03
10-200-03	0.5308	0.5308	0.5312	0.5620	0.5938	0.5928	0.5791	0.5938	1.7354	0.5942	0.68	1.74	0.53	0.37
10-200-04	0.5630	0.5942	0.5635	0.5942	0.5630	0.5630	0.6104	0.5781	0.5615	0.5308	0.57	0.61	0.53	0.02
10-200-05	0.5161	0.5312	0.5161	0.5161	0.5312	0.5161	0.5308	0.5322	0.5161	0.5474	0.53	0.55	0.52	0.01
10-200-06	0.5161	0.5469	1.6411	1.0781	0.5620	1.6411	0.5308	2.1558	1.0791	1.0620	1.08	2.16	0.52	0.57
10-200-07	1.6089	0.5474	0.5322	1.6411	1.6558	1.0308	1.1089	0.5469	0.5000	1.0781	1.03	1.66	0.50	0.48
10-200-08	0.5308	0.5308	0.5459	0.5322	0.5308	0.5469	0.5469	0.5322	0.5312	0.5308	0.54	0.55	0.53	0.01
10-200-09	0.5322	0.5151	0.5161	0.5322	0.5474	0.5474	0.5781	0.5620	0.5630	0.5630	0.55	0.58	0.52	0.02
10-200-10	0.5942	0.5620	0.6104	0.5469	0.5308	0.5469	0.5469	0.5308	0.5469	0.5308	0.55	0.61	0.53	0.03

Table A.4.a Results of Makespan for VNS-I for m=20

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
20-50-01	130	130	130	130	130	130	130	130	130	130	130	130	130	0.00	0.00
20-50-02	131	131	131	131	131	131	131	131	131	131	131	131	131	0.00	0.00
20-50-03	130	130	130	130	130	130	130	130	130	129	129.9	130	129	0.32	0.70
20-50-04	131	131	131	131	131	131	131	131	131	131	131	131	131	0.00	0.00
20-50-05	122	122	121	122	121	122	122	122	121	122	121.7	122	121	0.48	0.58
20-50-06	123	124	124	124	123	124	123	124	124	123	123.6	124	123	0.52	0.49
20-50-07	139	139	139	139	139	139	139	139	139	139	139	139	139	0.00	0.00
20-50-08	122	122	122	122	122	122	122	122	122	122	122	122	122	0.00	0.00
20-50-09	137	137	138	138	137	137	137	137	137	138	137.3	138	137	0.48	0.22
20-50-10	106	106	106	106	106	106	106	106	106	106	106	106	106	0.00	0.00
20-100-01	252	252	252	252	252	252	253	252	252	252	252.1	253	252	0.32	0.04
20-100-02	262	262	262	262	262	262	262	262	262	262	262	262	262	0.00	0.00
20-100-03	261	261	261	261	261	261	261	261	261	261	261	261	261	0.00	0.00
20-100-04	251	251	251	251	251	251	251	251	251	251	251	251	251	0.00	0.00
20-100-05	243	243	243	243	243	243	243	243	243	243	243	243	243	0.00	0.00
20-100-06	253	253	253	253	253	253	253	253	253	253	253	253	253	0.00	0.00
20-100-07	264	265	264	264	265	264	265	264	264	265	264.4	265	264	0.52	0.15
20-100-08	268	268	268	268	268	268	268	268	268	268	268	268	268	0.00	0.00
20-100-09	258	258	258	258	258	258	258	258	258	258	258	258	258	0.00	0.00
20-100-10	250	250	250	250	250	250	250	250	250	250	250	250	250	0.00	0.00
20-200-01	499	498	498	498	499	499	498	499	499	499	498.6	499	498	0.52	0.12
20-200-02	479	479	479	479	479	479	479	479	479	479	479	479	479	0.00	0.00
20-200-03	513	513	513	513	513	513	514	513	513	514	513.2	514	513	0.42	0.04
20-200-04	491	491	491	491	491	491	491	491	491	491	491	491	491	0.00	0.00
20-200-05	495	495	495	495	496	495	495	496	495	495	495.2	496	495	0.42	0.04
20-200-06	503	504	504	504	503	504	503	503	503	504	503.5	504	503	0.53	0.10
20-200-07	491	491	492	492	492	491	491	492	492	492	491.6	492	491	0.52	0.12
20-200-08	534	534	534	534	534	534	533	534	534	534	533.9	534	533	0.32	0.17
20-200-09	523	523	523	523	523	523	523	523	523	523	523	523	523	0.00	0.00
20-200-10	495	495	495	495	495	495	495	495	495	495	495	495	495	0.00	0.00

Table A.4.b Results of CPU for VNS-I for m=20

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
20-50-01	0.3604	0.7656	0.2500	0.7031	0.2031	0.6104	0.4219	0.6719	0.1553	0.1416	0.43	0.77	0.14	0.24
20-50-02	0.0156	0.0303	0.0459	0.0322	0.0469	0.0303	0.0312	0.0322	0.0312	0.0303	0.03	0.05	0.02	0.01
20-50-03	0.4219	0.4688	0.4375	0.1416	0.3281	0.3750	0.7031	0.5469	1.0615	1.1885	0.57	1.19	0.14	0.33
20-50-04	0.0322	0.1416	0.0312	0.0312	0.1562	0.1729	0.0625	0.0947	0.0303	0.0928	0.08	0.17	0.03	0.06
20-50-05	0.1719	0.1396	0.5146	0.0928	0.5938	0.0166	0.0615	0.1865	0.3584	0.1250	0.23	0.59	0.02	0.20
20-50-06	0.4365	0.0615	0.0635	0.5469	1.3291	0.0938	1.2197	0.3594	0.1416	0.2969	0.45	1.33	0.06	0.46
20-50-07	0.0771	0.2500	0.2822	0.1250	0.2188	0.1719	0.1572	0.5000	0.2969	0.0469	0.21	0.50	0.05	0.13
20-50-08	0.1719	0.0938	0.3125	0.2969	0.1406	0.0928	0.4688	0.3281	0.0303	0.2812	0.22	0.47	0.03	0.14
20-50-09	0.1885	0.7021	0.0625	0.0615	0.3584	0.1396	0.5312	0.1250	0.0771	0.0781	0.23	0.70	0.06	0.22
20-50-10	0.1250	0.1104	0.2656	0.0625	1.0156	0.4365	0.0635	0.2354	0.4531	0.7197	0.35	1.02	0.06	0.31
20-100-01	3.9072	1.9844	3.9531	0.2666	8.3115	0.8135	0.3916	6.0000	0.3896	1.1553	2.72	8.31	0.27	2.76
20-100-02	0.1875	0.2188	0.2188	0.1865	0.2188	0.3916	0.3750	0.3750	0.2021	0.2031	0.26	0.39	0.19	0.09
20-100-03	1.1572	0.3916	0.1885	0.9688	0.2041	0.2031	0.2031	0.2646	0.4219	0.2031	0.42	1.16	0.19	0.35
20-100-04	0.1865	0.1875	0.2021	0.1885	0.2031	0.3750	0.1865	0.1885	0.2031	0.2031	0.21	0.38	0.19	0.06
20-100-05	0.5781	0.2021	0.3750	1.2500	0.9521	0.2031	0.1885	0.5615	0.1865	0.1885	0.47	1.25	0.19	0.37
20-100-06	1.1250	2.2334	0.1875	1.1104	0.9531	1.3896	0.1865	0.4209	0.2031	1.1250	0.89	2.23	0.19	0.66
20-100-07	9.3584	0.2031	0.2031	4.7666	0.5635	4.7021	0.1885	2.5312	8.1094	0.3750	3.10	9.36	0.19	3.48
20-100-08	1.2500	1.7969	0.1865	3.0625	0.3594	0.3604	0.3750	2.1416	0.1865	1.9854	1.17	3.06	0.19	1.03
20-100-09	6.6719	0.7334	0.7197	0.5469	0.1719	2.7188	0.9072	0.5469	0.3584	3.0635	1.64	6.67	0.17	2.02
20-100-10	0.3750	0.3750	2.3750	0.9062	0.9219	0.9219	0.3750	0.5469	1.6553	0.7500	0.92	2.38	0.38	0.64
20-200-01	1.4219	32.0469	54.4375	6.9697	1.4072	1.4209	58.4531	1.4219	1.4219	1.4062	16.04	58.45	1.41	23.32
20-200-02	1.4219	53.4688	21.0781	8.4854	22.4531	5.6250	2.7969	16.9697	2.7969	19.6562	15.48	53.47	1.42	15.66
20-200-03	15.3896	54.4531	15.4062	11.2031	27.9229	54.4688	1.4209	13.9072	23.7500	1.4219	21.93	54.47	1.42	19.04
20-200-04	1.4219	1.4375	1.4375	1.3906	1.4062	1.4531	2.8438	4.3438	1.4355	1.4238	1.86	4.34	1.39	0.98
20-200-05	33.8770	26.8125	53.5312	7.0625	1.4375	19.9219	42.3281	1.4375	31.0918	2.7812	22.03	53.53	1.44	18.55
20-200-06	47.7656	1.4219	1.4375	1.4395	58.9062	1.4219	7.0332	47.6738	18.2832	1.4238	18.68	58.91	1.42	23.40
20-200-07	43.0000	40.2031	1.4219	1.4375	1.4219	47.1094	62.3906	1.4062	1.4375	1.4062	20.12	62.39	1.41	24.81
20-200-08	1.4219	1.4062	1.4219	1.4062	1.4082	1.4219	66.5000	1.4062	1.4219	1.4062	7.92	66.50	1.41	20.58
20-200-09	21.1562	2.8262	14.0801	1.4062	11.2969	1.4219	2.7812	1.4219	8.5020	1.4238	6.63	21.16	1.41	6.91
20-200-10	2.8438	4.2520	1.4238	5.7188	2.8301	2.8906	17.0938	5.6875	2.8594	5.6855	5.13	17.09	1.42	4.46

Table A.4.c Results of Makespan for VNS-II for m=20

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
20-50-01	130	131	130	130	130	130	131	130	130	131	130.3	131	130	0.48	0.23
20-50-02	131	131	131	131	131	131	131	131	131	131	131	131	131	0.00	0.00
20-50-03	130	130	131	130	130	131	130	130	130	130	130.2	131	130	0.42	0.15
20-50-04	130	131	131	131	131	131	131	131	131	131	130.9	131	130	0.32	0.69
20-50-05	122	122	122	122	122	122	122	122	122	122	122	122	122	0.00	0.00
20-50-06	124	124	124	124	124	124	124	124	124	124	124	124	124	0.00	0.00
20-50-07	139	140	139	140	140	139	139	140	139	140	139.5	140	139	0.53	0.36
20-50-08	122	123	122	122	122	122	122	122	122	122	122.1	123	122	0.32	0.08
20-50-09	138	137	137	138	138	138	138	138	138	137	137.7	138	137	0.48	0.51
20-50-10	107	106	106	106	107	106	107	106	107	106	106.4	107	106	0.52	0.38
20-100-01	252	252	252	253	252	253	253	252	252	252	252.3	253	252	0.48	0.12
20-100-02	261	262	262	262	261	262	262	262	262	262	261.8	262	261	0.42	0.31
20-100-03	261	261	261	261	261	261	261	261	261	261	261	261	261	0.00	0.00
20-100-04	251	251	251	251	251	251	251	251	251	251	251	251	251	0.00	0.00
20-100-05	243	243	243	243	243	243	243	243	243	243	243	243	243	0.00	0.00
20-100-06	253	253	253	253	253	253	253	253	253	253	253	253	253	0.00	0.00
20-100-07	264	264	265	265	264	264	264	265	265	264	264.4	265	264	0.52	0.15
20-100-08	268	268	268	268	268	268	268	268	268	268	268	268	268	0.00	0.00
20-100-09	258	258	258	258	258	258	258	258	258	258	258	258	258	0.00	0.00
20-100-10	250	250	250	250	250	250	250	250	250	250	250	250	250	0.00	0.00
20-200-01	499	498	499	499	498	498	498	499	499	499	498.6	499	498	0.52	0.12
20-200-02	479	479	479	479	479	479	479	479	479	479	479	479	479	0.00	0.00
20-200-03	514	513	514	514	514	514	513	513	513	513	513.5	514	513	0.53	0.10
20-200-04	491	491	491	491	491	491	491	491	491	491	491	491	491	0.00	0.00
20-200-05	495	496	496	495	495	495	495	495	495	495	495.2	496	495	0.42	0.04
20-200-06	503	503	503	503	503	503	503	503	504	503	503.1	504	503	0.32	0.02
20-200-07	492	492	491	492	492	492	492	492	492	492	491.9	492	491	0.32	0.18
20-200-08	534	534	534	534	534	534	534	533	534	534	533.9	534	533	0.32	0.17
20-200-09	523	523	523	523	523	523	523	523	523	523	523	523	523	0.00	0.00
20-200-10	495	495	495	495	495	495	495	495	495	495	495	495	495	0.00	0.00

Table A.4.d Results of CPU for VNS-II for m=20

1"	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
20-50-01	0.1719	0.0322	1.0938	0.0312	0.2969	1.1094	0.1562	0.2188	1.2188	0.1553	0.45	1.22	0.03	0.49
20-50-02	0.0303	0.0312	0.0469	0.0303	0.0479	0.0312	0.0303	0.0459	0.0635	0.0312	0.04	0.06	0.03	0.01
20-50-03	0.1396	0.6875	0.1250	0.8135	1.0938	0.0635	0.1250	0.5000	0.1562	0.1250	0.38	1.09	0.06	0.37
20-50-04	1.0469	0.0635	0.0312	0.2969	0.0322	0.1250	0.4375	0.4375	0.0928	0.2188	0.28	1.05	0.03	0.31
20-50-05	0.3115	0.0781	0.0303	0.0625	0.1553	0.7354	0.0322	0.6709	0.2666	0.1865	0.25	0.74	0.03	0.26
20-50-06	0.2666	0.1250	0.2500	0.2812	0.1250	0.2969	1.0947	0.1719	0.2500	1.0781	0.39	1.09	0.13	0.37
20-50-07	1.4688	0.1562	0.8906	0.0947	0.3438	0.1250	0.2812	0.0615	0.3115	0.1250	0.39	1.47	0.06	0.45
20-50-08	0.5781	0.0312	0.6250	1.3750	0.1250	0.0322	0.4834	0.0625	0.5156	0.0625	0.39	1.38	0.03	0.43
20-50-09	0.0312	0.9531	0.7500	0.3115	0.2021	0.0781	0.1104	0.0312	0.2500	1.1562	0.39	1.16	0.03	0.41
20-50-10	0.1250	0.1885	0.3604	0.9219	0.1416	0.4375	0.0615	1.4062	0.0303	1.1719	0.48	1.41	0.03	0.50
20-100-01	7.8447	6.2969	3.5312	0.1885	4.5781	0.1865	0.2031	1.3604	8.6250	7.5459	4.04	8.63	0.19	3.42
20-100-02	3.7354	0.2031	0.2031	0.2031	1.3438	0.2031	0.1875	0.2041	0.1875	0.1875	0.67	3.74	0.19	1.14
20-100-03	0.5781	0.7822	0.5947	0.3896	0.1885	0.3750	0.2021	0.7656	0.1865	1.3281	0.54	1.33	0.19	0.36
20-100-04	0.5928	0.2031	0.1865	0.3750	0.3750	0.5781	0.1885	0.1875	0.2031	0.1875	0.31	0.59	0.19	0.16
20-100-05	0.1865	0.3750	0.2041	0.2031	0.2031	0.1865	0.1885	0.5781	0.2031	0.2041	0.25	0.58	0.19	0.13
20-100-06	0.3750	0.2031	1.1562	0.5771	1.9521	0.4072	0.7666	0.2021	1.3750	0.6104	0.76	1.95	0.20	0.57
20-100-07	2.1875	0.9844	0.2021	0.2031	0.3750	0.2031	5.5156	0.2021	0.1865	5.8916	1.60	5.89	0.19	2.26
20-100-08	0.5781	1.1572	1.1719	3.5469	0.1865	7.5938	2.9688	7.2188	1.3438	1.5000	2.73	7.59	0.19	2.67
20-100-09	4.2959	2.7646	0.9697	1.1885	1.3281	5.9219	3.7500	2.1416	0.3896	0.7656	2.35	5.92	0.39	1.81
20-100-10	0.3906	0.3916	0.3896	0.7812	1.5625	0.9697	2.9385	2.4385	0.7500	0.5781	1.12	2.94	0.39	0.91
20-200-01	1.5312	34.1094	1.5000	1.4688	60.1875	32.4521	20.7969	1.5000	1.5000	1.4541	15.65	60.19	1.45	20.64
20-200-02	16.3594	4.5166	48.8135	4.5469	26.7812	14.9834	1.4209	13.4697	1.4385	22.2666	15.46	48.81	1.42	14.62
20-200-03	1.5146	7.5156	1.5000	1.5000	1.4844	1.5156	8.8750	45.7207	36.9238	19.2363	12.58	45.72	1.48	16.29
20-200-04	3.0312	1.5000	1.4219	1.5000	1.4863	1.4707	1.4707	1.4688	1.4844	1.5312	1.64	3.03	1.42	0.49
20-200-05	60.7500	1.5000	1.5176	10.5469	69.7520	4.5312	16.3906	53.4844	26.6094	15.0469	26.01	69.75	1.50	25.80
20-200-06	13.3438	71.0020	26.5938	38.5801	29.5469	17.9043	32.6875	13.4062	1.4844	20.9531	26.55	71.00	1.48	19.00
20-200-07	1.4688	1.5156	27.7969	1.5156	1.4844	1.4688	1.4980	1.5000	1.4824	1.4824	4.12	27.80	1.47	8.32
20-200-08	1.4688	1.5000	1.5000	1.4844	1.4844	1.4688	1.5000	39.6582	1.5137	1.4844	5.31	39.66	1.47	12.07
20-200-09	1.5000	22.4238	1.4688	1.5176	1.4688	18.0625	28.1406	9.0469	19.4688	6.0332	10.91	28.14	1.47	10.20
20-200-10	9.1113	4.6094	3.0781	6.0801	3.0605	10.5488	7.6113	1.4375	6.0781	9.1582	6.08	10.55	1.44	3.03

Table A.4.e Results of Makespan for VNS-III for m=20

Fitness	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev	ARPE
20-50-01	131	131	131	131	131	131	131	131	131	131	131	131	131	0.00	0.00
20-50-02	131	131	131	131	131	131	131	131	131	131	131	131	131	0.00	0.00
20-50-03	131	131	131	131	131	131	131	131	131	131	131	131	131	0.00	0.00
20-50-04	131	131	131	131	131	131	131	131	131	131	131	131	131	0.00	0.00
20-50-05	122	122	123	122	123	122	123	122	122	122	122.3	123	122	0.48	0.25
20-50-06	124	125	125	125	125	125	125	125	124	125	124.8	125	124	0.42	0.65
20-50-07	141	139	140	139	140	140	140	141	140	140	140	141	139	0.67	0.72
20-50-08	123	123	123	122	123	123	123	122	123	123	122.8	123	122	0.42	0.66
20-50-09	138	138	138	138	138	138	138	138	138	138	138	138	138	0.00	0.00
20-50-10	107	106	107	107	106	107	107	107	107	107	106.8	107	106	0.42	0.75
20-100-01	252	253	253	253	253	252	253	253	253	253	252.8	253	252	0.42	0.32
20-100-02	262	262	262	262	262	262	262	262	262	262	262	262	262	0.00	0.00
20-100-03	261	261	261	261	261	261	261	261	261	261	261	261	261	0.00	0.00
20-100-04	251	251	251	251	251	251	251	251	251	251	251	251	251	0.00	0.00
20-100-05	243	243	243	243	243	243	243	243	243	243	243	243	243	0.00	0.00
20-100-06	253	254	253	254	253	253	254	254	253	254	253.5	254	253	0.53	0.20
20-100-07	265	265	265	264	264	265	265	265	265	265	264.8	265	264	0.42	0.30
20-100-08	269	269	268	268	268	269	269	268	269	269	268.6	269	268	0.52	0.22
20-100-09	258	259	259	258	259	258	258	258	258	258	258.3	259	258	0.48	0.12
20-100-10	250	251	250	250	251	250	251	251	251	250	250.5	251	250	0.53	0.20
20-200-01	499	499	499	499	499	499	499	499	499	499	499	499	499	0.00	0.00
20-200-02	479	479	479	480	479	480	479	480	479	480	479.4	480	479	0.52	0.08
20-200-03	514	514	514	514	514	514	514	514	514	513	513.9	514	513	0.32	0.18
20-200-04	491	491	491	491	491	491	491	491	491	491	491	491	491	0.00	0.00
20-200-05	496	496	496	495	496	495	496	496	495	496	495.7	496	495	0.48	0.14
20-200-06	503	504	503	504	504	503	503	504	504	503	503.5	504	503	0.53	0.10
20-200-07	492	492	492	492	492	492	492	492	492	492	492	492	492	0.00	0.00
20-200-08	534	534	534	534	534	534	534	534	534	534	534	534	534	0.00	0.00
20-200-09	523	524	523	523	523	523	523	523	523	523	523.1	524	523	0.32	0.02
20-200-10	495	495	495	495	495	495	495	495	495	495	495	495	495	0.00	0.00

Table A.4.f Results of CPU for VNS-III for m=20

CPU	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Ave	Max	Min	Stdev
20-50-01	0.3750	0.1089	0.0469	0.1250	0.4688	0.1870	0.1089	0.1250	0.1250	0.0146	0.17	0.47	0.01	0.14
20-50-02	0.0791	0.0161	0.0151	0.0308	0.0776	0.0322	0.0942	0.0312	0.0146	0.0308	0.04	0.09	0.01	0.03
20-50-03	0.1250	0.1089	0.1411	0.0469	0.3115	0.2822	0.1572	0.1558	0.1089	0.1558	0.16	0.31	0.05	0.08
20-50-04	0.2661	0.2974	0.2339	0.6562	0.8120	0.2651	0.7969	0.0161	0.3750	0.6401	0.44	0.81	0.02	0.27
20-50-05	0.7500	0.0942	0.2661	0.5474	0.0630	0.2661	0.0942	0.3438	0.3589	0.4058	0.32	0.75	0.06	0.22
20-50-06	0.3599	0.0469	0.0469	0.1250	0.0459	0.1089	0.0474	0.2031	0.6562	0.0938	0.17	0.66	0.05	0.20
20-50-07	0.2500	0.0620	0.3589	0.5000	0.2339	0.6396	0.0942	0.0312	0.0942	0.7808	0.30	0.78	0.03	0.26
20-50-08	0.0161	0.0474	0.0146	0.5000	0.0161	0.0161	0.1089	0.0942	0.0308	0.0620	0.09	0.50	0.01	0.15
20-50-09	0.1724	0.4219	0.3281	0.6089	0.0459	0.1885	0.2188	0.0469	0.1724	0.2969	0.25	0.61	0.05	0.17
20-50-10	0.4839	0.3599	0.0308	0.0781	0.3130	0.1401	0.0469	0.0161	0.2808	0.0469	0.18	0.48	0.02	0.17
20-100-01	1.4209	0.2031	0.2969	0.3281	0.0938	4.1558	0.2178	0.0938	0.1870	0.3750	0.74	4.16	0.09	1.26
20-100-02	0.6411	0.4062	0.2192	0.2031	0.2822	0.7500	0.3120	0.5146	0.8442	0.1885	0.44	0.84	0.19	0.24
20-100-03	0.9370	0.4072	0.3130	0.6250	0.2188	0.3750	1.3130	0.0938	0.2969	0.2969	0.49	1.31	0.09	0.37
20-100-04	0.6250	0.4219	0.3911	2.0469	0.3281	0.5312	0.8115	0.5000	0.3130	0.5161	0.65	2.05	0.31	0.51
20-100-05	1.2339	2.3130	1.1880	0.4058	0.5146	0.8750	1.5308	2.3438	2.7661	0.2969	1.35	2.77	0.30	0.88
20-100-06	0.9219	0.0938	4.0781	0.2031	5.0781	0.7192	0.0942	0.2026	3.1250	0.0928	1.46	5.08	0.09	1.89
20-100-07	0.0942	0.0928	0.4062	2.4678	1.2339	0.1089	0.2192	0.3911	0.2031	0.3291	0.55	2.47	0.09	0.75
20-100-08	0.1099	0.1089	4.4692	4.1870	0.1089	0.2178	0.0938	4.8130	0.1089	0.0942	1.43	4.81	0.09	2.12
20-100-09	0.6104	0.1099	0.0942	3.6099	0.0942	3.9839	2.1250	1.3120	0.3750	0.5000	1.28	3.98	0.09	1.47
20-100-10	1.2188	0.1104	2.2500	3.6396	0.2969	2.2500	0.1089	0.0928	0.1104	1.2188	1.13	3.64	0.09	1.23
20-200-01	0.8281	0.7969	0.7500	0.7808	0.7969	0.7661	0.8120	0.7651	0.7661	0.7808	0.78	0.83	0.75	0.02
20-200-02	15.1724	14.5308	5.2339	0.8130	25.0000	0.7969	23.0000	0.7808	5.4370	0.7808	9.15	25.00	0.78	9.53
20-200-03	0.7808	0.7808	0.7969	0.7500	0.7500	0.7500	1.5156	1.4834	1.5156	0.7031	0.98	1.52	0.70	0.36
20-200-04	2.2969	2.9521	0.7500	3.0156	2.2500	0.7822	4.4072	1.4854	2.2500	2.2656	2.25	4.41	0.75	1.09
20-200-05	0.7656	0.7500	0.7500	22.6709	0.7354	3.6875	0.7656	0.7656	29.8594	0.7500	6.15	29.86	0.74	10.78
20-200-06	29.2178	0.7500	9.5156	0.7500	0.7334	34.5781	17.6094	0.7354	0.7500	2.1406	9.68	34.58	0.73	13.00
20-200-07	0.7656	0.7188	0.7500	0.8281	0.7188	0.7656	0.7656	0.7188	0.7656	0.7500	0.75	0.83	0.72	0.03
20-200-08	0.7646	2.2812	0.7500	0.7344	1.5146	0.7188	0.7500	1.5000	0.7188	0.7656	1.05	2.28	0.72	0.54
20-200-09	15.6094	0.7812	12.5156	5.9219	2.2500	0.7500	5.1729	23.3750	3.7500	16.1562	8.63	23.38	0.75	7.78
20-200-10	33.1406	3.1094	4.4072	6.6094	26.5000	2.2031	12.4688	11.0469	2.9219	0.7500	10.32	33.14	0.75	11.06

APPENDIX C

LOWERBOUNDS FOR PROBLEMS

Instance	OPT≥	Instance	OPT≥	Instance	OPT≥	Instance	OPT≥
2-20-01	492	5-20-01	128	10-20-01	87	20-50-01	103
2-20-02	429	5-20-02	173	10-20-02	79	20-50-02	99
2-20-03	401	5-20-03	148	10-20-03	82	20-50-03	106
2-20-04	477	5-20-04	176	10-20-04	75	20-50-04	106
2-20-05	411	5-20-05	144	10-20-05	76	20-50-05	95
2-20-06	458	5-20-06	164	10-20-06	88	20-50-06	99
2-20-07	507	5-20-07	184	10-20-07	81	20-50-07	115
2-20-08	369	5-20-08	171	10-20-08	88	20-50-08	96
2-20-09	560	5-20-09	194	10-20-09	91	20-50-09	116
2-20-10	439	5-20-10	168	10-20-10	98	20-50-10	83
2-50-01	977	5-50-01	420	10-50-01	246	20-100-01	194
2-50-02	1089	5-50-02	395	10-50-02	202	20-100-02	202
2-50-03	1119	5-50-03	395	10-50-03	184	20-100-03	201
2-50-04	1147	5-50-04	413	10-50-04	179	20-100-04	192
2-50-05	1111	5-50-05	468	10-50-05	217	20-100-05	186
2-50-06	1039	5-50-06	459	10-50-06	202	20-100-06	197
2-50-07	1043	5-50-07	364	10-50-07	207	20-100-07	208
2-50-08	1053	5-50-08	365	10-50-08	225	20-100-08	207
2-50-09	1030	5-50-09	374	10-50-09	200	20-100-09	197
2-50-10	892	5-50-10	382	10-50-10	183	20-100-10	191
2-100-01	2338	5-100-01	872	10-100-01	353	20-200-01	380
2-100-02	2087	5-100-02	806	10-100-02	410	20-200-02	365
2-100-03	1781	5-100-03	671	10-100-03	397	20-200-03	392
2-100-04	2037	5-100-04	863	10-100-04	360	20-200-04	373
2-100-05	2305	5-100-05	767	10-100-05	398	20-200-05	377
2-100-06	2187	5-100-06	764	10-100-06	382	20-200-06	383
2-100-07	2074	5-100-07	741	10-100-07	370	20-200-07	375
2-100-08	2314	5-100-08	814	10-100-08	378	20-200-08	406
2-100-09	2199	5-100-09	769	10-100-09	368	20-200-09	400
2-100-10	2309	5-100-10	739	10-100-10	388	20-200-10	376
2-200-01	4308	5-200-01	1745	10-200-01	774		
2-200-02	4052	5-200-02	1573	10-200-02	784		
2-200-03	4334	5-200-03	1569	10-200-03	739		
2-200-04	4105	5-200-04	1472	10-200-04	780		
2-200-05	3993	5-200-05	1655	10-200-05	778		
2-200-06	4269	5-200-06	1592	10-200-06	811		
2-200-07	4289	5-200-07	1600	10-200-07	732		
2-200-08	4300	5-200-08	1569	10-200-08	798		
2-200-09	4307	5-200-09	1605	10-200-09	786		
2-200-10	4110	5-200-10	1563	10-200-10	772		

APPENDIX D

LPT RESULTS

Instance	LPT	Instance	LPT	Instance	LPT	Instance	LPT
2-20-01	574	5-20-01	162	10-20-01	113	20-50-01	136
2-20-02	501	5-20-02	219	10-20-02	103	20-50-02	131
2-20-03	468	5-20-03	188	10-20-03	106	20-50-03	140
2-20-04	557	5-20-04	223	10-20-04	98	20-50-04	140
2-20-05	479	5-20-05	183	10-20-05	99	20-50-05	125
2-20-06	534	5-20-06	208	10-20-06	114	20-50-06	131
2-20-07	592	5-20-07	233	10-20-07	105	20-50-07	151
2-20-08	431	5-20-08	217	10-20-08	115	20-50-08	127
2-20-09	653	5-20-09	246	10-20-09	118	20-50-09	153
2-20-10	512	5-20-10	213	10-20-10	127	20-50-10	109
2-50-01	1140	5-50-01	532	10-50-01	320	20-100-01	256
2-50-02	1270	5-50-02	500	10-50-02	263	20-100-02	266
2-50-03	1306	5-50-03	500	10-50-03	239	20-100-03	265
2-50-04	1338	5-50-04	523	10-50-04	233	20-100-04	253
2-50-05	1296	5-50-05	593	10-50-05	282	20-100-05	245
2-50-06	1212	5-50-06	581	10-50-06	263	20-100-06	259
2-50-07	1217	5-50-07	461	10-50-07	269	20-100-07	274
2-50-08	1229	5-50-08	462	10-50-08	292	20-100-08	272
2-50-09	1202	5-50-09	474	10-50-09	260	20-100-09	260
2-50-10	1041	5-50-10	484	10-50-10	238	20-100-10	251
2-100-01	2728	5-100-01	1104	10-100-01	459	20-200-01	500
2-100-02	2435	5-100-02	1021	10-100-02	533	20-200-02	480
2-100-03	2078	5-100-03	850	10-100-03	516	20-200-03	516
2-100-04	2377	5-100-04	1093	10-100-04	468	20-200-04	491
2-100-05	2689	5-100-05	971	10-100-05	518	20-200-05	496
2-100-06	2552	5-100-06	968	10-100-06	496	20-200-06	504
2-100-07	2420	5-100-07	939	10-100-07	481	20-200-07	494
2-100-08	2700	5-100-08	1031	10-100-08	491	20-200-08	534
2-100-09	2565	5-100-09	974	10-100-09	479	20-200-09	527
2-100-10	2694	5-100-10	936	10-100-10	505	20-200-10	495
2-200-01	5026	5-200-01	2210	10-200-01	1006		
2-200-02	4727	5-200-02	1993	10-200-02	1019		
2-200-03	5056	5-200-03	1988	10-200-03	961		
2-200-04	4789	5-200-04	1864	10-200-04	1014		
2-200-05	4659	5-200-05	2096	10-200-05	1012		
2-200-06	4981	5-200-06	2016	10-200-06	1054		
2-200-07	5004	5-200-07	2027	10-200-07	951		
2-200-08	5017	5-200-08	1987	10-200-08	1038		
2-200-09	5025	5-200-09	2033	10-200-09	1022		
2-200-10	4795	5-200-10	1980	10-200-10	1003		

APPENDIX E

EXAMPLE OF A RUN'S EXPORTED DATA

Example of a run's exported data (1 problem's (2x20) 1st, 2nd, 3rd and 4th replications results obtained with VNS algorithm)

```
Problem Name....=2-20-01

Replication Number........=1
Seed=8569 Iteration=50 Popsize=100 dimension=20
CPU in seconds............=0.0000
Global Fitness............=567

8     0     16    14    15    2     13    3     12    9     10    19
      1     5     11    7     17    6     18    4

Problem Name....=2-20-01

Replication Number........=2
Seed=8570 Iteration=50 Popsize=100 dimension=20
CPU in seconds............=0.0000
Global Fitness............=567

19    16    2     5     9     10    3     17    6     8     12    13
      7     18    4     15    11    0     14    1

Problem Name....=2-20-01

Replication Number........=3
Seed=8571 Iteration=50 Popsize=100 dimension=20
CPU in seconds............=0.0000
Global Fitness............=567

6     18    0     11    3     8     15    7     17    16    12    5
      10    19    2     1     13    9     14    4

Problem Name....=2-20-01

Replication Number........=4
Seed=8572 Iteration=50 Popsize=100 dimension=20
CPU in seconds............=0.0000
Global Fitness............=567

18    11    9     16    8     2     3     4     10    13    19    14
      1     15    5     7     17    0     6     12
```