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Installation of Smog-Free Towers using novel Real Coded Genetic Algorithm

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ABSTRACT The circle packing problem involves finding the best way to place non-overlapping circles within a given space, while the smog-free tower installation problem aims to minimize the exposure of residents to secondhand smog by identifying the optimal tower locations. This study proposes a Real Coded Genetic Algorithm (RCGA) that uses real-valued representations of circle positions to solve the smog-free tower installation problem. A new crossover operator is introduced, combining the information from two parent solutions to generate two new offspring solutions. The operator uses a random crossover point and two scaling factors to control the amount of information exchanged. The performance of the operator is evaluated on CEC-2017 benchmark problem set and compared to other commonly used operators, with results indicating that it produces high-quality solutions and outperforms other operators in terms of solution quality and convergence speed. This research contributes to developing effective optimization algorithms that can have important implications for improving public health and reducing the negative effects of secondhand smog.

INDEX TERMS Burr Distribution, Crossover Operators, Real Coded Genetic Algorithms, Smog Free Tower

I. INTRODUCTION

THE negative impacts of air pollution on the environment and human health have been found to be severe across the world due to the multiplicity of pollutants generated and spread into the environment. Among these pollutants, fine particulate matter like PM2.5, and PM10 are the serious environmental problem. The extremely small particles can enter the human respiratory system and reach the deep lung epithelia, causing coughing, sneezing, shortness of breath, and respiratory infections. It is estimated that air pollution kills around seven million people in worldwide each year, with fine PM accounting for nearly 25% of all deaths. "Smog" is a combination of the terms smoke and fog. Fog is a visible aerosol made up of microscopic water droplets or ice crystals that are floating in the air; it is a type of low-lying cloud. Wind, temperature, and sunshine all influence the spread and qualities of smog. Coal-fired power stations, traffic emissions, stubble burning, and erupting volcanoes are the primary sources of particles and pollutants required for smog production. These activities can either directly or indirectly contribute to the generation of PM2.5, and PM10, the major precursor of smog. Smog has been recorded pretty often in several major places across the world. The environmental relevance of smog has been bringing awareness since the $1950s$, with reports of well-known air pollution episodes in London, UK. Clean Air Acts were adopted by the governments of the United Kingdom and the United States to address smog [1]. In recent years, the most concerning issue has been pollution not only in India but across the whole world. To tackle this problem, a massive 100-meter air purification tower [2] was inaugurated in China's northwest city of Xi'an in June 2016. A Smog Free Tower (SFT) is the name given to this massive air filter. An SFT is used to remove PM particles from the air. An SFT is made up of the four fundamental components [3] as a full-scale unit, which include a solar collector with a transparent roof, a tower, filters, and fans to increase airflow. Solar irradiation causes the air under the solar collector to be denser than the surrounding ambient air. As a result, rising updraft wind is formed within it. Polluted atmospheric air enters the solar collector through the inlets on all four sides, and air toxins are cleaned by filters. Following that, clean air is expelled in a circular pattern from the tower outlet into the surrounding spatial layout. That was a huge success on their first try. After that, a number of more SFTs were placed in various locations around the country. These towers have proved effective in lowering PM2.5, and PM10, and other pollutants in the surrounding areas, improving air quality, and making it safer for people to breathe. Furthermore, the SFTs have increased public awareness of the hazards of air pollution and the necessity for comprehensive actions to address the issue. SFTs have become a symbol of the fight against air pollution, inspiring many individuals to take action to save the environment.

After the success of SFTs in China, a large number of SFTs have been installed in various countries. As one of India's major environmental issues has been air pollution. The situation in Delhi is going worsen day by day. Delhi is the capital of the India and as well as the largest city of the country. Delhi marked fourth in the latest air quality index (AQI) rankings among the world's most polluted cities. As a result, the most serious problem in Delhi is how to regulate air pollution on a wide scale, therefore needed to be installed the SFTs all over the city. So in this paper, we propose a method to install the SFTs across Delhi city with the help of the circle packing problem.

The main objective of this paper is to understand how to address the problem of installing SFTs in an optimal manner. It suggests the total number of SFTs are required to reduce the air pollution in Delhi. For this, the problem is modeled as a nonlinear continuous optimization problem and then solved using 15 versions of Real Coded Genetic Algorithms (RCGAs), including a newly proposed RCGA, named Burr Crossover which is based on the Burr Distribution.

This paper is organized as follows: Section II provides an overview of the literature review. Section III explores the placement of smog free towers. Section IV presents the proposed approach for solving the problem. Section V describes the experimental setup. Section VI presents the results and provides a discussion. Section VII offers an analysis of the findings. Finally, concluding observations are presented in Section VIII.

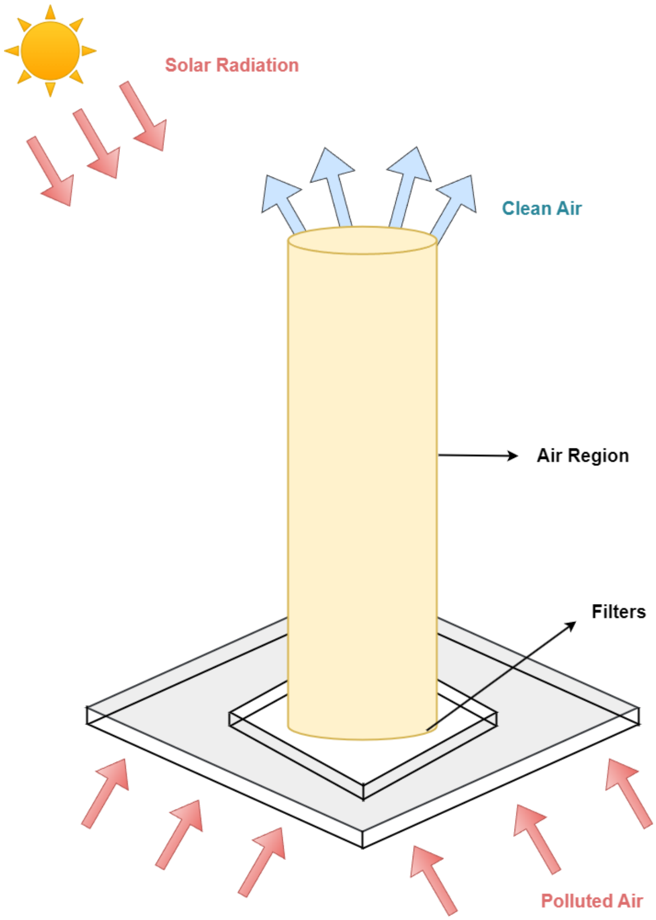
II. LITERATURE REVIEW

In many cities, the AQI is in the hazardous category, which is extremely damaging to both the environment and human health. It will be a wonderful victory for the environment if we can optimize some pollutants and transform the situation from a dangerous to a mild category.

The Solar-Assisted Large-Scale Cleaning System (SALSCS) is a large-scale air purification system that uses a mix of technologies such as solar energy, air filters, and electrostatic precipitation. The Avicennia Environmental Research Institute in China created it. On the other hand, the Smog Free Tower is a massive air purifier that removes tiny airborne particles, including smog, from the surrounding air using unique ionization technology. It was created by Daan Roosegaarde and his team of Dutch designers. In their particular applications, both methods have been effective in improving air quality and lowering pollution which is demonstrated in Figure 1.

The horizontal dimensions of SALSCS unit 1 are 43×60 $meter^2$, and the height is 60 $meter$, whereas the horizontal dimensions of SALSCS unit 2 are 18×18 $meter^2$, and the height is 16 $meter$. The coverage area of around 19.63 km^2 and 3 km of SALSCS and smog free tower, respectively.

Lan et al. [2] discussed the consequences of installing the SFTs. They adjust local people's willingness to pay (WTP) for decreased haze exposure by evaluating the price reactions of houses in SFT areas. They also shown a substantially higher proportion of high-priced housing responding to SFT operation than low-priced dwelling, implying an unbalanced distribution of welfare gains from improved air quality. Cao et al. [3], [4] described the field measurements done during three days in January 2017 in Xi'an (China) for the Solar-Assisted Large-Scale Cleaning System (SALSCS) and get good agreement for six of the eight measurement situations. In Pakistan, Saeed and colleagues initiated a proposal to create a 7.62-meter solar-powered smog-cleaning tower [1]. The project would give smog-free, pure air to 90, 000 nearby inhabitants. Qui et al. [5] suggested the hypothesis that SALSCS intervention and reduced ambient air pollution result in a lower whole-body burden of systemic inflammation as well as oxidative stress in an older population. Predicted that the SALSCS decreases the cardiopulmonary health consequences of air pollution and preserves public health by lowering oxidative stress and systemic inflammatory biomarkers. Huang et al. [6] studied the SALSCS simulation unit in Xi'an, China, and examined it with non-uniform sun irradiation. In Yancheng, China, a Solar Assisted Large Scale Cleaning System (SALSCS, 2nd generation) based on rain shower scavenging was designed and built to remove both PM2.5 and CO_2 from the atmosphere at the same time. The principle of particle filtering and CO_2 reduction are discussed by chen et al. [7]. Based on heterogeneous condensation, a novel filterless indoor air purifier for particulate matter and bioaerosol had been proposed by Yan et al. [8]. Ultra-fine particles develop and gather using heterogeneous condensation and supergravity technology, while chemical and UV disinfection swiftly disinfects bioaerosols. Cooper et al. [9] provided extends to our understanding of the possible impact on mortality from the widespread use of air purifiers in UK households. Although focused on UK homes, the findings are expected to represent other developed countries in Europe with similar housing types and ambient PM2.5 levels. Kwag et al. [10] implemented a "Housewife Cohort" and investigated the influence of PM exposure on the anemia index as well as the effect of air purifiers. Furthermore, the source and degree of PM exposure were determined by using data generated during cohort recruitment and varied exposure levels by monitoring PM exposure. The effectiveness of air cleaners in removing chemical components of PM2.5 from the indoor air of Tehran University of Medical Sciences dorms in Iran was evaluated by Fazlzadeh et al. [11] . They found that using indoor air purifiers might considerably lower the risk of carcinogenicity and non-carcinogenicity due to heavy metals, particularly in non-smoking environments. Li et al. [12] determined PM2.5 concentrations from several interior sources in the winter and summer and assessed the attenuation effect of indoor PM2.5 for various purification procedures. The analysis revealed



(a) SALSCS

(b)

FIGURE 1: (a) Solar-Assisted Large-Scale Cleaning System (SALSCS), (b) Smog Free Tower

that cooking fumes contributed the most to interior PM2.5, smoking contributed the least, and air purifiers benefit indoor PM2.5 management and population health management. Cooper et al. [13] investigated the influence of a commercially available air purifier on indoor PM2.5 concentrations and perceived indoor air quality, as well as to understand and illustrate how inhabitants employ portable air purifiers. In the literature, there are some paper in which the authors discuss the advantages and disadvantages of the SFTs which is demonstrated in the Table 1.

To reduce air pollution, governments in many different nations are aggressively promoting the use of electric vehicles. This topic is also being investigated by researchers through studies of traffic power networks and electric automobiles [19].

Since the clean air outlet by SFT flows circular region around the tower. Therefore, the installment of the SFTs is modeled by the Circle Packing Problem (CPP) and solved with the help of the Real Coded Genetic Algorithm (RCGA). With the help of this, we can find the number of SFTs required to install in the city.

Genetic Algorithms (GAs) [20], are the most versatile optimization techniques. They are population-based probabilistic technique to search for the global optimum solution. Also, they have the properties of self-adaption, self-organization. With these properties, GAs are used to solve a wide variety of optimization problems. RCGA have been widely used in areas such artificial intelligence [21], agriculture sector [22], pattern recognition [23], traveling salesman problem [24] and many more. Although they do not ensure the exact optimum value, but they try to give the best possible optimal feasible solution [25], [26]. RCGAs, are very well suited to continuous optimization problems with a large search space. The installation of SFTs is a continuous optimization problem with a large number of variables in the presence of constraints. Thus, this problem has numerous local and global optimal solutions. Therefore, RCGAs are best suited for this problem at hand. This is main reason for selecting the RCGAs to solve the above problem. In addition to RCGA, other metaheuristic algorithms such as PSO, DE, and ABC have demonstrated success across a diverse range of engineering applications [27]. RCGA works mainly with three operators: Selection, Crossover, and Mutation. Among these three operators, the crossover operator is one of the main operators. Several types of real-coded crossover operators have been proposed over the years. For example, Wright [28] proposed the first real coded crossover operator named as Heuristic Crossover (HX). In this crossover, only one offspring was produced and characterized as the convex linear combination of the parents, and gene positioning was chosen at random by exchanging the positions of their respective genes. Following that, various types of real coded crossover operators [29], [30], [31], [32], [33], [34] were developed to achieve faster convergence as well as greater accuracy and efficiency. We develop a novel real-coded crossover operator for this purpose.

TABLE 1: Existing work related to the Smog Free Towers

S. No.	Authors	Comments
1	Sija et al. [14]	In this study author discuss the construction of a pollution tower in Kolkata seems like a good way to stimulate the local economy and tourism surrounding the Victoria Memorial. Installing the smog tower in an optimal location will assist address the problem. This paper suggests a only one location for installing the smog tower, neglecting to address the broader need for smog towers across the entire city.
2	Sangam et al. [15]	The article presents an overview of techniques for removing smog and other pollutants from buildings and infrastructure. The study examines the difficulties associated with monitoring air quality and how the Internet of Things (IoT) can enhance monitoring in various environmental circumstances. This paper lacks clarity on the optimal locations for installing smog free towers and the extent to which they effectively control pollution.
3	Shazia et al. [16]	Using satellite technology, an appropriate site has been identified to install a Smog Tower to filter air. In addition author suggested, to maintain air quality regulations, the Forest Department, Parks and Horticulture Authorities, and others may collaborate to encourage the placement of Liquid Trees close to residential areas. This paper lacks a statistical analysis regarding the installation of smog-free towers.
4	Shubham et al. [17]	In this study authors revealed that the efficiency of the Smog Depleting Tower is 95.95%. This paper lacks a thorough mathematical analysis, which is essential for a comprehensive understanding and validation of the presented findings.
5	Elzbieta et al. [18]	This article thoroughly summarizes strategies for reducing smog and other pollutants that may be applied to infrastructure and buildings. Various approaches are examined, initially with the incorporation of plants as a biophilic solution through green roofs and façades. Another choice is proposed by author to install anti-smog towers with various technologies in position. Furthermore, concrete-related treatments include surface-modifying admixtures like activated carbon and nano titanium dioxide. This paper falls short in conducting a thorough and in-depth examination of smog-free tower technology.

III. PLACEMENT OF SMOG-FREE TOWERS

Since SFTs are made to improve the air quality in urban cities so that the people in that area get healthy air. The airflow from the SFTs circulates in a circular region, therefore the placement of smog free towers are modeled by the circle packing problem. In every two-dimensional container, the generic circle packing problem fitting a finite number of non-overlapping circles. There are three different categories of problems:

i. If size of the container has been determined, draw a circle with the maximum area that will fit into the remaining vacant space.

ii. If size of the container has been determined, find the maximum number of circles of same size that will fit within the container.

iii. If the number of circles has been determined, calculate the size of the container so that the gap between each and every circle is as small as possible.

This paper is concerned with the second type and can be modeled as an optimization problem. Mathematically, under the 2-dimensional coordinate system, let the container be a rectangle and the length and breadth are l and b respectively. Let there be n given circles $c_1, c_2, \ldots, c_n$ of radii r_i, $i = 1, 2, \ldots, n$.

This is subject to two families of constraints:

a. The boundary constraints restrict the given n circles to lie inside the container. Mathematically,

$$a_0 + r_i \leq x_i \leq a_0 + l - r_i$$
$$b_0 + r_i \leq y_i \leq b_0 + b - r_i$$

b. The non-overlapping constraint restricts all the n circles inside the container should be non-overlapping. Mathematically,

$$\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \geq r_i + r_j \quad \text{for} \quad i, j = 1, 2, \ldots, n \quad \text{with} \quad i < j \quad \text{and} \quad i \neq j$$

where (x_i, y_i) and (x_j, y_j) are the centers and r_i and r_j are the radii of the circle c_i and c_j, respectively. (a_0, b_0) be the initial vertex of the container. Even while the placement of Smog Free Towers (SFTs) and the circle packing problem have some similarities, they are not the same. But we may compare the two ideas to comprehend the SFT placement's optimization aspect better. The city may be a container for SFT deployment, and the range of each SFT is a circular area. The objective is to arrange the SFTs so that they maximize coverage throughout the city while minimizing waste. This is comparable to the circle packing problem's objective of reducing the number of circles required to fill a container. Each circle's center corresponds to the location of an SFT and its radius to the area it covers. The number of circles necessary to cleanse the air across the city adequately can be reduced by carefully planning the locations and coverage radii of the SFTs. This optimization strategy aims to minimize the wastage of resources and space. Several of the issues listed in the preceding response, including pollution hotspots, airflow patterns, urban design, and data-driven analysis, can be considered to accomplish this objective. These factors aid in determining the best locations for SFTs, guaranteeing complete coverage of regions subject to pollution while reducing the number of SFTs needed. By adopting an optimization mindset motivated by the circle packing problem, we can achieve an efficient and effective placement of SFTs across the city, minimizing waste and maximizing the air purifying benefit.

IV. THE PROPOSED METHOD FOR THE PROBLEM

In this section, the circle packing problem is used as a model for Installing the SFTs, and Real Coded Genetic Algorithms (RCGAs) are used to solve the problem. Since the crossover operator is one of the primary operators in RCGAs, in order to introduce a novel real-coded crossover operator based on the following properties of the Burr XII Distribution.

Flexibility: The Burr XII distribution is a highly adaptable distribution that may be used to replicate a wide range of data sets. It might be skewed or symmetrical, and it can be unimodal or multimodal.

Goodness-of-fit: Numerous real-world data sets have been proven to replicate well with the Burr XII distribution, including those from banking, engineering, and environmental sciences.

Modeling extreme events: The Burr XII distribution is particularly useful for replicating exceptional and high-value losses or gains. This is because to its long tail, which allows it to capture additional severe events than other frequently used distributions.

Based on the above properties of Burr XII distribution, we developed a Burr Crossover Operator. The density function of the Burr XII distribution is:

$$f(x) = abc^{-a}\frac{x^{a-1}}{\left(1+\frac{x^a}{c^a}\right)^{b+1}} \quad ; x \geq 0$$

and the distribution function of the given distribution is:

$$F(x) = 1 - \frac{1}{\left(1+\frac{x^a}{c^a}\right)^{b}} \quad ; x \geq 0$$

Where a, b are the shape parameters where $a > 0, b > 0$. Also, $c(c > 0)$ is the scale parameter. If both $a = b = 1$, then Burr Distribution becomes Log-Logistic Distribution, sometimes referred to as Fisk Distribution. If $a = 1$, then Burr XII Distribution becomes the Pareto type II Distribution. As $b \to \infty$, it becomes Weibull Distribution. The inverse Burr XII Distribution is known as the Burr type III Distribution. The density function of Burr XII Distribution when a is fixed, and the value b is varied, and when the value of b is fixed and varies, the value of a is simultaneously shown in Figures 2, and 3. When the shape parameters are fixed, the use of a smaller scale parameter value leads to offspring that are farther away from the parents, while a larger scale parameter value produces offspring that are closer to the parents. The Figures 2, and 3 clearly illustrates that the choice of the shape parameter value is a critical factor in determining the distribution of the Burr Distribution. This is because the Burr Distribution can exhibit both symmetric and skewed forms, which are determined by the value of the shape parameter.

A pair of offspring $O^1 = (o_1^1, o_2^1, \ldots, o_n^1)$, and $O^2 = (o_1^2, o_2^2, \ldots, o_n^2)$ is generated from a pair of parents $P^1 = (p_1^1, p_2^1, \ldots, p_n^1)$, and $P^2 = (p_1^2, p_2^2, \ldots, p_n^2)$ as follows:

Step 1: Generate a uniformly distributed random number z_i in $(-1, 1)$.

Step 2: Calculate the value of δ_i where,

$$\delta_i = \begin{cases} \left[\frac{ab}{u_i \cdot c^a} \exp\left((b+1)z_i\right)\right]^{\frac{1}{1+ab}} & ; z_i < 0 \\ \left[\frac{ab}{u_i \cdot c^a} \exp\left(-(b+1)z_i\right)\right]^{\frac{1}{1+ab}} & ; \text{otherwise} \end{cases}$$

where, u_i are the random numbers following Burr XII Distribution.

Step 3: The offsprings are generated and defined in this manner:

$$o_i^1 = \delta_i \cdot p_i^1 + (1-\delta_i) \cdot p_i^2 \quad \forall \quad i = 1, 2, \ldots, n$$
$$o_i^2 = \delta_i \cdot p_i^2 + (1-\delta_i) \cdot p_i^1 \quad \forall \quad i = 1, 2, \ldots, n$$

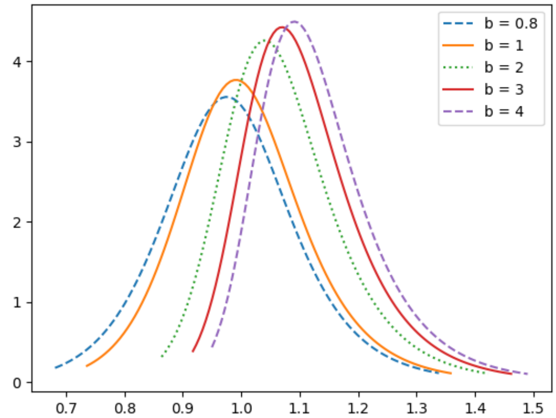


FIGURE 2: Pdf of Burr XII Distribution for fixed $a = 15$

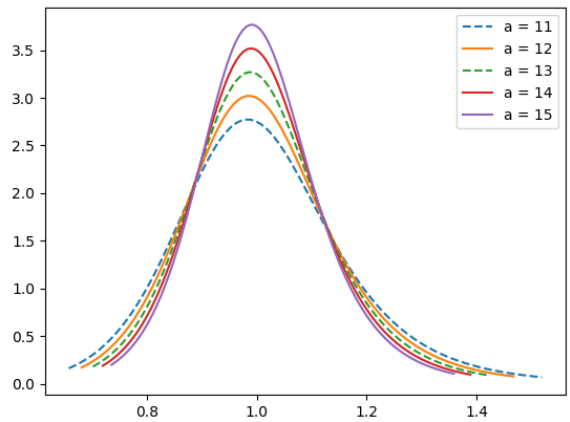


FIGURE 3: Pdf of Burr XII Distribution for fixed $b = 1$

V. EXPERIMENTAL SETUP

CEC-2017 benchmark problem set has been selected to test the performance of the proposed real-coded crossover operator. To make a comparison with four existing real-coded crossover operators, namely, Logistic Crossover (Log-X) [35], Exponentiated Pareto Distribution Crossover (EPX) [36], Laplace Crossover (LX) [37], and Weibull Crossover (WX) [38]. These five real-coded crossover operators have been used with the existing real-coded mutation operators, namely, Direction-based Exponential Mutation (DEM) [39], Makinen, Periaux, and Toivanen Mutation (MPTM) [40], and Polynomial Mutation (PLYM) [41]. The population size is taken 100 for all the RCGAs. To evaluate the effectiveness and compatibility, thirty independent runs are conducted with each RCGA. Mean, standard deviation, and best and worst of objective function values are considered in the final result. The maximum number of generations is taken as 1000 and considered as the stopping criteria for all the RCGAs. The Tournament Selection operator is used as the selection operator. The crossover probability (P_c) and mutation probability (P_m) are taken as 0.9 and 0.05, respectively which is demonstrated in Table 2. Elitism with size one is applied in the whole process. The decision variables are taken as 10, 30, 50, and 100. For BX, a, b, and c are taken as $15, 0.8$, and 1, respectively. For Log-X, location and scale parameters are taken as 0 and 5, respectively. Location and scale parameters are considered 2 and 5, respectively, in the EPX. For LX, scale and location parameters are considered as 1 and 0, respectively. In WX, shape and scale parameters are taken as 5 and 1, respectively. Distribution of mutation is taken 4 in MPTM. For PLYM, the fixed value of a parameter is taken as 20. The value of parameters is kept fixed during all runs. All the RCGAs are implemented in Python, and experiments are done on a 2.10 GHz machine with 96 GB RAM.

TABLE 2: The mean, median and standard deviation of the objective function value for BX-DEM, BX-MPTM and BX-PLYM by taking various value of P_c and P_m

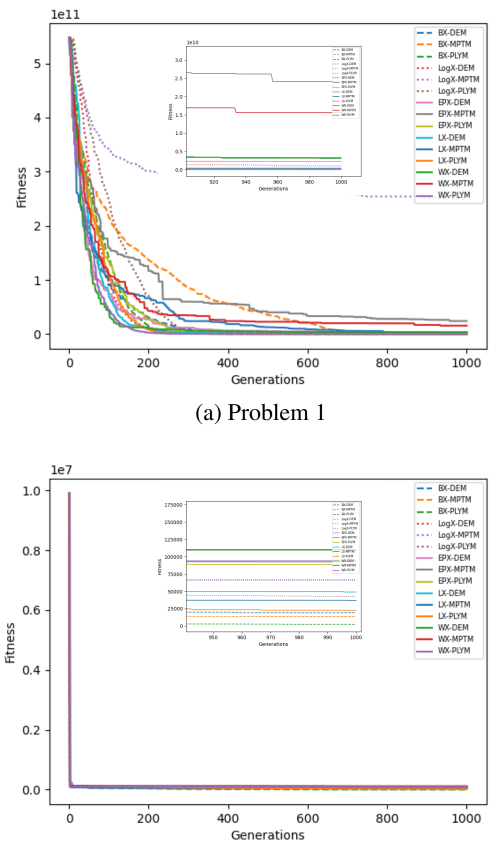
S. No.	P_c	P_m	BX-DEM			BX-MPTM			BX-PLYM		
			Mean	Median	Stdev	Mean	Median	Stdev	Mean	Median	Stdev
1	0.3	0.05	4.88E+02	4.79E+02	2.13E+01	1.53E+03	1.51E+03	1.87E+02	4.80E+02	4.76E+02	1.77E+01
2	0.3	0.1	5.16E+02	4.96E+02	3.38E+01	1.21E+03	1.15E+03	2.81E+02	4.81E+02	4.77E+02	1.49E+01
3	0.6	0.05	4.93E+02	4.81E+02	2.88E+01	**5.46E+02**	6.39E+02	7.86E+01	4.84E+02	4.76E+02	2.09E+01
4	0.6	0.1	5.19E+02	5.10E+02	3.94E+01	6.80E+02	6.17E+02	1.48E+02	4.86E+02	4.80E+02	2.98E+01
5	0.9	0.05	**4.81E+02**	4.79E+02	9.40E+00	6.51E+02	5.44E+02	5.00E+01	**4.69E+02**	4.75E+02	2.07E+01
6	0.9	0.1	5.20E+02	5.18E+02	2.94E+01	5.81E+02	5.72E+02	5.03E+01	4.84E+02	4.78E+02	2.99E+01

TABLE 3: Operators used in this study

	Operators used			
RCGA version	**Selection**	**Crossover**	**Mutation**	**Elitism**
BX-DEM	Tournament	Burr	DEM	Yes
BX-MPTM	Tournament	Burr	MPTM	Yes
BX-PLYM	Tournament	Burr	Polynomial	Yes
LogX-DEM	Tournament	Logistic	DEM	Yes
LogX-MPTM	Tournament	Logistic	MPTM	Yes
LogX-PLYM	Tournament	Logistic	Polynomial	Yes
EPX-DEM	Tournament	EPX	DEM	Yes
EPX-MPTM	Tournament	EPX	MPTM	Yes
EPX-PLYM	Tournament	EPX	Polynomial	Yes
LX-DEM	Tournament	Laplace	DEM	Yes
LX-MPTM	Tournament	Laplace	MPTM	Yes
LX-PLYM	Tournament	Laplace	Polynomial	Yes
WX-DEM	Tournament	Weibull	DEM	Yes
WX-MPTM	Tournament	Weibull	MPTM	Yes
WX-PLYM	Tournament	Weibull	Polynomial	Yes

VI. RESULTS AND DISCUSSION

In this section, a comparison of proposed operators BX-DEM, BX-MPTM, and BX-PLYM is made with the other operators LogX-DEM, LogX-MPTM, LogX-PLYM, EPX-DEM, EPX-MPTM, EPX-PLYM, LX-DEM, LX-MPTM, LX-PLYM, WX-DEM, WX-MPTM, WX-PLYM. The comparisons are done based on the mean, standard deviation, and



(a) Problem 1

(b) Problem 3

FIGURE 4: Convergence graph for Unimodal functions of CEC-2017 benchmark problem

best and worst. Burr crossover operator performed better than all the other four crossover operators on CEC-2017 problems. Table 3 represents the summary of the operators used in this study.

The results are shown in Tables 4, 5, 6, and 7 when the dimensions are 10, 30, 50, and 100, respectively. These tables use average (mean), standard deviation (stdev), and best and worst of the objective function value for the 30 runs for all problems. Tables 8 summarizes Friedman mean ranking test for all the 15 RCGAs considered here for all the dimensions 10, 30, 50, and 100 and their Friedman mean ranking is shown in Figure 8.

The benchmark functions of CEC-2017 and divides into four groups: Unimodal, Multimodal, Hybrid, and Composite. Unimodal functions are problems 1 to 3. Multimodal functions are problems 4 through 10. Problems 11 to 20 are classified as Hybrid functions, whereas problems 21 to 30 are classified as Composite functions.

For dimensions 10, 30, 50, and 100, BX-PLYM outperforms all other RCGAs in unimodal functions. The convergence graph of the unimodal function is presented in Figure 9 and their Friedman mean ranking test is provided in Figure 4. As with the multimodal functions, BX-MPTM performs

TABLE 4: The mean, standard deviation, best and worst of the objective function value for problem no. 1 to 10 (with dimension = 10)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P1	Mean	5.856E+03	**2.195E+03**	4.258E+03	5.450E+09	8.490E+10	7.090E+10	4.090E+06	1.300E+08	8.150E+05	1.084E+03	1.903E+06	7.104E+04	1.368E+06	4.964E+07	9.524E+05
	Stdev	6.735E+03	**1.796E+03**	4.438E+03	2.620E+10	2.830E+10	2.790E+09	3.330E+06	6.480E+07	4.480E+05	6.537E+03	1.618E+06	4.169E+04	8.102E+05	2.355E+07	4.863E+05
	Best	3.700E+02	**5.107E+02**	1.659E+03	1.550E+10	1.940E+10	2.130E+10	5.970E+05	1.380E+07	1.800E+05	1.425E+03	3.564E+05	1.240E+04	3.282E+05	8.062E+06	2.664E+05
	Worst	2.694E+04	**9.040E+03**	2.102E+04	9.240E+10	1.240E+11	1.190E+11	1.680E+07	3.210E+08	2.150E+06	2.857E+04	6.499E+06	2.016E+05	3.634E+06	8.981E+07	2.241E+06
	Rank	3	1	2	13	15	14	10	12	6	4	9	5	8	11	7
P2	Mean	2.550E+02	2.000E+02	**2.000E+02**	1.900E+12	2.690E+12	1.710E+12	2.940E+05	3.140E+06	2.330E+02	2.490E+02	3.020E+02	2.140E+02	2.660E+02	1.500E+03	2.000E+02
	Stdev	1.930E+02	1.090E-01	**1.800E-04**	6.110E+11	7.020E+12	3.930E+12	5.850E+05	1.670E+07	1.190E+02	1.140E+02	1.980E+02	6.530E+01	2.740E+02	2.850E+03	5.240E-02
	Best	2.000E+02	2.000E+02	**2.000E+02**	5.830E+08	5.500E+07	2.760E+07	2.300E+02	6.810E+02	2.000E+02	2.000E+02	2.000E+02	2.000E+02	2.000E+02	2.190E+02	2.000E+02
	Worst	1.260E+03	2.010E+02	**2.000E+02**	3.090E+13	3.700E+13	2.060E+13	2.380E+06	9.180E+07	8.230E+02	6.310E+02	1.070E+03	5.540E+02	1.680E+03	1.370E+04	2.000E+02
	Rank	7	2	1	14	15	13	11	12	5	6	9	4	8	10	3
P3	Mean	6.305E+02	3.061E+02	**3.000E+02**	1.746E+04	1.809E+04	1.676E+04	9.262E+03	9.187E+03	8.470E+03	3.042E+02	3.125E+02	3.008E+02	6.113E+03	8.461E+03	3.507E+02
	Stdev	2.715E+02	1.114E+01	**1.308E-01**	3.771E+03	2.928E+03	3.582E+03	3.011E+03	2.848E+03	2.827E+03	1.108E+01	1.082E+01	1.105E+00	3.211E+03	2.901E+03	5.732E+01
	Best	3.004E+02	3.000E+02	**3.000E+02**	9.571E+03	1.086E+04	9.970E+03	4.546E+03	4.039E+03	1.633E+03	3.000E+02	3.013E+02	3.001E+02	1.467E+03	3.719E+03	3.070E+02
	Worst	1.193E+03	3.518E+02	**3.005E+02**	2.117E+04	2.112E+04	2.051E+04	1.434E+04	1.717E+04	1.664E+04	3.599E+02	3.457E+02	3.061E+02	1.177E+04	1.638E+04	5.752E+02
	Rank	7	4	1	14	15	13	12	11	10	3	5	2	8	9	6
P4	Mean	4.085E+02	4.172E+02	4.037E+02	9.698E+02	1.191E+03	8.902E+02	4.050E+02	4.099E+02	4.066E+02	4.060E+02	**4.018E+02**	4.036E+02	4.042E+02	4.050E+02	4.043E+02
	Stdev	1.690E+01	2.997E+01	2.339E+00	3.959E+02	4.412E+02	2.078E+02	2.865E+00	1.369E+01	1.184E+01	1.233E+01	**2.157E+00**	1.811E+00	2.218E+00	2.415E+00	1.196E+01
	Best	4.000E+02	4.000E+02	4.000E+02	4.278E+02	6.072E+02	5.247E+02	4.000E+02	4.009E+02	4.000E+02	4.000E+02	**4.000E+02**	4.000E+02	4.000E+02	4.004E+02	4.000E+02
	Worst	4.700E+02	4.742E+02	4.062E+02	1.709E+03	1.982E+03	1.259E+03	4.095E+02	4.683E+02	4.681E+02	4.704E+02	**4.057E+02**	4.057E+02	4.068E+02	4.073E+02	4.664E+02
	Rank	10	12	3	14	15	13	7	11	9	8	1	2	4	6	5
P5	Mean	5.226E+02	**5.125E+02**	5.169E+02	5.928E+02	5.906E+02	5.766E+02	5.213E+02	5.304E+02	5.224E+02	5.277E+02	5.278E+02	5.461E+02	5.554E+02	5.247E+02	5.572E+02
	Stdev	1.140E+01	**5.882E+00**	8.405E+00	1.756E+01	1.482E+01	1.248E+01	7.479E+00	8.076E+00	6.823E+00	1.046E+01	8.715E+00	8.424E+00	9.292E+00	5.669E+00	1.329E+01
	Best	5.109E+02	**5.056E+02**	5.031E+02	5.588E+02	5.453E+02	5.343E+02	5.103E+02	5.148E+02	5.092E+02	5.049E+02	5.100E+02	5.298E+02	5.368E+02	5.142E+02	5.288E+02
	Worst	5.539E+02	**5.286E+02**	5.398E+02	6.317E+02	6.119E+02	5.953E+02	5.385E+02	5.517E+02	5.408E+02	5.507E+02	5.517E+02	5.656E+02	5.716E+02	5.351E+02	5.825E+02
	Rank	5	1	2	15	14	13	3	9	4	7	8	10	11	6	12
P6	Mean	6.204E+02	**6.005E+02**	6.385E+02	6.698E+02	6.670E+02	6.663E+02	6.017E+02	6.089E+02	6.036E+02	6.084E+02	6.030E+02	6.232E+02	6.248E+02	6.031E+02	6.008E+02
	Stdev	1.709E+01	**4.441E-01**	1.173E+01	1.240E+01	1.404E+01	1.482E+01	1.535E+00	5.074E+00	4.391E+00	1.056E+01	2.191E+00	1.055E+01	9.643E+00	1.402E+00	1.257E+00
	Best	6.012E+02	**6.002E+02**	6.203E+02	6.432E+02	6.371E+02	6.316E+02	6.003E+02	6.027E+02	6.003E+02	6.000E+02	6.005E+02	6.084E+02	6.082E+02	6.012E+02	6.001E+02
	Worst	6.561E+02	**6.006E+02**	6.603E+02	6.829E+02	6.826E+02	6.793E+02	6.070E+02	6.224E+02	6.181E+02	6.406E+02	6.086E+02	6.506E+02	6.455E+02	6.066E+02	6.070E+02
	Rank	9	1	12	15	14	13	3	8	6	7	4	10	11	5	2
P7	Mean	7.334E+02	**7.231E+02**	7.334E+02	7.854E+02	7.729E+02	7.802E+02	7.292E+02	7.334E+02	7.256E+02	7.271E+02	7.302E+02	7.294E+02	7.248E+02	7.283E+02	7.242E+02
	Stdev	7.000E+00	**4.410E+00**	8.019E+00	1.438E+01	1.371E+01	1.195E+01	8.217E+00	6.241E+00	6.199E+00	4.949E+00	6.622E+00	6.626E+00	4.254E+00	5.464E+00	5.760E+00
	Best	7.219E+02	**7.167E+02**	7.161E+02	7.589E+02	7.499E+02	7.451E+02	7.169E+02	7.231E+02	7.156E+02	7.175E+0 2	7.207E+02	7.195E+02	7.153E+02	7.194E+02	7.173E+02
	Worst	7.487E+02	**7.352E+02**	7.463E+02	8.123E+02	8.052E+02	8.051E+02	7.577E+02	7.455E+02	7.439E+02	7.359E+02	7.433E+02	7.485E+02	7.317E+02	7.441E+02	7.368E+02
	Rank	10	1	11	15	13	14	7	11	4	5	9	8	3	6	2
P8	Mean	8.129E+02	8.134E+02	8.260E+02	8.422E+02	8.373E+02	8.369E+02	8.164E+02	8.192E+02	8.187E+02	8.204E+02	8.167E+02	8.226E+02	**8.119E+02**	8.162E+02	8.240E+02
	Stdev	4.884E+00	3.633E+00	7.670E+00	7.813E+00	1.058E+01	4.305E+00	6.243E+00	5.103E+00	7.388E+00	5.428E+00	4.220E+00	4.824E+00	**6.087E+00**	5.364E+00	7.232E+00
	Best	8.030E+02	8.060E+02	8.170E+02	8.271E+02	8.204E+02	8.297E+02	8.044E+02	8.112E+02	8.060E+02	8.099E+02	8.079E+02	8.159E+02	**8.031E+02**	8.055E+02	8.101E+02
	Worst	8.239E+02	8.219E+02	8.488E+02	8.626E+02	8.565E+02	8.481E+02	8.312E+02	8.347E+02	8.390E+02	8.309E+02	8.250E+02	8.349E+02	**8.231E+02**	8.267E+02	8.379E+02
	Rank	2	3	12	15	14	13	5	8	7	9	6	10	1	4	11
P9	Mean	9.103E+02	9.551E+02	1.010E+03	1.388E+03	1.501E+03	1.479E+03	9.003E+02	9.025E+02	9.000E+02	9.013E+02	9.173E+02	9.511E+02	9.000E+02	9.006E+02	**9.000E+02**
	Stdev	1.768E+01	3.267E+01	9.223E+01	1.603E+02	1.701E+02	1.120E+02	3.111E-01	2.848E+00	4.845E-02	3.324E+00	2.329E+01	7.826E+01	4.507E-02	3.139E-01	**2.945E-02**
	Best	9.000E+02	9.100E+02	9.000E+02	9.606E+02	9.681E+02	1.238E+03	9.000E+02	9.003E+02	9.000E+02	9.000E+02	9.000E+02	9.000E+02	9.000E+02	9.001E+02	**9.000E+02**
	Worst	9.862E+02	1.021E+03	1.126E+03	1.725E+03	1.809E+03	1.658E+03	9.011E+02	9.151E+02	9.000E+02	9.162E+02	9.778E+02	1.146E+03	9.002E+02	9.013E+02	**9.001E+02**
	Rank	8	11	12	13	15	14	4	7	2	6	9	10	3	5	1
P10	Mean	1.710E+03	1.641E+03	1.880E+03	2.548E+03	2.554E+03	2.354E+03	1.941E+03	1.981E+03	1.891E+03	**1.401E+03**	1.450E+03	1.613E+03	1.953E+03	2.038E+03	1.787E+03
	Stdev	2.383E+02	1.418E+02	2.304E+02	2.768E+02	2.944E+02	3.743E+02	2.756E+02	2.348E+02	2.727E+02	**1.874E+02**	2.865E+02	2.012E+02	2.527E+02	2.193E+02	3.053E+02
	Best	1.018E+03	1.359E+03	1.370E+03	2.002E+03	1.629E+03	1.613E+03	1.198E+03	1.564E+03	1.288E+03	**1.043E+03**	1.022E+03	1.203E+03	1.435E+03	1.448E+03	1.163E+03
	Worst	2.147E+03	1.953E+03	2.386E+03	3.053E+03	3.010E+03	3.052E+03	2.368E+03	2.460E+03	2.309E+03	**1.706E+03**	2.153E+03	2.041E+03	2.365E+03	2.526E+03	2.315E+03
	Rank	5	4	7	14	15	13	9	11	8	1	2	3	10	12	6

TABLE 4 (continued): The mean, standard deviation, best and worst of the objective function value for problem no. 11 to 20 (with dimension = 10)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P11	Mean	1.119E+03	1.110E+03	1.110E+03	4.411E+03	4.301E+03	6.035E+03	1.111E+03	1.113E+03	1.111E+03	1.111E+03	1.110E+03	1.134E+03	**1.105E+03**	1.109E+03	1.139E+03
	Stdev	1.088E+01	4.339E+00	4.481E+00	3.225E+03	2.978E+03	5.749E+03	2.277E+01	4.975E+00	5.982E+00	7.266E+00	4.406E+00	1.508E+01	**1.234E+00**	2.190E+00	1.396E+01
	Best	1.104E+03	1.102E+03	1.105E+03	1.203E+03	1.259E+03	1.343E+03	1.101E+03	1.105E+03	1.102E+03	1.102E+03	1.103E+03	1.110E+03	**1.103E+03**	1.104E+03	1.119E+03
	Worst	1.146E+03	1.118E+03	1.123E+03	1.745E+04	1.301E+04	2.861E+04	1.231E+03	1.127E+03	1.128E+03	1.133E+03	1.125E+03	1.168E+03	**1.110E+03**	1.113E+03	1.171E+03
	Rank	10	4	3	14	13	15	7	9	6	8	5	11	1	2	12
P12	Mean	9.087E+04	1.481E+04	**6.168E+03**	2.920E+08	6.280E+08	9.210E+07	9.649E+05	4.650E+05	8.197E+04	7.831E+03	8.459E+03	6.658E+03	2.061E+05	3.849E+04	3.156E+04
	Stdev	1.761E+05	1.682E+04	**1.038E+03**	3.860E+08	5.800E+08	1.430E+08	1.341E+06	3.340E+05	6.837E+04	4.509E+03	3.329E+03	1.727E+03	6.003E+05	2.858E+04	2.068E+04
	Best	4.464E+03	4.321E+03	**4.511E+03**	6.730E+06	2.410E+07	3.380E+06	3.383E+04	2.690E+04	1.361E+04	1.699E+03	2.434E+03	3.348E+03	9.108E+03	7.550E+03	7.581E+03
	Worst	7.009E+05	7.311E+04	**8.180E+03**	1.640E+09	2.460E+09	5.610E+08	6.300E+06	1.340E+06	2.964E+05	2.383E+04	1.832E+04	1.081E+04	3.341E+06	1.296E+05	9.300E+04
	Rank	9	5	1	14	15	13	12	11	8	3	4	2	10	7	6
P13	Mean	1.109E+04	1.964E+04	1.306E+04	2.500E+08	2.060E+08	2.770E+07	1.295E+04	1.432E+04	1.373E+04	1.141E+04	1.049E+04	**9.039E+03**	1.163E+04	1.184E+04	1.166E+04
	Stdev	4.744E+03	4.867E+03	3.926E+03	3.240E+08	2.480E+08	5.730E+07	3.954E+03	5.835E+03	4.412E+03	5.937E+03	4.103E+03	**3.247E+03**	2.555E+03	2.759E+03	3.170E+03
	Best	3.350E+03	5.098E+03	3.281E+03	1.370E+06	1.890E+05	2.140E+04	6.977E+03	6.349E+03	6.772E+03	4.617E+03	4.999E+03	**4.008E+03**	6.514E+03	7.279E+03	7.182E+03
	Worst	1.991E+04	2.662E+04	2.334E+04	1.270E+09	1.400E+09	2.360E+08	2.090E+04	3.140E+04	2.349E+04	3.087E+04	2.328E+04	**1.868E+04**	1.758E+04	1.820E+04	1.897E+04
	Rank	3	12	9	15	14	13	8	11	10	4	2	1	5	7	6
P14	Mean	5.600E+03	1.423E+03	5.463E+03	1.109E+05	9.159E+04	9.094E+04	1.544E+03	1.452E+03	1.467E+03	1.445E+03	**1.418E+03**	1.537E+03	1.433E+03	1.428E+03	1.113E+04
	Stdev	3.729E+03	4.858E+00	3.152E+03	1.624E+05	9.866E+04	2.009E+05	1.832E+02	1.110E+01	3.447E+01	4.457E+01	**1.212E+01**	1.393E+02	7.199E+00	3.415E+00	2.614E+03
	Best	1.497E+03	1.408E+03	1.564E+03	1.612E+03	2.495E+03	2.560E+03	1.428E+03	1.426E+03	1.425E+03	1.403E+03	**1.405E+03**	1.418E+03	1.424E+03	1.419E+03	6.586E+03
	Worst	1.268E+04	1.434E+03	1.051E+04	6.467E+05	3.689E+05	1.094E+06	2.305E+03	1.479E+03	1.546E+03	1.565E+03	**1.459E+03**	1.929E+03	1.465E+03	1.433E+03	1.916E+04
	Rank	11	2	10	15	14	13	9	6	7	5	1	8	4	3	12
P15	Mean	1.505E+03	2.323E+03	2.021E+03	2.650E+04	3.310E+04	3.040E+04	1.642E+03	1.673E+03	1.556E+03	2.354E+03	2.797E+03	2.920E+32	2.369E+03	1.509E+03	**1.504E+03**
	Stdev	4.909E+00	1.108E+03	2.238E+02	1.550E+04	1.220E+04	1.540E+04	2.129E+02	5.083E+02	5.701E+01	1.086E+03	1.323E+03	1.025E+03	8.513E+02	3.531E+00	**6.777E+00**
	Best	1.500E+03	1.542E+03	1.667E+03	4.810E+03	7.260E+03	4.470E+03	1.503E+03	1.511E+03	1.507E+03	1.504E+03	1.507E+03	1.509E+03	1.550E+03	1.503E+03	**1.500E+03**
	Worst	1.521E+03	7.873E+03	2.619E+03	4.980E+04	4.780E+04	4.950E+04	2.390E+03	4.308E+03	1.749E+03	5.044E+03	5.663E+03	4.831E+03	4.987E+03	1.516E+03	**1.538E+03**
	Rank	2	8	7	13	15	14	5	6	4	9	11	12	10	3	1
P16	Mean	1.877E+03	1.985E+03	**1.609E+03**	2.280E+03	2.200E+03	2.460E+03	1.634E+03	1.664E+03	1.673E+03	1.890E+03	1.939E+03	1.915E+03	1.639E+03	1.619E+03	1.934E+03
	Stdev	1.152E+02	9.920E+01	**2.243E+01**	1.430E+02	1.420E+02	1.174E+02	3.622E+01	6.638E+01	8.287E+01	1.054E+02	4.534E+01	7.869E+01	3.862E+01	1.091E+01	7.966E+01
	Best	1.601E+03	1.838E+03	**1.601E+03**	1.950E+03	1.890E+03	1.933E+03	1.602E+03	1.610E+03	1.601E+03	1.601E+03	1.839E+03	1.719E+03	1.602E+03	1.604E+03	1.837E+03
	Worst	2.072E+03	2.233E+03	**1.719E+03**	2.470E+03	2.480E+03	2.442E+03	1.771E+03	1.867E+03	1.856E+03	1.977E+03	1.976E+03	1.997E+03	1.804E+03	1.652E+03	2.135E+03
	Rank	7	12	1	15	13	14	3	5	6	8	11	9	4	2	10
P17	Mean	1.744E+03	**1.729E+03**	1.783E+03	1.779E+03	1.784E+03	1.764E+03	1.925E+03	1.781E+03	1.806E+03	1.866E+03	1.734E+03	1.936E+03	1.826E+03	1.942E+03	1.906E+03
	Stdev	3.102E+01	**1.297E+01**	4.557E+01	4.358E+01	4.303E+01	1.897E+01	1.017E+02	3.543E+01	6.519E+01	1.028E+02	1.056E+01	8.523E+01	6.754E+01	5.118E+01	9.423E+01
	Best	1.723E+03	**1.702E+03**	1.724E+03	1.737E+03	1.722E+03	1.716E+03	1.799E+03	1.727E+03	1.751E+03	1.755E+03	1.701E+03	1.798E+03	1.782E+03	1.818E+03	1.768E+03
	Worst	1.864E+03	**1.760E+03**	1.862E+03	1.889E+03	1.921E+03	1.810E+03	2.213E+03	1.873E+03	2.014E+03	2.041E+03	1.741E+03	2.065E+03	1.907E+03	2.005E+03	2.048E+03
	Rank	3	1	7	5	8	4	13	6	9	11	2	14	10	15	12
P18	Mean	**3.764E+03**	7.533E+03	4.150E+03	1.060E+08	1.310E+08	1.232E+07	1.273E+04	3.638E+04	1.112E+04	1.561E+04	1.014E+04	9.185E+03	4.817E+03	5.202E+03	1.283E+04
	Stdev	**2.568E+03**	5.497E+03	2.897E+03	1.670E+08	1.520E+08	2.530E+07	1.039E+04	4.259E+04	3.233E+04	2.338E+04	7.931E+03	6.813E+03	3.366E+03	4.304E+03	1.124E+04
	Best	**1.873E+03**	1.958E+03	1.829E+03	1.900E+05	1.670E+05	1.251E+04	2.198E+03	2.770E+03	2.120E+03	1.908E+03	1.822E+03	1.836E+03	1.830E+03	1.914E+03	1.975E+03
	Worst	**1.159E+04**	2.743E+04	1.350E+04	6.070E+08	5.080E+08	1.060E+08	4.589E+04	1.896E+05	1.815E+05	1.226E+05	3.160E+04	2.802E+04	1.428E+04	1.705E+04	4.356E+04
	Rank	1	5	2	14	15	13	9	12	8	11	7	6	3	4	10
P19	Mean	3.819E+03	**3.030E+03**	5.127E+03	5.510E+07	6.950E+07	3.580E+06	4.060E+03	3.962E+03	3.952E+03	5.096E+03	4.253E+03	4.946E+03	5.143E+03	3.995E+03	4.225E+03
	Stdev	1.169E+03	**1.929E+03**	1.829E+03	6.240E+07	1.380E+08	4.790E+07	1.834E+03	1.486E+03	1.210E+03	2.749E+03	2.303E+03	2.485E+03	2.092E+03	1.599E+03	1.182E+03
	Best	1.905E+03	**1.903E+03**	2.448E+03	3.460E+05	1.090E+05	4.120E+05	1.921E+03	1.917E+03	1.908E+03	1.965E+03	1.908E+03	1.933E+03	1.917E+03	1.975E+03	2.811E+03
	Worst	6.230E+03	**1.214E+04**	1.062E+04	2.230E+08	4.700E+08	1.860E+08	9.331E+03	8.563E+03	8.305E+03	1.164E+04	9.594E+03	9.370E+03	9.484E+03	8.513E+03	6.673E+03
	Rank	2	1	11	14	15	13	6	4	3	10	8	9	12	5	7
P20	Mean	2.031E+03	2.035E+03	2.136E+03	2.176E+03	2.109E+03	2.078E+03	2.240E+03	2.168E+03	**2.028E+03**	2.081E+03	2.219E+03	3.200E+03	2.410E+03	2.350E+03	2.753E+03
	Stdev	2.232E+01	9.316E+01	2.471E+01	6.345E+01	5.077E+01	7.295E+01	2.050E+01	6.059E+01	**3.987E+01**	7.927E+01	7.171E+01	1.002E+02	1.045E+02	1.005E+02	1.085E+02
	Best	2.001E+03	2.033E+03	2.055E+03	2.030E+03	2.031E+03	2.021E+03	2.230E+03	2.226E+03	**2.009E+03**	2.005E+03	2.031E+03	3.025E+03	2.304E+03	2.205E+03	2.647E+03
	Worst	2.120E+03	2.209E+03	2.030E+03	2.305E+03	2.196E+03	2.276E+03	2.330E+03	2.244E+03	**2.163E+03**	2.344E+03	2.363E+03	3.304E+03	2.642E+03	2.456E+03	2.904E+03
	Rank	2	3	7	9	6	4	11	8	1	5	10	15	13	12	14

TABLE 4 (continued): The mean, standard deviation, best and worst of the objective function value for problem no. 21 to 30 (with dimension = 10)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P21	Mean	2.343E+03	2.350E+03	2.373E+03	2.390E+03	2.390E+03	2.382E+03	2.317E+03	**2.290E+03**	2.313E+03	2.345E+03	2.332E+03	2.354E+03	2.309E+03	2.316E+03	2.314E+03
	Stdev	3.000E+01	5.336E+01	6.619E+00	3.300E+01	1.910E+01	1.927E+01	1.358E+01	**4.950E+01**	3.453E+01	1.004E+01	1.061E+01	1.008E+01	1.879E+01	1.440E+01	6.448E+00
	Best	2.200E+03	2.200E+03	2.361E+03	2.250E+03	2.360E+03	2.325E+03	2.251E+03	**2.210E+03**	2.200E+03	2.332E+03	2.310E+03	2.326E+03	2.240E+03	2.246E+03	2.304E+03
	Worst	2.373E+03	2.393E+03	2.389E+03	2.430E+03	2.430E+03	2.416E+03	2.330E+03	**2.340E+03**	2.340E+03	2.374E+03	2.352E+03	2.370E+03	2.333E+03	2.333E+03	2.326E+03
	Rank	8	10	12	14	14	13	6	1	3	9	7	11	2	5	4
P22	Mean	2.305E+03	2.303E+03	2.302E+03	2.700E+03	2.870E+03	2.714E+03	2.306E+03	2.309E+03	2.302E+03	**2.299E+03**	2.304E+03	2.301E+03	2.304E+03	2.307E+03	2.302E+03
	Stdev	3.076E+00	3.205E+00	1.891E+00	2.420E+02	2.470E+02	2.628E+02	2.050E+00	1.403E+00	7.361E+00	**1.617E+01**	2.054E+00	7.481E-01	1.155E+00	1.524E+00	9.482E-01
	Best	2.300E+03	2.300E+03	2.300E+03	2.390E+03	2.450E+03	2.389E+03	2.303E+03	2.306E+03	2.264E+03	**2.211E+03**	2.300E+03	2.300E+03	2.302E+03	2.305E+03	2.300E+03
	Worst	2.312E+03	2.313E+03	2.309E+03	3.220E+03	3.220E+03	3.302E+03	2.310E+03	2.311E+03	2.309E+03	**2.306E+03**	2.309E+03	2.304E+03	2.306E+03	2.310E+03	2.304E+03
	Rank	9	6	3	13	15	14	10	12	4	1	8	2	7	11	5
P23	Mean	2.641E+03	**2.613E+03**	2.830E+03	2.720E+03	2.710E+03	2.726E+03	2.620E+03	2.640E+03	2.622E+03	2.628E+03	2.645E+03	2.685E+03	2.737E+03	2.629E+03	2.616E+03
	Stdev	1.522E+01	**4.884E+00**	9.668E+01	2.580E+01	2.550E+01	3.073E+01	6.004E+00	1.031E+01	9.143E+00	1.157E+01	1.449E+01	2.713E+01	4.251E+01	6.822E+00	8.240E+00
	Best	2.624E+03	**2.605E+03**	2.652E+03	2.670E+03	2.670E+03	2.654E+03	2.609E+03	2.617E+03	2.607E+03	2.607E+03	2.622E+03	2.637E+03	2.670E+03	2.614E+03	2.604E+03
	Worst	2.679E+03	**2.621E+03**	3.025E+03	2.770E+03	2.760E+03	2.787E+03	2.633E+03	2.658E+03	2.642E+03	2.654E+03	2.677E+03	2.743E+03	2.841E+03	2.645E+03	2.641E+03
	Rank	8	1	15	12	11	13	3	7	4	5	9	10	14	6	2
P24	Mean	2.517E+03	**2.500E+03**	**2.500E+03**	2.870E+03	2.880E+03	2.858E+03	2.706E+03	2.707E+03	2.680E+03	2.544E+03	2.533E+03	2.540E+03	2.720E+03	2.729E+03	2.705E+03
	Stdev	6.848E+01	**3.200E-03**	**2.020E-03**	1.180E+02	6.740E+01	1.277E+02	7.265E+01	9.233E+01	9.645E+01	1.016E+02	8.219E+01	1.221E+02	5.316E+01	5.706E+01	7.956E+01
	Best	2.500E+03	**2.500E+03**	**2.500E+03**	2.610E+03	2.650E+03	2.570E+03	2.500E+31	2.542E+03	2.500E+03	2.500E+03	2.500E+03	2.500E+03	2.568E+03	2.502E+03	2.500E+03
	Worst	2.770E+03	**2.500E+03**	**2.500E+03**	3.070E+03	2.970E+03	3.026E+03	2.771E+03	2.789E+03	2.781E+03	2.808E+03	2.784E+03	2.942E+03	2.758E+03	2.768E+03	2.757E+03
	Rank	3	1	1	14	15	13	9	10	7	6	4	5	11	12	8
P25	Mean	2.917E+03	2.943E+03	**2.903E+03**	3.240E+03	3.360E+03	3.204E+03	2.935E+03	2.935E+03	2.936E+03	2.927E+03	2.942E+03	2.922E+03	2.929E+03	2.940E+03	2.931E+03
	Stdev	2.355E+01	8.244E+00	**1.373E+01**	2.040E+02	1.770E+02	1.044E+02	1.802E+01	1.925E+01	1.710E+01	2.231E+01	8.169E+00	2.306E+01	2.148E+01	1.372E+01	2.020E+01
	Best	2.897E+03	2.899E+03	**2.897E+03**	2.990E+03	3.020E+03	3.018E+03	2.898E+03	2.900E+03	2.898E+03	2.897E+03	2.899E+03	2.897E+03	2.897E+03	2.899E+03	2.897E+03
	Worst	2.949E+03	2.947E+03	**2.944E+03**	3.600E+03	3.670E+03	3.405E+03	2.944E+03	2.948E+03	2.948E+03	2.945E+03	2.945E+03	2.944E+03	2.946E+03	2.947E+03	2.944E+03
	Rank	2	12	1	14	15	13	7	8	9	4	11	3	5	10	6
P26	Mean	2.908E+03	2.943E+03	2.942E+03	4.390E+03	4.310E+03	4.329E+03	**2.843E+03**	2.859E+03	2.893E+03	2.907E+03	2.862E+03	2.966E+03	2.843E+03	2.856E+03	2.862E+03
	Stdev	1.180E+02	1.976E+02	1.884E+02	4.330E+02	3.540E+02	3.126E+02	**5.764E+01**	4.890E+01	2.308E+02	1.698E+02	9.436E+01	2.550E+02	4.718E+01	4.261E+01	8.025E+01
	Best	2.800E+03	2.800E+03	2.800E+03	3.330E+03	3.500E+03	3.752E+03	**2.805E+03**	2.822E+03	2.803E+03	2.800E+03	2.801E+03	2.801E+03	2.804E+03	2.814E+03	2.805E+03
	Worst	3.183E+03	3.275E+03	3.265E+03	4.880E+03	4.720E+03	4.772E+03	**3.000E+03**	3.030E+03	4.043E+03	3.339E+03	3.147E+03	3.667E+03	2.900E+03	2.952E+03	3.085E+03
	Rank	9	11	10	15	13	14	1	4	7	8	5	12	2	3	6
P27	Mean	**3.086E+03**	3.237E+03	3.323E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.194E+03	3.200E+03	3.196E+03	3.190E+03	3.207E+03	3.180E+03	3.192E+03	3.194E+03
	Stdev	**2.243E+01**	8.302E+01	9.080E+01	5.640E-05	7.520E-05	4.280E-05	5.380E-05	2.018E+01	9.610E-06	8.570E+00	2.690E+01	6.330E+01	3.620E+01	2.120E+01	1.670E+01
	Best	**3.072E+03**	3.075E+03	3.083E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.114E+03	3.200E+03	3.170E+03	3.092E+03	3.110E+03	3.097E+03	3.118E+03	3.129E+03
	Worst	**3.164E+03**	3.413E+03	3.478E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.511E+03	3.200E+03	3.200E+03	3.200E+03
	Rank	1	14	15	8	8	8	8	6	8	7	3	13	2	4	5
P28	Mean	3.253E+03	**3.174E+03**	3.239E+03	3.300E+03	3.300E+03	3.299E+03	3.284E+03	3.279E+03	3.285E+03	3.281E+03	3.282E+03	3.286E+03	3.284E+03	3.287E+03	3.289E+03
	Stdev	4.980E+01	**7.410E+01**	7.401E+01	1.930E+00	1.850E+00	9.326E-01	9.965E+00	5.120E+00	7.922E+00	9.423E+00	7.060E+00	1.080E+01	6.500E+00	6.410E+00	7.450E+00
	Best	3.100E+03	**3.100E+03**	3.100E+03	3.290E+03	3.290E+03	3.294E+03	3.272E+03	3.273E+03	3.273E+03	3.272E+03	3.272E+03	3.272E+03	3.275E+03	3.274E+03	3.277E+03
	Worst	3.287E+03	**3.300E+03**	3.288E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.291E+03	3.300E+03	3.300E+03	3.297E+03	3.299E+03	3.300E+03	3.297E+03	3.300E+03
	Rank	3	1	2	14	13	15	7	4	9	5	6	10	8	11	12
P29	Mean	3.204E+03	3.228E+03	**3.126E+03**	3.245E+03	3.341E+03	3.215E+03	3.319E+03	5.743E+03	3.184E+03	3.168E+03	3.331E+03	4.012E+03	3.852E+03	3.942E+03	4.014E+03
	Stdev	3.685E+01	6.963E+01	**8.535E+01**	4.823E+01	1.038E+02	6.173E+01	7.030E+01	8.806E+01	5.043E+01	1.569E+01	9.577E+01	9.823E+01	8.524E+01	1.003E+02	1.245E+02
	Best	3.158E+03	3.136E+03	**3.183E+03**	3.146E+03	3.199E+03	3.131E+03	3.206E+03	4.442E+03	3.144E+03	3.134E+03	3.191E+03	3.824E+03	4.000E+03	3.806E+03	3.845E+03
	Worst	3.329E+03	3.352E+03	**3.485E+03**	3.339E+03	3.628E+03	3.340E+03	3.495E+03	8.224E+03	3.330E+03	3.208E+03	3.516E+03	4.295E+03	4.200E+03	4.094E+03	4.201E+03
	Rank	4	6	1	7	10	5	8	15	3	2	9	13	11	12	14
P30	Mean	8.318E+04	3.804E+04	**3.257E+03**	3.450E+07	3.370E+07	4.070E+07	7.828E+03	4.230E+03	3.615E+03	1.325E+04	3.406E+03	1.414E+04	3.634E+03	3.457E+03	1.983E+04
	Stdev	6.222E+04	2.277E+04	**3.316E+01**	3.600E+07	2.810E+07	3.410E+07	6.029E+03	9.788E+02	6.374E+02	1.943E+04	2.602E+02	1.005E+04	5.935E+02	3.069E+02	1.108E+04
	Best	3.330E+03	3.308E+03	**3.212E+03**	1.320E+06	2.540E+06	1.140E+06	3.244E+03	3.316E+03	3.234E+03	3.237E+03	3.227E+03	3.231E+03	3.236E+03	3.232E+03	4.981E+03
	Worst	2.164E+05	9.929E+04	**3.343E+03**	1.440E+08	1.180E+08	1.340E+08	2.989E+04	6.359E+03	5.598E+03	8.851E+04	4.387E+03	4.117E+04	6.198E+03	4.602E+03	5.501E+04
	Rank	12	11	1	14	13	15	7	6	4	8	2	9	5	3	10

TABLE 5: The mean, standard deviation, best and worst of the objective function value for problem no. 1 to 10 (with dimension = 30)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P1	Mean	1.440E+07	5.727E+08	**6.962E+06**	2.250E+11	3.060E+11	2.490E+11	1.660E+09	1.880E+10	1.500E+08	3.759E+08	3.416E+09	5.538E+07	2.134E+09	1.375E+10	1.790E+08
	Stdev	7.260E+06	3.542E+08	**1.822E+06**	7.060E+10	3.960E+10	4.200E+10	4.650E+08	4.360E+09	3.830E+07	1.237E+08	1.140E+09	1.747E+07	7.305E+08	3.660E+09	4.817E+07
	Best	3.977E+06	1.905E+08	**4.261E+06**	9.590E+10	2.420E+11	1.560E+11	8.850E+08	1.050E+10	8.360E+06	2.193E+08	1.712E+09	3.069E+07	1.061E+09	5.802E+09	9.399E+07
	Worst	3.400E+07	1.812E+09	**1.173E+07**	3.960E+11	3.870E+11	3.270E+11	2.690E+09	2.710E+10	2.130E+08	8.334E+08	5.923E+09	9.502E+07	4.076E+09	2.172E+10	2.637E+08
	Rank	2	7	1	13	15	14	8	12	4	6	10	3	9	11	5
P2	Mean	9.210E+23	1.160E+20	**8.450E+12**	2.270E+49	8.110E+47	7.620E+52	8.280E+24	6.750E+25	2.500E+17	5.080E+27	1.810E+27	2.490E+18	3.660E+25	1.170E+26	1.160E+16
	Stdev	5.040E+24	6.060E+20	**1.460E+13**	9.670E+49	4.420E+48	4.170E+53	2.890E+25	1.790E+26	4.460E+17	2.780E+28	9.780E+27	1.330E+19	1.720E+26	4.330E+26	3.180E+16
	Best	6.060E+14	2.180E+14	**1.975E+08**	2.990E+33	1.710E+34	5.680E+40	2.730E+17	2.590E+20	8.030E+13	6.550E+17	5.540E+18	1.070E+12	3.840E+17	1.760E+20	2.210E+11
	Worst	2.760E+25	3.320E+21	**7.140E+13**	4.170E+50	2.420E+49	2.290E+54	1.550E+26	8.120E+26	1.650E+18	1.502E+29	5.360E+28	7.270E+19	9.330E+26	1.940E+27	1.460E+17
	Rank	6	5	1	14	13	15	7	9	3	12	11	4	8	1	2
P3	Mean	1.440E+04	1.071E+04	**3.457E+03**	1.344E+05	1.209E+05	1.408E+05	8.778E+04	8.814E+04	8.923E+04	6.003E+04	4.058E+04	3.200E+04	1.076E+05	9.505E+04	8.473E+04
	Stdev	4.709E+03	3.780E+03	**1.868E+03**	5.587E+03	2.653E+04	8.966E+04	1.832E+04	1.122E+04	9.331E+03	1.161E+04	7.416E+03	8.206E+03	2.007E+04	1.114E+04	1.598E+04
	Best	8.452E+03	5.031E+03	**1.008E+03**	8.683E+04	8.657E+04	8.688E+04	1.247E+04	7.053E+04	7.387E+04	3.943E+04	2.835E+04	1.691E+04	6.588E+04	8.098E+04	5.380E+04
	Worst	2.637E+04	2.155E+04	**8.113E+03**	3.026E+05	2.162E+05	6.068E+05	1.272E+05	1.183E+05	1.093E+05	8.256E+04	6.231E+04	5.110E+04	1.437E+05	1.231E+05	1.290E+05
	Rank	3	2	1	14	13	15	8	9	11	6	5	4	12	11	7
P4	Mean	4.885E+02	5.296E+02	**4.702E+02**	5.972E+03	7.441E+03	5.651E+03	5.411E+02	9.048E+02	4.900E+02	5.110E+02	6.200E+02	4.810E+02	5.560E+02	7.520E+02	4.890E+02
	Stdev	2.677E+01	3.958E+01	**2.447E+01**	7.990E+03	1.238E+03	8.960E+02	2.039E+01	1.354E+02	1.260E+01	2.100E+01	3.738E+01	6.135E+00	2.298E+01	6.500E+01	1.649E+01
	Best	4.140E+02	4.790E+02	**4.050E+02**	2.338E+03	4.317E+03	4.225E+03	5.070E+02	6.980E+02	4.780E+02	4.890E+02	5.340E+02	4.700E+02	5.110E+02	6.090E+02	4.800E+02
	Worst	5.390E+02	6.250E+02	**5.240E+02**	4.769E+04	9.064E+03	7.506E+03	5.930E+02	1.179E+03	5.280E+02	5.720E+02	6.840E+02	5.090E+02	6.120E+02	8.950E+02	5.400E+02
	Rank	3	7	1	14	15	13	8	12	5	6	10	2	9	11	4
P5	Mean	6.503E+02	6.559E+02	7.098E+02	7.965E+02	8.078E+02	7.715E+02	6.816E+02	7.370E+02	6.896E+02	6.640E+02	6.870E+02	6.980E+02	6.450E+02	6.970E+02	**6.070E+02**
	Stdev	2.269E+01	2.004E+01	1.516E+01	1.916E+01	2.632E+01	2.326E+01	2.811E+01	2.845E+01	2.663E+01	3.700E+01	2.052E+01	1.454E+01	2.411E+01	1.918E+01	**2.169E+01**
	Best	5.980E+02	6.090E+02	6.710E+02	7.520E+02	7.520E+02	7.300E+02	6.340E+02	6.890E+02	6.350E+02	5.780E+02	6.510E+02	6.510E+02	5.900E+02	6.470E+02	**5.620E+02**
	Worst	6.850E+02	6.940E+02	7.370E+02	8.350E+02	8.770E+02	8.280E+02	7.380E+02	7.980E+02	7.320E+02	7.240E+02	7.350E+02	7.200E+02	6.970E+02	7.360E+02	**6.530E+02**
	Rank	3	4	11	14	15	13	6	12	8	5	7	10	2	9	1
P6	Mean	6.505E+02	6.492E+02	6.728E+02	6.749E+02	6.938E+02	6.925E+02	6.338E+02	6.595E+02	6.434E+02	6.260E+02	6.480E+02	6.630E+02	6.180E+02	6.450E+02	**6.160E+02**
	Stdev	1.354E+01	7.093E+00	5.213E+00	7.975E+00	1.064E+01	7.659E+00	1.115E+01	6.765E+00	1.053E+01	8.040E+00	5.290E+00	6.086E+00	3.840E+00	5.790E+00	**5.846E+00**
	Best	6.300E+02	6.350E+02	6.620E+02	6.800E+02	6.650E+02	6.770E+02	6.270E+02	6.470E+02	6.240E+02	6.140E+02	6.380E+02	6.480E+02	6.110E+02	6.340E+02	**6.040E+02**
	Worst	6.710E+02	6.630E+02	6.840E+02	7.120E+02	7.090E+02	7.080E+02	6.660E+02	6.690E+02	6.610E+02	6.520E+02	6.590E+02	6.780E+02	6.270E+02	6.550E+02	**6.260E+02**
	Rank	9	8	12	13	15	14	4	10	5	3	7	11	2	6	1
P7	Mean	9.307E+02	9.204E+02	9.055E+02	1.303E+03	1.222E+03	1.349E+03	9.380E+02	1.008E+03	1.007E+03	8.930E+02	9.620E+02	8.720E+02	8.960E+02	9.500E+02	**8.620E+02**
	Stdev	4.483E+01	3.794E+01	4.699E+01	7.084E+01	6.271E+01	5.248E+01	3.155E+01	3.878E+01	2.986E+01	2.400E+01	3.020E+01	2.429E+01	2.752E+01	2.343E+01	**1.594E+01**
	Best	8.510E+02	8.560E+02	8.320E+02	1.077E+03	1.109E+03	1.218E+03	8.780E+02	9.370E+02	9.410E+02	8.540E+02	9.040E+02	8.300E+02	8.430E+02	9.040E+02	**8.310E+02**
	Worst	1.011E+03	1.018E+03	1.024E+03	1.400E+03	1.343E+03	1.417E+03	9.940E+02	1.123E+03	1.081E+03	9.430E+02	1.030E+03	9.240E+02	9.590E+02	1.002E+03	**9.000E+02**
	Rank	7	6	5	14	13	15	8	12	11	3	10	2	4	9	1
P8	Mean	9.278E+02	9.213E+02	9.575E+02	1.059E+03	1.054E+03	1.026E+03	9.570E+02	9.806E+02	9.872E+02	9.360E+02	9.430E+02	9.420E+02	9.410E+02	9.620E+02	**8.880E+02**
	Stdev	1.667E+01	2.262E+01	1.338E+01	2.946E+01	2.262E+01	2.592E+01	2.505E+01	1.673E+01	2.654E+01	2.237E+01	1.811E+01	1.640E+01	1.927E+01	2.211E+01	**1.727E+01**
	Best	8.990E+02	8.650E+02	9.280E+02	9.970E+02	1.019E+03	9.830E+02	9.070E+02	9.480E+02	9.280E+02	8.860E+02	9.120E+02	9.130E+02	9.010E+02	9.150E+02	**8.640E+02**
	Worst	9.690E+02	9.580E+02	1.004E+03	1.116E+03	1.120E+03	1.089E+03	1.034E+03	1.018E+03	1.033E+03	9.930E+02	9.850E+02	9.840E+02	9.860E+02	1.013E+03	**9.340E+02**
	Rank	3	2	9	15	14	13	8	11	12	4	7	6	5	10	1
P9	Mean	2.499E+03	2.425E+03	2.575E+03	8.116E+03	7.477E+03	7.798E+03	1.608E+03	4.564E+03	1.357E+03	1.156E+03	3.449E+03	1.005E+03	1.124E+03	2.594E+03	**9.130E+02**
	Stdev	8.626E+02	4.957E+02	1.252E+03	6.870E+02	1.244E+03	8.851E+02	7.508E+02	1.063E+03	3.101E+02	1.080E+02	6.360E+02	2.720E+02	1.164E+02	4.980E+02	**5.120E+00**
	Best	1.083E+03	1.444E+03	1.007E+03	7.062E+03	4.631E+03	5.404E+03	1.021E+03	3.063E+03	9.440E+02	9.790E+02	1.943E+03	9.110E+02	9.950E+02	1.886E+03	**9.030E+02**
	Worst	4.294E+03	3.762E+03	4.978E+03	9.475E+03	9.462E+03	9.070E+03	3.959E+03	6.675E+03	2.019E+03	1.450E+03	4.821E+03	2.372E+03	1.522E+03	4.222E+03	**9.250E+02**
	Rank	8	7	9	15	13	14	6	12	5	4	11	2	3	10	1
P10	Mean	4.186E+03	**4.072E+03**	4.842E+03	7.149E+03	7.194E+03	6.613E+03	6.894E+03	6.786E+03	5.979E+03	5.640E+03	5.739E+03	4.652E+03	7.093E+03	6.998E+03	6.153E+03
	Stdev	4.138E+02	**4.955E+02**	4.857E+02	5.763E+02	5.714E+02	4.678E+02	5.639E+02	6.566E+02	5.812E+02	8.990E+02	8.880E+02	4.970E+02	6.470E+02	6.030E+02	5.290E+02
	Best	3.591E+03	**2.900E+03**	3.855E+03	6.034E+03	5.710E+03	5.737E+03	6.149E+03	5.681E+03	4.205E+03	4.015E+03	3.911E+03	3.632E+03	5.763E+03	5.652E+03	5.071E+03
	Worst	5.303E+03	**5.231E+03**	6.153E+03	8.195E+03	8.376E+03	7.670E+03	8.460E+03	8.235E+03	6.786E+03	7.020E+03	7.607E+03	5.538E+03	8.364E+03	8.470E+03	7.192E+03
	Rank	2	1	4	14	15	9	11	10	7	5	6	3	13	12	8

TABLE 5 (continued): The mean, standard deviation, best and worst of the objective function value for problem no. 11 to 20 (with dimension = 30)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P11	Mean	1.461E+03	1.649E+03	**1.214E+03**	6.582E+03	6.195E+03	1.068E+04	2.442E+03	3.290E+03	1.438E+03	1.810E+03	1.959E+03	1.241E+03	2.166E+03	2.075E+03	1.343E+03
	Stdev	2.220E+02	1.953E+02	**2.991E+01**	1.622E+03	1.341E+03	1.221E+04	5.295E+02	1.122E+03	8.668E+01	4.440E+02	2.670E+02	4.336E+01	5.140E+02	2.690E+02	7.485E+01
	Best	1.205E+03	1.280E+03	**1.175E+03**	2.815E+03	3.208E+03	3.572E+03	1.554E+03	1.742E+03	1.248E+03	1.228E+03	1.594E+03	1.182E+03	1.302E+03	1.569E+03	1.218E+03
	Worst	2.142E+03	1.988E+03	**1.284E+03**	9.501E+03	8.869E+03	7.406E+04	3.515E+03	6.027E+03	1.629E+03	3.199E+03	2.567E+03	1.331E+03	3.440E+03	2.538E+03	1.534E+03
	Rank	5	6	1	14	13	15	11	12	4	7	8	2	10	9	3
P12	Mean	5.843E+06	8.069E+06	**2.370E+06**	3.200E+10	6.830E+10	4.880E+10	9.772E+07	6.010E+08	3.459E+07	2.167E+07	3.596E+07	9.613E+06	1.810E+08	2.764E+08	2.584E+07
	Stdev	5.429E+06	8.331E+06	**1.344E+06**	1.890E+10	2.020E+10	1.550E+10	4.027E+07	3.380E+08	1.746E+07	1.742E+07	1.147E+07	4.218E+06	1.465E+08	9.047E+07	1.549E+07
	Best	8.597E+05	6.590E+05	**4.785E+05**	3.680E+09	2.690E+10	9.430E+09	3.712E+07	1.330E+08	5.921E+06	4.351E+06	1.920E+07	2.240E+06	3.212E+07	1.228E+08	7.632E+06
	Worst	2.682E+07	3.812E+07	**5.114E+06**	7.470E+10	1.000E+11	7.670E+10	1.850E+08	1.440E+09	6.293E+07	6.991E+07	5.883E+07	1.824E+07	6.674E+08	4.871E+08	7.599E+07
	Rank	2	3	1	13	15	14	9	12	7	5	8	4	10	11	6
P13	Mean	**1.388E+04**	1.389E+04	2.060E+04	4.610E+10	5.500E+10	5.040E+10	3.140E+07	5.960E+07	5.507E+05	3.665E+05	4.172E+05	1.924E+05	1.475E+08	2.184E+07	1.110E+06
	Stdev	**9.934E+03**	2.710E+03	1.014E+04	2.600E+10	2.770E+10	2.770E+10	3.446E+07	4.196E+07	2.654E+05	2.891E+05	3.802E+05	1.556E+05	2.569E+08	1.144E+07	5.804E+05
	Best	**2.234E+03**	1.013E+04	5.515E+03	1.480E+10	9.880E+09	2.350E+09	1.230E+06	1.263E+07	1.576E+05	5.509E+04	9.660E+04	5.207E+04	7.588E+06	2.222E+06	3.561E+05
	Worst	**4.217E+04**	1.872E+04	5.361E+04	1.300E+11	1.290E+11	1.160E+11	1.620E+08	1.770E+08	1.209E+06	1.211E+06	1.980E+06	7.062E+05	1.416E+08	5.150E+07	3.018E+06
	Rank	1	2	3	13	15	14	10	11	7	5	6	4	12	9	8
P14	Mean	5.463E+04	3.320E+05	6.698E+04	1.108E+07	2.158E+07	9.970E+06	1.025E+06	1.590E+05	5.593E+04	7.204E+05	1.458E+05	**4.947E+04**	6.784E+05	7.000E+04	6.601E+05
	Stdev	2.813E+04	1.575E+05	3.565E+04	1.059E+07	1.747E+07	7.766E+06	5.135E+05	1.253E+05	4.362E+04	3.038E+05	1.285E+05	**2.272E+04**	4.044E+05	3.579E+04	6.008E+05
	Best	1.849E+04	8.160E+04	4.307E+03	1.709E+06	3.344E+05	8.956E+05	3.563E+04	1.969E+04	7.665E+03	1.189E+05	7.805E+03	**1.575E+04**	6.872E+04	2.144E+04	2.984E+04
	Worst	1.426E+05	6.933E+05	1.321E+05	4.702E+07	5.867E+07	2.818E+07	2.011E+06	5.417E+05	2.249E+05	1.363E+06	4.472E+05	**1.186E+05**	1.554E+06	1.658E+05	2.226E+06
	Rank	2	8	4	14	15	13	12	7	3	11	6	1	10	5	9
P15	Mean	**1.818E+03**	1.929E+03	2.013E+03	4.490E+09	5.980E+09	2.390E+09	1.852E+06	1.821E+05	6.632E+04	4.491E+03	2.317E+03	4.491E+03	3.521E+06	2.118E+04	1.237E+05
	Stdev	**2.345E+02**	4.061E+02	5.969E+02	1.990E+09	2.660E+09	1.810E+09	2.586E+06	2.009E+05	2.832E+04	3.762E+03	5.290E+02	1.056E+03	3.082E+06	1.210E+04	5.675E+04
	Best	**1.578E+03**	1.580E+03	1.616E+03	1.250E+09	5.470E+08	2.220E+07	1.224E+05	1.019E+04	1.630E+04	1.907E+03	1.828E+03	2.588E+03	1.161E+05	5.530E+03	4.643E+04
	Worst	**2.457E+03**	3.055E+03	3.717E+03	7.690E+09	1.020E+10	6.610E+09	1.219E+07	1.032E+06	1.234E+05	1.983E+04	4.062E+03	7.260E+03	1.297E+07	5.415E+04	2.162E+05
	Rank	1	2	3	14	15	13	11	10	8	5	4	5	12	7	9
P16	Mean	2.626E+03	2.693E+03	3.099E+03	5.390E+03	5.780E+03	5.803E+03	2.949E+03	3.127E+03	2.676E+03	2.529E+03	2.644E+03	3.036E+03	2.881E+03	2.930E+03	**2.332E+03**
	Stdev	2.412E+02	3.145E+02	3.099E+02	6.610E+02	8.250E+02	9.010E+02	3.050E+02	2.791E+02	3.057E+02	3.090E+02	3.750E+02	4.110E+02	3.110E+02	2.280E+02	**2.660E+02**
	Best	2.131E+03	1.962E+03	2.483E+03	4.280E+03	4.500E+03	4.791E+03	2.339E+03	2.510E+03	1.999E+03	1.892E+03	1.933E+03	2.155E+03	2.063E+03	2.593E+03	**1.805E+03**
	Worst	2.989E+03	3.327E+03	3.699E+03	6.570E+03	7.810E+03	7.687E+03	3.714E+03	3.853E+03	3.246E+03	3.127E+03	3.512E+03	4.133E+03	3.345E+03	3.387E+03	**2.829E+03**
	Rank	3	6	11	13	14	15	9	12	5	2	4	10	7	8	1
P17	Mean	1.834E+03	1.865E+03	**1.831E+03**	2.945E+03	2.775E+03	2.143E+03	1.984E+03	2.125E+03	1.987E+03	1.883E+03	1.909E+03	1.884E+03	1.890E+03	1.880E+03	1.857E+03
	Stdev	1.167E+01	3.203E+01	**1.308E+01**	3.326E+02	3.427E+02	1.760E+01	1.242E+02	7.799E+01	1.139E+02	4.668E+01	6.620E+01	4.414E+01	4.463E+01	3.654E+01	1.908E+02
	Best	1.802E+03	1.834E+03	**1.803E+03**	1.995E+03	1.918E+03	1.957E+03	1.902E+03	1.932E+03	1.866E+03	1.835E+03	1.862E+03	1.833E+03	1.840E+03	1.838E+03	1.827E+03
	Worst	1.852E+03	1.975E+03	**1.780E+03**	2.318E+03	2.316E+03	2.121E+03	2.136E+03	2.110E+03	2.125E+03	1.973E+03	2.125E+03	1.032E+03	1.990E+03	1.984E+03	1.920E+03
	Rank	2	4	1	15	14	13	11	12	10	5	9	6	8	7	3
P18	Mean	5.420E+05	1.695E+05	**1.539E+05**	6.740E+07	6.820E+07	6.553E+07	1.916E+06	9.887E+05	2.910E+05	6.085E+05	2.317E+05	1.678E+05	1.800E+06	8.121E+05	2.419E+05
	Stdev	5.960E+05	9.270E+04	**9.699E+04**	6.410E+07	6.980E+06	9.439E+07	1.856E+06	1.083E+06	1.936E+05	5.775E+05	1.803E+05	1.021E+05	1.525E+06	1.575E+06	1.172E+05
	Best	4.665E+04	5.056E+04	**4.237E+04**	1.690E+06	3.120E+06	1.329E+06	1.948E+05	2.336E+04	5.252E+04	6.118E+04	3.492E+04	3.647E+04	3.075E+05	1.403E+05	4.082E+04
	Worst	2.030E+06	3.598E+05	**3.986E+05**	2.280E+08	2.680E+08	4.310E+08	8.853E+06	4.250E+06	8.496E+05	2.392E+06	8.204E+05	3.660E+05	5.740E+06	8.937E+06	6.019E+05
	Rank	7	3	1	14	15	13	12	10	6	8	4	2	11	9	5
P19	Mean	1.008E+04	9.716E+03	9.900E+03	8.460E+09	1.090E+10	7.710E+09	7.052E+05	4.164E+05	2.198E+05	1.055E+04	**5.922E+03**	7.332E+03	3.869E+06	6.412E+04	9.773E+04
	Stdev	2.956E+03	2.969E+03	4.071E+03	3.910E+09	4.560E+09	4.150E+09	1.160E+06	3.087E+05	1.788E+05	1.395E+04	**2.508E+03**	3.058E+03	3.727E+06	4.015E+04	7.288E+04
	Best	2.001E+03	2.417E+03	2.033E+03	1.230E+09	2.210E+09	1.370E+09	2.550E+04	2.589E+04	1.615E+04	2.674E+03	**2.597E+03**	3.084E+03	2.232E+05	1.640E+04	3.414E+04
	Worst	1.447E+04	1.635E+04	1.583E+04	1.480E+10	1.780E+10	1.530E+10	6.405E+06	1.090E+06	6.461E+05	8.178E+04	**1.170E+04**	1.392E+04	1.434E+07	2.106E+05	4.363E+05
	Rank	5	3	4	14	15	13	11	10	9	6	1	2	12	7	8
P20	Mean	**2.041E+03**	2.159E+03	2.197E+03	2.237E+03	2.462E+03	2.910E+03	2.310E+03	2.522E+03	2.278E+03	2.348E+03	2.215E+03	2.275E+03	2.419E+03	2.194E+03	2.132E+03
	Stdev	**2.582E+01**	3.998E+01	7.306E+01	6.160E+01	1.166E+01	2.173E+02	9.427E+01	1.458E+02	6.458E+01	2.159E+01	5.188E+01	7.282E+01	1.714E+02	7.938E+01	2.343E+01
	Best	**2.116E+03**	2.110E+03	2.132E+03	2.142E+03	2.261E+03	2.711E+03	2.166E+03	2.391E+03	2.141E+03	2.337E+03	2.142E+03	2.144E+03	2.211E+03	2.121E+03	2.111E+03
	Worst	**2.256E+03**	2.274E+03	2.387E+03	2.355E+03	2.561E+03	3.110E+03	2.592E+03	2.782E+03	2.416E+03	2.441E+03	2.207E+03	2.474E+03	2.501E+03	2.455E+03	2.231E+03
	Rank	1	5	2	8	13	15	7	14	10	11	6	9	12	4	3

TABLE 5 (continued): The mean, standard deviation, best and worst of the objective function value for scalable problems for problem no. 21 to 30 (with dimension = 30)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P21	Mean	2.428E+03	2.456E+03	2.493E+03	2.650E+03	2.680E+03	2.663E+03	2.454E+03	2.519E+03	2.485E+03	2.450E+03	2.478E+03	2.505E+03	2.442E+03	2.480E+03	**2.399E+03**
	Stdev	2.136E+01	3.122E+01	2.386E+01	5.600E+01	3.270E+01	3.685E+01	5.490E+01	2.951E+01	7.343E+01	5.468E+01	5.469E+01	8.810E+01	2.061E+01	2.671E+01	**2.280E+01**
	Best	2.376E+03	2.404E+03	2.464E+03	2.490E+03	2.630E+03	2.586E+03	2.224E+03	2.466E+03	2.209E+03	2.222E+03	2.229E+03	2.208E+03	2.404E+03	2.420E+03	**2.358E+03**
	Worst	2.474E+03	2.544E+03	2.595E+03	2.720E+03	2.740E+03	2.770E+03	2.579E+03	2.587E+03	2.599E+03	2.528E+03	2.552E+03	2.577E+03	2.483E+03	2.525E+03	**2.468E+03**
	Rank	2	6	10	13	15	14	5	12	9	4	7	11	3	8	1
P22	Mean	**2.311E+03**	2.404E+03	5.621E+03	8.270E+03	7.950E+03	8.238E+03	2.445E+03	2.684E+03	2.527E+03	2.331E+03	2.417E+03	3.088E+03	2.377E+03	2.546E+03	2.324E+03
	Stdev	**2.943E+01**	8.548E+02	2.257E+03	7.940E+02	8.940E+02	4.938E+02	2.680E+02	7.710E+01	1.129E+03	3.822E+01	5.506E+01	1.758E+03	1.417E+01	3.859E+01	2.261E+01
	Best	**2.306E+03**	2.329E+03	2.306E+03	4.730E+03	6.100E+03	6.116E+03	2.335E+03	2.553E+03	2.315E+03	2.325E+03	2.363E+03	2.314E+03	2.352E+03	2.467E+03	2.320E+03
	Worst	**2.318E+03**	2.684E+03	7.915E+03	9.010E+03	9.330E+03	9.043E+03	3.698E+03	2.924E+03	8.509E+03	2.339E+03	2.652E+03	7.531E+03	2.405E+03	2.613E+03	2.330E+03
	Rank	1	5	12	15	13	14	7	10	8	3	6	11	4	9	2
P23	Mean	2.879E+03	2.459E+03	3.508E+03	3.310E+03	3.310E+03	3.637E+03	2.869E+03	2.995E+03	2.710E+03	2.823E+03	**2.296E+03**	3.498E+03	2.825E+03	2.908E+03	2.765E+03
	Stdev	5.421E+01	2.228E+01	1.506E+02	1.330E+02	9.010E+01	1.695E+02	2.920E+01	4.224E+01	6.298E+01	3.483E+01	**5.653E+01**	2.230E+02	2.512E+01	3.431E+01	3.092E+01
	Best	2.783E+03	2.419E+03	3.237E+03	3.120E+03	3.140E+03	3.251E+03	2.810E+03	2.920E+03	2.747E+03	2.757E+03	**2.842E+03**	3.102E+03	2.763E+03	2.827E+03	2.695E+03
	Worst	2.989E+03	2.501E+03	3.814E+03	3.590E+03	3.550E+03	3.972E+03	2.934E+03	3.106E+03	3.046E+03	2.885E+03	**3.049E+03**	3.990E+03	2.858E+03	3.007E+03	2.844E+03
	Rank	8	2	14	12	11	15	6	10	7	4	1	13	5	9	3
P24	Mean	3.032E+03	3.198E+03	2.989E+03	3.670E+03	3.550E+03	3.681E+03	3.028E+03	3.178E+03	3.023E+03	3.228E+03	3.202E+03	3.627E+03	2.983E+03	3.097E+03	**2.929E+03**
	Stdev	5.303E+01	7.610E+01	3.796E+01	1.560E+02	9.080E+01	1.786E+02	3.925E+01	3.871E+01	4.247E+01	7.881E+01	5.961E+01	2.550E+02	2.986E+01	3.169E+01	**3.245E+01**
	Best	2.926E+03	3.041E+03	2.916E+03	3.390E+03	3.290E+03	3.373E+03	2.925E+03	3.061E+03	2.964E+03	3.085E+03	3.090E+03	3.162E+03	2.914E+03	2.994E+03	**2.874E+03**
	Worst	3.155E+03	3.368E+03	3.049E+03	4.030E+03	3.290E+03	4.106E+03	3.114E+03	3.234E+03	3.121E+03	3.380E+03	3.306E+03	4.178E+03	3.034E+03	3.164E+03	**2.978E+03**
	Rank	6	9	3	14	12	15	5	8	4	11	10	13	2	7	1
P25	Mean	**2.890E+03**	2.956E+03	2.895E+03	3.840E+03	3.830E+03	3.879E+03	2.951E+03	3.037E+03	2.922E+03	2.908E+03	2.948E+03	2.892E+03	2.933E+03	2.989E+03	2.895E+03
	Stdev	**1.476E+01**	3.746E+01	1.760E+01	2.750E+02	2.420E+02	2.334E+02	2.212E+01	3.159E+01	2.084E+01	1.791E+01	2.149E+01	9.054E+00	2.120E+01	2.961E+01	8.809E+01
	Best	**2.876E+03**	2.825E+03	2.878E+03	3.420E+03	3.260E+03	3.545E+03	2.914E+03	2.995E+03	2.891E+03	2.887E+03	2.912E+03	2.877E+03	2.902E+03	2.934E+03	2.879E+03
	Worst	**2.928E+03**	3.014E+03	2.937E+03	4.510E+03	4.320E+03	4.500E+03	2.986E+03	3.139E+03	2.958E+03	2.949E+03	2.997E+03	2.906E+03	2.982E+03	3.051E+03	2.908E+03
	Rank	1	10	4	14	13	15	9	12	6	5	8	2	7	11	3
P26	Mean	3.712E+03	3.988E+03	4.182E+03	1.050E+04	1.000E+04	1.092E+04	4.213E+03	4.820E+03	4.818E+03	**3.465E+03**	3.749E+03	5.923E+03	3.612E+03	4.379E+03	6.757E+03
	Stdev	1.401E+03	1.672E+03	1.577E+03	8.740E+02	6.790E+02	6.150E+02	1.419E+03	1.220E+03	1.827E+03	**1.146E+03**	1.018E+03	2.061E+03	8.821E+02	1.118E+03	1.551E+03
	Best	2.830E+03	2.891E+03	2.892E+03	7.790E+03	8.500E+03	9.684E+03	3.009E+03	3.621E+03	2.885E+03	**2.917E+03**	3.163E+03	2.867E+03	3.113E+03	3.501E+03	2.822E+03
	Worst	6.855E+03	7.580E+03	7.052E+03	1.200E+04	1.140E+04	1.182E+03	7.018E+03	7.770E+03	7.859E+03	**6.699E+03**	6.797E+03	8.432E+03	5.783E+03	6.979E+03	7.851E+03
	Rank	3	5	6	14	13	15	7	10	9	1	4	11	2	8	12
P27	Mean	3.200E+03	**3.196E+03**	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.594E+03
	Stdev	0.000E+00	**9.832E+00**	8.190E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.170E-04	1.300E-04	9.690E-05	1.130E-04	9.880E-05	5.186E+02
	Best	3.200E+03	**3.162E+03**	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.157E+03
	Worst	3.200E+03	**3.200E+03**	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	5.211E+03
	Rank	7	1	2	11	8	12	9	10	13	5	6	14	4	3	15
P28	Mean	3.279E+03	3.299E+03	**3.207E+03**	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.308E+03	3.320E+03	3.260E+03	3.300E+03	3.299E+03	3.296E+03
	Stdev	2.697E+01	4.230E+00	**7.288E+00**	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.507E+01	2.647E+01	2.880E+01	3.105E-02	6.010E-02	1.480E+01
	Best	3.195E+03	3.277E+03	**3.198E+03**	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.261E+03	3.299E+03	3.203E+03	3.299E+03	3.299E+03	3.226E+03
	Worst	3.300E+03	3.300E+03	**3.233E+03**	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.362E+03	3.380E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03
	Rank	3	2	1	9	10	12	11	13	8	6	15	14	7	5	4
P29	Mean	3.321E+03	3.341E+03	**3.270E+03**	3.420E+03	3.620E+03	3.961E+03	3.430E+03	5.840E+03	4.399E+03	3.200E+03	3.440E+03	3.969E+03	3.311E+03	3.420E+03	3.331E+03
	Stdev	6.281E+01	4.931E+01	**1.680E+01**	7.140E+01	1.350E+02	1.309E+02	9.690E+01	8.921E+01	2.770E+02	5.150E+01	1.150E+01	2.241E+02	3.709E+01	8.650E+01	6.979E+01
	Best	3.241E+03	3.257E+03	**3.244E+03**	3.317E+03	3.432E+03	3.904E+03	3.201E+03	4.551E+03	3.068E+03	3.255E+03	3.200E+03	3.888E+03	3.271E+03	3.294E+03	3.247E+03
	Worst	3.451E+03	3.450E+03	**3.320E+03**	3.610E+03	3.790E+03	4.301E+03	3.630E+03	8.331E+03	4.640E+03	3.440E+03	3.740E+03	4.310E+03	3.440E+03	3.501E+03	3.460E+03
	Rank	4	6	1	7	11	12	9	15	14	2	10	13	3	8	5
P30	Mean	**5.156E+03**	1.274E+05	1.487E+04	2.260E+10	2.680E+10	2.370E+10	2.586E+06	7.181E+06	8.761E+05	1.258E+04	1.217E+04	4.480E+04	3.947E+06	3.683E+05	3.733E+04
	Stdev	**3.569E+03**	3.027E+05	5.397E+03	1.050E+10	9.850E+09	9.710E+09	3.286E+06	3.767E+06	7.273E+05	1.084E+04	1.583E+04	3.950E+04	3.664E+06	2.415E+05	1.641E+04
	Best	**3.285E+03**	3.323E+03	8.752E+03	2.250E+09	5.720E+09	8.050E+09	1.427E+05	3.079E+05	4.096E+04	4.938E+03	4.130E+03	7.492E+03	2.541E+05	6.142E+04	1.123E+04
	Worst	**2.135E+04**	1.526E+06	3.073E+04	3.810E+10	3.910E+10	4.070E+10	1.427E+05	1.499E+07	3.135E+06	5.306E+04	8.945E+04	1.278E+04	1.522E+07	8.998E+05	9.150E+04
	Rank	1	7	4	13	15	14	10	12	9	3	2	6	11	8	5

TABLE 6: The mean, standard deviation, best and worst of the objective function value for problem no. 1 to 10 (with dimension = 50)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P1	Mean	1.257E+09	1.376E+10	**2.483E+08**	4.989E+11	5.972E+11	6.120E+11	1.442E+10	1.267E+11	1.137E+09	6.002E+09	5.183E+10	5.236E+08	2.011E+10	1.137E+11	1.241E+09
	Stdev	4.507E+08	6.680E+09	**7.346E+07**	7.460E+10	6.083E+10	5.445E+10	3.489E+09	1.868E+10	2.299E+08	1.613E+09	1.270E+10	1.092E+08	3.851E+09	1.431E+10	1.759E+08
	Best	6.899E+08	5.315E+09	**1.639E+08**	3.535E+11	4.861E+11	5.328E+11	8.076E+09	9.193E+10	8.036E+08	3.140E+09	3.535E+10	3.144E+08	1.368E+10	8.921E+10	9.754E+08
	Worst	2.215E+09	3.096E+10	**4.302E+08**	6.170E+11	6.959E+11	7.321E+11	1.948E+10	1.613E+11	1.665E+09	1.096E+10	8.169E+10	6.836E+08	3.073E+10	1.371E+11	1.607E+09
	Rank	5	7	1	13	14	15	8	12	3	6	10	2	9	11	4
P2	Mean	5.030E+46	4.400E+43	**4.550E+29**	5.360E+81	1.220E+82	1.860E+81	2.050E+52	1.230E+56	2.670E+39	5.860E+45	1.040E+47	7.520E+31	2.420E+51	1.060E+51	3.450E+36
	Stdev	2.110E+47	1.970E+44	**1.850E+30**	2.100E+82	5.360E+82	4.220E+81	9.140E+52	4.040E+56	7.500E+39	1.790E+46	2.810E+47	2.850E+32	1.060E+52	3.700E+51	1.100E+37
	Best	9.950E+32	6.130E+34	**1.930E+22**	8.150E+68	7.140E+73	6.230E+76	3.010E+40	5.120E+47	1.710E+32	1.360E+40	7.480E+42	2.950E+26	3.160E+42	6.250E+45	5.170E+28
	Worst	9.470E+47	8.800E+44	**8.310E+30**	9.420E+82	2.400E+83	1.420E+82	4.090E+53	1.680E+57	2.670E+32	7.820E+46	1.200E+48	1.280E+33	4.760E+52	1.650E+52	4.550E+37
	Rank	7	5	1	14	15	13	11	12	4	6	8	2	11	9	3
P3	Mean	4.066E+04	5.113E+04	**2.740E+04**	2.916E+06	1.452E+06	1.489E+06	2.155E+05	2.058E+05	2.148E+05	1.498E+05	9.973E+04	1.429E+05	2.252E+05	1.993E+05	2.136E+05
	Stdev	9.187E+03	1.177E+04	**2.670E+04**	8.315E+06	4.128E+06	3.398E+06	4.564E+04	3.272E+04	3.285E+04	3.382E+04	1.290E+04	2.597E+04	5.587E+04	2.296E+04	3.323E+04
	Best	2.937E+04	3.141E+04	**1.210E+04**	1.895E+05	1.860E+05	1.895E+05	1.625E+05	1.683E+05	1.711E+05	9.963E+04	6.936E+04	9.516E+04	1.647E+05	1.671E+05	1.681E+05
	Worst	6.383E+04	7.659E+04	**1.263E+05**	3.754E+07	1.883E+07	1.537E+07	3.491E+05	2.756E+05	3.219E+05	2.405E+05	1.178E+05	1.899E+05	4.334E+05	2.463E+05	3.079E+05
	Rank	2	3	1	15	13	14	11	8	10	6	4	5	12	7	9
P4	Mean	6.810E+02	9.690E+02	**5.870E+02**	1.608E+04	1.963E+04	2.177E+04	9.120E+02	2.730E+03	6.990E+02	7.840E+02	1.418E+03	6.340E+02	9.290E+02	2.182E+03	6.290E+02
	Stdev	5.400E+01	1.299E+02	**4.459E+01**	2.717E+03	2.723E+03	2.612E+03	6.610E+01	3.180E+02	4.251E+01	7.507E+01	1.470E+02	2.379E+01	8.560E+01	3.400E+02	5.028E+01
	Best	5.790E+02	8.018E+02	**4.866E+02**	1.119E+04	1.504E+04	1.735E+04	7.900E+02	2.197E+03	5.930E+02	6.630E+02	1.186E+03	5.860E+02	7.610E+02	1.691E+03	4.940E+02
	Worst	8.560E+02	1.275E+03	**6.603E+02**	2.027E+04	2.415E+04	2.513E+04	1.004E+04	3.318E+03	7.610E+02	9.530E+02	1.683E+03	6.690E+02	1.062E+03	2.895E+03	6.910E+03
	Rank	4	9	1	13	14	15	7	12	5	6	10	3	8	11	2
P5	Mean	8.385E+02	8.260E+02	8.840E+02	1.065E+03	1.061E+03	1.027E+03	9.130E+02	9.550E+02	8.630E+02	8.660E+02	9.020E+02	8.570E+02	8.430E+02	9.140E+02	**7.840E+02**
	Stdev	4.295E+01	3.575E+01	1.907E+01	3.915E+01	3.141E+01	3.642E+01	4.605E+01	2.479E+01	4.474E+01	4.431E+01	2.299E+01	2.499E+01	3.413E+01	3.236E+01	**3.937E+01**
	Best	7.414E+02	7.621E+02	8.403E+02	9.770E+02	1.018E+03	9.600E+02	8.380E+02	9.100E+02	7.830E+02	7.850E+02	8.580E+02	7.990E+02	7.900E+02	8.640E+02	**7.060E+02**
	Worst	8.932E+02	8.987E+02	9.251E+02	1.124E+03	1.131E+03	1.088E+03	1.015E+03	9.990E+02	9.370E+02	9.260E+02	9.670E+02	8.960E+02	9.290E+02	9.800E+02	**8.680E+02**
	Rank	3	2	8	15	14	13	10	12	6	7	9	5	4	11	1
P6	Mean	6.797E+02	6.716E+02	6.909E+02	7.180E+02	7.193E+02	7.180E+02	6.530E+02	6.910E+02	6.610E+02	6.500E+02	6.710E+02	6.850E+02	6.350E+02	6.720E+02	**6.250E+02**
	Stdev	9.692E+00	7.563E+00	6.167E+00	6.690E+00	8.466E+00	9.990E+00	7.880E+00	7.732E+00	1.338E+01	7.630E+00	6.190E+00	6.830E+00	5.110E+00	6.980E+00	**6.710E+00**
	Best	6.632E+02	6.601E+02	6.802E+02	7.080E+02	7.058E+02	7.003E+02	6.420E+02	6.810E+02	6.420E+02	6.330E+02	6.580E+02	6.710E+02	6.271E+02	9.590E+02	**6.130E+02**
	Worst	7.004E+02	6.867E+02	7.059E+02	7.310E+02	7.326E+02	7.310E+02	6.690E+02	7.100E+02	6.850E+02	6.650E+02	6.800E+02	6.960E+02	6.432E+02	6.910E+02	**6.410E+02**
	Rank	9	7	11	13	15	13	4	12	5	3	6	10	2	8	1
P7	Mean	1.247E+03	1.251E+03	1.172E+03	1.832E+03	1.671E+03	1.869E+03	1.259E+03	1.416E+03	1.206E+03	1.169E+03	1.320E+03	1.094E+03	1.162E+03	1.304E+03	**1.073E+03**
	Stdev	6.800E+01	7.069E+01	7.203E+01	9.400E+01	8.507E+01	5.581E+01	4.752E+01	5.886E+01	5.411E+01	3.012E+01	4.900E+01	3.475E+01	3.690E+01	5.683E+01	**3.619E+01**
	Best	1.140E+03	1.089E+03	1.072E+03	1.611E+03	1.554E+03	1.757E+03	1.190E+03	1.290E+03	1.138E+03	1.114E+03	1.241E+03	1.016E+03	1.121E+03	1.176E+03	**1.011E+03**
	Worst	1.384E+03	1.362E+03	1.332E+03	1.987E+03	1.878E+03	1.949E+03	1.375E+03	1.573E+03	1.313E+03	1.222E+03	1.430E+03	1.154E+03	1.246E+03	1.366E+03	**1.141E+03**
	Rank	7	8	5	14	13	15	9	12	6	4	11	2	3	10	1
P8	Mean	1.129E+03	1.086E+03	1.134E+03	1.336E+03	1.330E+03	1.276E+03	1.185E+03	1.239E+03	1.138E+03	1.143E+03	1.170E+03	1.111E+03	1.144E+03	1.226E+03	**1.052E+03**
	Stdev	3.709E+01	2.110E+01	1.792E+01	4.000E+01	4.582E+01	3.458E+01	2.680E+01	2.998E+01	3.445E+01	3.175E+01	2.800E+01	2.163E+01	3.302E+01	3.078E+01	**3.276E+01**
	Best	1.054E+03	1.052E+03	1.099E+03	1.262E+03	1.243E+03	1.192E+03	1.126E+03	1.178E+03	1.075E+03	1.082E+03	1.108E+03	1.077E+03	1.074E+03	1.162E+03	**9.970E+02**
	Worst	1.202E+03	1.121E+03	1.173E+03	1.396E+03	1.416E+03	1.337E+03	1.227E+03	1.292E+03	1.202E+03	1.200E+03	1.219E+03	1.160E+03	1.223E+03	1.271E+03	**1.104E+03**
	Rank	4	2	5	15	14	13	10	12	6	7	9	3	8	11	1
P9	Mean	1.555E+04	1.223E+04	1.182E+04	2.777E+04	2.729E+04	2.913E+04	1.207E+04	2.006E+04	1.011E+04	4.428E+03	1.527E+04	4.785E+03	4.019E+03	1.415E+04	**1.099E+03**
	Stdev	4.172E+03	1.910E+03	3.578E+03	3.082E+03	2.826E+03	3.004E+03	4.549E+03	2.680E+03	3.544E+03	1.277E+03	2.107E+03	1.329E+03	1.180E+03	2.299E+03	**8.144E+02**
	Best	7.278E+03	8.916E+03	4.214E+03	2.140E+04	2.091E+04	2.397E+04	6.412E+03	1.435E+04	5.104E+03	2.684E+03	1.097E+04	2.918E+03	2.326E+03	1.058E+04	**9.850E+02**
	Worst	2.292E+04	1.650E+04	1.730E+04	3.224E+04	3.182E+04	3.741E+04	2.050E+04	2.530E+04	1.850E+04	7.056E+03	2.012E+04	7.690E+03	6.570E+03	1.882E+04	**1.217E+03**
	Rank	11	8	6	14	13	15	7	12	5	3	10	4	2	9	1
P10	Mean	**7.387E+03**	7.571E+03	8.02E+031	1.268E+04	1.271E+04	1.146E+04	1.166E+04	1.169E+04	1.032E+04	9.780E+03	9.700E+03	8.286E+03	1.195E+04	1.187E+04	1.047E+04
	Stdev	**7.780E+02**	6.890E+02	8.890E+02	8.570E+02	1.089E+03	7.780E+02	9.040E+02	6.990E+02	9.110E+02	1.629E+03	9.630E+02	1.042E+03	8.870E+02	5.260E+02	1.011E+03
	Best	**5.434E+03**	6.398E+03	6.513E+03	1.019E+04	9.933E+03	1.012E+04	9.988E+03	1.041E+04	8.984E+03	6.653E+03	7.892E+03	6.718E+03	1.032E+04	1.091E+04	8.076E+03
	Worst	**9.275E+03**	8.837E+03	9.955E+03	1.377E+04	1.486E+04	1.408E+04	1.314E+04	1.323E+04	1.232E+04	1.258E+04	1.162E+04	1.001E+04	1.381E+04	1.296E+04	1.220E+04
	Rank	1	2	3	14	15	9	10	11	7	6	5	4	13	12	8

TABLE 6 (continued): The mean, standard deviation, best and worst of the objective function value for problem no. 11 to 20 (with dimension = 50)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P11	Mean	2.561E+03	2.498E+03	**1.382E+03**	1.867E+04	1.781E+04	1.850E+04	1.121E+04	1.357E+04	3.759E+03	3.092E+03	3.455E+03	1.542E+03	9.775E+03	4.340E+03	1.730E+03
	Stdev	6.353E+02	3.649E+02	**9.775E+01**	2.131E+03	1.272E+03	1.550E+03	2.683E+03	2.294E+03	2.817E+03	6.560E+02	5.790E+02	1.650E+02	2.016E+03	7.120E+02	1.820E+02
	Best	1.660E+03	1.647E+03	**1.291E+03**	1.466E+04	1.467E+04	1.598E+04	6.000E+03	8.803E+03	1.746E+03	2.021E+03	2.249E+03	1.357E+03	6.750E+03	3.344E+03	1.459E+03
	Worst	4.040E+03	3.133E+03	**1.737E+03**	2.204E+04	1.966E+04	2.111E+04	1.638E+04	1.856E+04	1.017E+04	4.690E+03	4.404E+03	1.947E+03	1.407E+04	6.098E+03	2.224E+03
	Rank	5	4	1	15	13	14	11	12	8	6	7	2	10	9	3
P12	Mean	3.272E+09	3.216E+08	**1.556E+07**	2.743E+11	5.015E+11	4.435E+11	1.972E+09	1.616E+10	5.344E+08	1.179E+09	2.362E+09	1.225E+08	5.988E+09	1.287E+10	3.428E+08
	Stdev	3.129E+08	2.089E+08	**7.949E+06**	8.672E+10	7.201E+10	9.585E+10	9.745E+08	4.537E+09	3.020E+08	9.426E+08	5.898E+08	5.283E+07	2.816E+09	2.833E+09	2.415E+08
	Best	9.100E+07	1.149E+08	**5.847E+06**	1.212E+11	3.820E+11	2.199E+11	6.110E+08	8.377E+09	1.120E+08	2.660E+08	1.450E+09	4.852E+07	2.618E+09	7.707E+09	1.074E+08
	Worst	1.448E+09	1.118E+09	**3.432E+07**	4.218E+11	6.466E+11	5.974E+11	4.758E+09	2.651E+10	1.122E+09	3.526E+09	3.696E+09	2.225E+08	1.311E+10	2.013E+10	8.437E+08
	Rank	9	3	1	13	15	14	7	12	5	6	8	2	10	11	4
P13	Mean	7.316E+06	1.836E+06	**8.040E+04**	2.606E+11	4.061E+11	3.319E+11	5.331E+08	1.931E+09	1.213E+07	6.739E+07	1.308E+08	2.824E+06	3.866E+09	1.303E+09	1.696E+07
	Stdev	1.384E+07	1.072E+06	**2.980E+04**	1.231E+11	1.237E+11	5.737E+10	3.607E+08	8.377E+08	4.320E+06	6.273E+07	5.853E+07	1.332E+06	3.344E+09	3.014E+08	7.858E+06
	Best	4.984E+05	5.851E+05	**4.085E+04**	6.713E+10	1.741E+11	1.788E+11	1.314E+08	5.388E+08	5.430E+06	2.026E+07	4.006E+07	1.215E+06	5.271E+08	8.019E+08	6.067E+06
	Worst	6.532E+07	4.959E+06	**1.458E+05**	4.821E+11	5.442E+11	4.483E+11	1.248E+09	3.613E+09	2.201E+07	3.030E+08	2.214E+08	4.996E+06	1.112E+10	1.786E+09	3.665E+07
	Rank	4	2	1	13	15	14	9	11	5	7	8	3	12	10	6
P14	Mean	9.418E+05	6.256E+05	**1.499E+05**	1.198E+08	1.120E+08	1.008E+08	7.670E+06	1.942E+06	1.775E+05	4.030E+06	4.998E+05	2.618E+05	6.900E+06	2.168E+06	2.488E+05
	Stdev	5.075E+05	4.876E+05	**7.945E+04**	5.865E+07	6.597E+07	6.148E+07	7.727E+06	1.273E+06	1.010E+05	3.412E+06	2.609E+05	6.942E+05	4.200E+06	1.606E+06	2.146E+05
	Best	5.898E+04	7.694E+04	**6.092E+04**	3.699E+07	8.072E+06	3.496E+06	8.168E+05	2.702E+05	2.224E+04	6.237E+05	1.321E+05	2.726E+04	1.293E+06	3.149E+05	5.094E+04
	Worst	1.827E+06	1.872E+06	**3.467E+05**	2.278E+08	2.264E+08	2.009E+08	3.234E+07	5.660E+06	4.414E+05	1.486E+07	9.800E+05	3.200E+06	1.684E+07	5.835E+06	8.168E+05
	Rank	7	6	1	15	14	13	12	8	2	10	5	4	11	9	3
P15	Mean	1.050E+05	**9.360E+04**	1.395E+04	4.970E+10	6.752E+10	6.638E+10	7.127E+07	3.612E+07	1.336E+06	3.068E+06	3.015E+05	1.464E+05	6.172E+08	2.014E+07	2.490E+06
	Stdev	7.602E+04	**3.258E+03**	6.156E+03	2.809E+10	2.474E+10	1.394E+10	6.579E+07	2.399E+07	6.974E+05	5.098E+06	2.256E+05	7.272E+04	5.343E+08	1.264E+07	1.119E+06
	Best	2.506E+04	**5.098E+03**	5.356E+03	9.421E+09	1.713E+10	2.990E+10	2.235E+07	5.623E+06	4.803E+05	1.723E+05	8.081E+04	4.000E+04	5.904E+07	4.153E+06	1.055E+06
	Worst	3.047E+05	**1.714E+04**	2.829E+04	1.010E+11	1.064E+11	9.326E+10	3.261E+08	8.421E+07	3.110E+06	2.156E+07	1.024E+06	3.047E+05	1.776E+09	6.213E+07	4.813E+06
	Rank	3	1	2	13	15	14	11	10	6	8	5	4	12	9	7
P16	Mean	3.516E+03	**3.118E+03**	3.668E+03	7.873E+03	8.587E+03	9.172E+03	3.974E+03	4.424E+03	3.417E+03	3.646E+03	3.488E+03	3.634E+03	4.237E+03	4.089E+03	3.159E+03
	Stdev	4.390E+02	**4.410E+02**	2.830E+02	1.505E+03	1.626E+03	1.579E+03	3.870E+02	4.250E+02	3.530E+02	4.260E+02	4.190E+02	4.790E+02	4.040E+02	4.320E+02	3.220E+02
	Best	2.777E+03	**2.110E+03**	3.085E+03	6.368E+03	6.186E+03	6.595E+03	3.349E+03	3.689E+03	2.440E+03	2.933E+03	2.792E+03	2.967E+03	3.502E+03	3.553E+03	2.610E+03
	Worst	4.201E+03	**3.960E+03**	4.414E+03	1.350E+04	1.162E+04	1.260E+04	4.619E+03	5.121E+03	3.997E+03	4.325E+03	4.244E+03	4.364E+03	4.916E+03	4.916E+03	3.923E+03
	Rank	5	1	8	13	14	15	9	12	3	7	4	6	11	10	2
P17	Mean	3.232E+03	**2.421E+03**	2.510E+03	3.672E+03	4.151E+03	3.352E+03	4.934E+03	4.456E+03	4.400E+03	3.363E+03	3.181E+03	3.409E+03	3.480E+03	2.571E+03	2.544E+03
	Stdev	3.661E+02	**1.736E+02**	1.998E+02	3.130E+02	1.876E+02	2.706E+02	3.655E+02	3.287E+02	1.134E+02	2.910E+02	3.124E+02	3.688E+02	4.166E+02	1.501E+02	1.745E+02
	Best	2.964E+03	**2.112E+03**	2.211E+03	3.112E+03	3.902E+03	3.203E+03	4.583E+03	3.987E+03	4.290E+03	3.115E+03	2.822E+03	2.830E+03	2.368E+03	2.300E+03	2.112E+03
	Worst	3.580E+03	**2.812E+03**	2.891E+03	4.321E+03	4.231E+03	3.532E+03	5.348E+03	4.795E+03	4.420E+03	3.452E+03	3.427E+03	4.183E+03	4.020E+03	2.612E+03	2.712E+03
	Rank	6	1	2	11	12	7	15	14	13	8	5	10	9	4	3
P18	Mean	2.655E+06	**1.130E+06**	1.153E+06	1.785E+08	1.671E+08	1.344E+08	3.829E+06	3.831E+06	1.772E+06	3.096E+06	2.682E+06	1.554E+06	7.343E+06	3.118E+06	1.490E+06
	Stdev	1.294E+06	**5.215E+05**	4.725E+05	8.912E+07	8.145E+07	3.754E+07	1.671E+06	1.248E+06	7.920E+05	1.900E+06	1.031E+06	8.671E+05	3.808E+06	1.059E+06	6.458E+05
	Best	6.915E+05	**4.017E+05**	3.275E+05	5.116E+07	6.287E+07	8.608E+07	1.411E+06	1.992E+06	5.570E+05	6.770E+05	3.799E+05	4.348E+05	1.663E+06	1.351E+06	3.292E+05
	Worst	5.865E+06	**2.170E+06**	2.223E+06	4.084E+08	3.530E+08	2.083E+08	7.112E+06	7.076E+06	3.820E+06	6.993E+06	4.564E+06	4.251E+06	1.485E+07	5.574E+06	3.028E+06
	Rank	6	1	2	15	14	13	10	11	5	8	7	4	12	9	3
P19	Mean	3.535E+04	1.943E+04	**1.568E+04**	3.981E+09	3.900E+10	4.610E+10	9.894E+06	1.982E+07	7.233E+05	9.343E+05	1.905E+05	9.042E+04	7.942E+07	8.910E+06	7.542E+05
	Stdev	1.737E+04	3.530E+03	**4.415E+03**	1.768E+10	1.359E+10	1.605E+10	6.199E+06	1.135E+07	4.138E+05	1.542E+06	8.267E+04	5.160E+04	7.922E+07	3.696E+06	2.961E+05
	Best	1.030E+04	1.498E+04	**8.848E+03**	1.659E+10	1.231E+10	1.875E+10	9.664E+05	3.110E+06	2.604E+05	6.793E+04	6.364E+04	3.009E+04	6.263E+06	2.718E+06	3.686E+05
	Worst	6.868E+04	2.704E+04	**2.687E+04**	7.252E+10	6.798E+10	7.829E+10	2.122E+07	4.676E+07	1.894E+06	6.851E+06	3.698E+05	2.149E+05	9.963E+08	1.616E+07	1.536E+06
	Rank	3	2	1	13	14	15	10	11	6	8	5	4	12	9	7
P20	Mean	2.961E+03	2.618E+03	**2.472E+03**	4.191E+03	3.533E+03	3.294E+03	3.799E+03	3.333E+03	3.334E+03	3.171E+03	3.229E+03	3.330E+03	3.211E+03	3.099E+03	2.579E+03
	Stdev	6.751E+02	1.490E+02	**1.600E+02**	2.301E+02	2.939E+02	3.208E+02	4.532E+02	3.273E+02	3.575E+02	2.627E+02	3.256E+02	3.990E+02	3.761E+02	1.770E+02	1.400E+02
	Best	2.415E+03	2.367E+03	**2.266E+03**	3.830E+03	3.315E+03	2.837E+03	3.516E+03	3.112E+03	3.000E+03	2.909E+03	2.610E+03	3.164E+03	2.715E+03	2.846E+03	2.425E+03
	Worst	3.718E+03	2.952E+03	**2.835E+03**	4.679E+03	3.900E+03	3.982E+03	4.342E+03	3.709E+03	3.516E+03	3.512E+03	3.932E+03	3.956E+03	3.905E+03	3.376E+03	2.974E+03
	Rank	4	3	1	15	13	9	14	11	12	6	8	10	7	5	2

TABLE 6 (continued): The mean, standard deviation, best and worst of the objective function value for problem no. 21 to 30 (with dimension = 50)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P21	Mean	2.540E+03	2.639E+03	2.773E+03	3.034E+03	3.015E+03	3.050E+03	2.688E+03	2.812E+03	**2.469E+03**	2.670E+03	2.744E+03	2.766E+03	2.643E+03	2.750E+03	2.629E+03
	Stdev	3.872E+01	5.096E+01	5.308E+01	9.000E+01	6.120E+01	1.010E+02	4.032E+01	3.142E+01	**3.181E+01**	4.733E+01	4.300E+01	3.428E+01	3.895E+01	3.106E+01	5.727E+01
	Best	2.464E+03	2.563E+03	2.662E+03	2.847E+03	2.899E+03	2.832E+03	2.602E+03	2.740E+03	**2.536E+03**	2.593E+03	2.650E+37	2.716E+03	2.583E+03	2.695E+03	2.540E+03
	Worst	2.603E+03	2.717E+03	2.874E+03	3.221E+03	3.154E+03	3.208E+03	2.756E+03	2.866E+03	**2.762E+03**	2.756E+03	2.804E+03	2.835E+03	2.711E+03	2.821E+03	2.734E+03
	Rank	2	3	10	13	12	14	6	11	1	5	7	9	4	8	15
P22	Mean	9.077E+03	**8.128E+03**	1.090E+04	1.436E+04	1.443E+04	1.334E+04	1.344E+04	1.410E+04	1.189E+04	8.996E+03	9.727E+03	9.883E+03	1.350E+04	1.378E+04	1.098E+04
	Stdev	1.836E+03	**3.052E+03**	7.670E+02	8.010E+02	7.056E+02	8.220E+02	9.850E+02	9.531E+02	1.703E+03	4.028E+03	2.691E+03	1.035E+03	7.530E+02	1.228E+03	3.738E+03
	Best	2.391E+03	**3.100E+03**	9.237E+03	1.230E+04	1.325E+04	1.219E+04	1.201E+04	1.253E+04	5.539E+03	2.475E+03	4.230E+03	7.862E+03	1.203E+04	1.078E+04	2.363E+03
	Worst	1.113E+04	**1.124E+04**	1.212E+04	1.575E+04	1.551E+04	1.521E+04	1.533E+04	1.567E+04	1.365E+04	1.403E+04	1.336E+04	1.170E+04	1.467E+04	1.597E+04	1.341E+04
	Rank	3	1	6	14	15	9	10	13	8	2	4	5	11	12	7
P23	Mean	3.312E+03	5.250E+03	**3.026E+03**	3.970E+03	3.831E+03	4.393E+03	3.255E+03	3.437E+03	3.247E+03	3.188E+03	3.369E+03	3.757E+03	3.200E+03	3.224E+03	4.316E+03
	Stdev	9.578E+01	1.720E+03	**8.013E+01**	2.472E+02	1.490E+02	1.590E+02	8.060E+00	1.130E+02	1.028E+02	5.405E+01	1.760E+02	2.300E+02	9.000E+01	1.170E+02	2.684E+02
	Best	3.132E+03	3.736E+03	**2.898E+03**	3.660E+03	3.406E+03	4.068E+03	3.151E+03	3.204E+03	3.081E+03	3.094E+03	3.064E+03	3.339E+03	3.092E+03	3.093E+03	3.826E+03
	Worst	3.518E+03	9.753E+03	**3.205E+03**	4.463E+03	4.063E+03	4.613E+03	3.453E+03	3.590E+03	3.402E+03	3.286E+03	3.593E+03	4.199E+03	3.477E+03	3.475E+03	4.828E+03
	Rank	7	15	1	12	11	14	6	9	5	2	8	10	3	4	13
P24	Mean	3.510E+03	3.724E+03	3.644E+03	4.533E+03	4.257E+03	4.791E+03	3.432E+03	3.737E+03	3.475E+03	3.347E+03	3.783E+03	4.503E+03	3.329E+03	3.585E+03	**3.077E+03**
	Stdev	8.371E+01	1.400E+02	1.333E+02	3.530E+02	1.279E+02	2.710E+02	6.816E+01	5.820E+01	9.850E+01	3.863E+01	5.400E+01	3.240E+02	4.012E+01	5.400E+01	**2.731E+01**
	Best	3.398E+03	3.527E+03	3.393E+03	3.907E+03	4.007E+03	4.231E+03	3.344E+03	3.608E+03	3.309E+03	3.286E+03	3.672E+03	3.866E+03	3.238E+03	3.496E+03	**3.039E+03**
	Worst	3.689E+03	3.958E+03	3.841E+03	5.372E+03	4.512E+03	5.371E+03	3.544E+03	3.850E+03	3.665E+03	3.416E+03	3.884E+03	5.035E+03	3.405E+03	3.709E+03	**3.124E+03**
	Rank	6	9	8	14	12	15	4	10	5	3	11	13	2	7	1
P25	Mean	3.120E+03	3.291E+03	**3.064E+03**	9.201E+03	1.000E+04	1.118E+04	3.369E+03	4.291E+03	3.165E+03	3.218E+03	3.500E+03	3.067E+03	3.386E+03	3.880E+03	3.076E+03
	Stdev	3.783E+01	7.080E+01	**4.295E+01**	1.355E+03	9.120E+02	9.680E+02	6.501E+01	2.620E+02	3.490E+01	5.260E+01	8.927E+01	2.961E+01	7.600E+01	1.380E+02	3.271E+01
	Best	3.021E+03	3.171E+03	**2.958E+03**	5.963E+03	8.406E+03	9.060E+03	3.258E+03	3.791E+03	3.104E+03	3.076E+03	3.374E+03	3.021E+03	3.291E+03	3.661E+03	3.006E+03
	Worst	3.186E+03	3.447E+03	**3.144E+03**	1.163E+04	1.213E+04	1.267E+04	3.539E+03	4.676E+03	3.221E+03	3.297E+03	3.681E+03	3.117E+03	3.556E+03	4.132E+03	3.134E+03
	Rank	4	7	1	13	14	15	8	12	5	6	10	2	9	11	3
P26	Mean	3.845E+03	4.819E+03	4.273E+03	1.528E+04	1.483E+04	1.540E+04	5.231E+03	8.992E+03	8.355E+03	3.814E+03	6.496E+03	5.543E+03	4.493E+03	6.142E+03	**3.797E+03**
	Stdev	2.528E+02	1.206E+03	2.653E+03	8.738E+02	7.060E+02	4.410E+02	2.323E+03	1.819E+03	2.726E+03	2.000E+02	1.014E+03	3.231E+03	1.052E+03	4.530E+02	**1.725E+03**
	Best	3.102E+03	3.635E+03	2.959E+03	1.322E+04	1.326E+04	1.479E+04	3.874E+03	6.558E+03	3.718E+03	3.379E+03	5.037E+03	3.017E+03	3.906E+03	5.329E+03	**2.996E+03**
	Worst	4.178E+03	8.879E+03	1.083E+04	1.669E+04	1.611E+04	1.620E+04	1.067E+04	1.256E+04	1.240E+04	4.147E+03	8.990E+03	1.121E+04	8.904E+03	6.726E+03	**1.022E+04**
	Rank	3	6	4	14	13	15	7	12	11	2	10	8	5	9	1
P27	Mean	3.200E+03	3.724E+03	**3.200E+03**	3.200E+03	3.200E+03	4.807E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.242E+03	3.200E+03	3.200E+03	3.200E+03
	Stdev	0.000E+00	3.270E+02	**6.940E-05**	1.380E-03	1.230E-03	8.590E+02	1.650E-04	1.230E-04	8.160E-05	1.200E-04	1.900E-04	1.500E+02	1.120E-04	1.640E-04	8.520E-05
	Best	3.200E+03	3.200E+03	**3.200E+03**	3.200E+03	3.200E+03	3.221E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03
	Worst	3.200E+03	4.667E+03	**3.200E+03**	3.200E+03	3.200E+03	5.864E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.872E+03	3.200E+03	3.200E+03	3.200E+03
	Rank	12	14	1	11	10	15	8	6	2	5	9	13	4	7	3
P28	Mean	3.311E+03	3.485E+03	**3.300E+03**	3.356E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.319E+03	3.709E+03	3.371E+03	3.300E+03	3.355E+03	3.338E+03
	Stdev	3.784E+01	1.510E+02	**7.090E-05**	5.100E+01	1.141E-03	8.670E-05	1.610E-04	1.420E-04	1.040E-04	6.240E+01	4.270E+02	6.220E+01	1.070E-04	2.470E+02	7.520E+01
	Best	3.300E+03	3.300E+03	**3.300E+03**	3.268E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.294E+03	3.300E+03	3.300E+03	3.300E+03
	Worst	3.458E+03	3.718E+03	**3.300E+03**	3.462E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.540E+03	4.265E+03	3.492E+03	3.300E+03	4.407E+03	3.528E+03
	Rank	8	14	1	12	7	2	6	5	3	9	15	13	4	11	10
P29	Mean	3.583E+03	4.279E+03	4.901E+03	4.944E+03	6.121E+03	8.707E+03	5.799E+03	8.612E+03	4.956E+03	4.755E+03	6.342E+03	4.912E+03	3.853E+03	4.799E+03	**3.769E+03**
	Stdev	1.612E+02	3.969E+02	3.486E+02	4.135E+02	1.210E+02	1.310E+02	4.200E+02	6.979E+02	3.893E+02	3.791E+02	7.400E+02	4.693E+02	1.704E+02	2.830E+02	**1.659E+02**
	Best	3.355E+03	3.540E+03	4.394E+03	4.396E+03	5.516E+03	8.104E+03	4.887E+03	7.572E+03	4.960E+03	4.299E+03	5.319E+03	3.894E+03	3.242E+03	4.205E+03	**3.250E+03**
	Worst	3.507E+03	3.962E+03	4.516E+03	4.518E+03	5.738E+03	8.326E+03	4.999E+03	7.794E+03	4.182E+03	4.400E+03	5.531E+03	3.916E+03	3.465E+03	4.427E+03	**3.472E+03**
	Rank	2	5	4	9	12	15	11	14	10	7	13	8	3	6	1
P30	Mean	5.182E+05	**3.412E+05**	2.363E+06	7.658E+10	7.275E+10	8.307E+10	6.499E+07	2.085E+08	8.898E+07	7.352E+06	3.325E+06	1.037E+07	1.583E+08	6.814E+07	6.381E+06
	Stdev	1.649E+06	**6.003E+05**	7.170E+05	2.638E+10	2.182E+10	1.957E+10	3.182E+07	6.873E+07	5.870E+07	6.173E+06	2.070E+06	2.854E+06	1.014E+08	3.611E+07	5.308E+06
	Best	9.237E+03	**1.027E+04**	1.617E+06	2.277E+11	3.052E+10	5.251E+10	1.799E+07	6.679E+07	1.297E+07	2.250E+06	9.808E+05	5.325E+06	4.186E+07	1.860E+07	7.561E+05
	Worst	7.505E+06	**1.929E+06**	3.781E+06	1.124E+11	1.252E+11	1.270E+11	1.278E+08	3.639E+08	2.357E+08	2.089E+07	7.900E+06	1.657E+07	5.007E+08	1.362E+08	2.109E+07
	Rank	2	1	3	14	13	15	8	12	10	6	4	7	11	9	5

TABLE 7: The mean, standard deviation, best and worst of the objective function value for problem no. 1 to 10 (with dimension = 100)

Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P1	Mean	8.605E+10	2.503E+11	**7.494E+09**	1.612E+12	1.623E+12	1.854E+12	1.772E+11	8.031E+10	2.788E+10	1.144E+11	4.944E+11	8.422E+09	2.846E+11	7.358E+11	1.163E+10
	Stdev	1.940E+10	3.024E+10	**8.558E+08**	1.483E+11	8.434E+10	8.510E+10	2.563E+10	6.011E+10	7.009E+09	1.723E+10	3.618E+10	1.272E+09	4.611E+10	5.163E+10	1.634E+09
	Best	5.562E+10	1.849E+11	**5.770E+09**	1.339E+12	1.292E+12	1.679E+12	1.351E+11	6.308E+11	1.584E+10	8.257E+10	4.173E+11	6.387E+09	1.787E+11	6.258E+11	9.002E+09
	Worst	1.461E+11	2.984E+10	**9.400E+09**	1.991E+12	1.800E+12	2.019E+12	2.176E+11	8.888E+11	4.814E+10	1.528E+11	5.640E+11	1.146E+10	3.664E+10	8.068E+11	1.483E+10
	Rank	6	9	1	13	14	15	8	5	4	7	11	2	10	12	3
P2	Mean	1.350E+143	2.040E+124	2.200E+103	2.380E+169	2.960E+166	7.520E+167	9.640E+136	7.840E+139	1.570E+122	5.370E+129	3.990E+134	2.380E+100	2.070E+145	8.170E+138	**2.580E+97**
	Stdev	6.030E+143	9.110E+124	9.810E+103	inf	inf	inf	4.310E+137	2.040E+140	6.940E+122	2.060E+130	1.750E+135	1.060E+101	9.250E+145	3.570E+139	**7.880E+97**
	Best	9.900E+118	9.980E+106	7.430E+86	1.990E+153	5.330E+155	2.840E+156	4.550E+117	1.750E+130	9.430E+104	3.790E+110	7.870E+120	2.910E+87	4.490E+119	1.220E+127	**4.420E+88**
	Worst	2.700E+144	4.070E+125	4.388E+104	1.960E+170	1.860E+170	2.010E+170	1.930E+138	8.650E+140	3.100E+123	9.170E+130	7.860E+135	4.760E+101	4.140E+146	1.590E+140	**3.450E+98**
	Rank	11	5	3	15	13	14	8	10	4	6	7	2	12	9	1
P3	Mean	2.706E+05	2.306E+05	**2.124E+05**	5.326E+05	7.759E+05	2.768E+07	4.174E+05	4.727E+05	4.437E+05	3.386E+05	2.850E+05	3.786E+05	5.757E+05	5.675E+05	4.460E+05
	Stdev	2.933E+04	1.692E+04	**7.230E+04**	3.512E+05	1.327E+06	1.210E+08	4.438E+04	1.896E+05	1.469E+05	2.664E+04	2.799E+04	2.610E+04	1.794E+05	4.961E+05	7.260E+04
	Best	2.122E+05	2.024E+05	**1.416E+05**	3.638E+05	3.641E+05	3.691E+05	3.504E+05	3.215E+05	3.374E+05	2.796E+05	2.567E+05	3.356E+05	3.713E+05	3.622E+05	3.207E+05
	Worst	3.242E+05	2.635E+05	**4.070E+05**	1.962E+06	6.372E+06	5.421E+08	5.323E+05	1.116E+06	1.006E+06	3.902E+05	3.380E+05	4.375E+05	9.660E+05	2.617E+06	6.017E+05
	Rank	3	2	1	11	14	15	7	10	8	5	4	6	13	12	9
P4	Mean	2.486E+03	5.312E+03	**1.015E+03**	5.377E+04	5.738E+04	7.329E+04	3.582E+03	1.251E+04	1.505E+03	2.852E+03	7.791E+03	1.059E+03	4.769E+03	1.115E+04	1.123E+03
	Stdev	4.949E+03	7.840E+02	**5.222E+01**	8.506E+03	6.815E+03	7.609E+03	4.481E+02	1.946E+03	1.520E+02	5.580E+02	8.980E+02	5.653E+01	1.171E+03	1.184E+03	4.699E+01
	Best	1.823E+03	3.500E+03	**9.158E+02**	3.202E+04	4.248E+04	5.373E+04	2.481E+03	8.767E+03	1.186E+03	1.920E+03	5.622E+03	9.790E+02	2.888E+03	9.063E+03	1.044E+03
	Worst	3.491E+03	6.318E+03	**1.103E+03**	6.878E+04	6.754E+04	8.457E+04	4.189E+03	1.562E+04	1.900E+03	3.696E+03	8.904E+03	1.167E+03	7.759E+03	1.351E+04	1.197E+03
	Rank	5	9	1	13	14	15	7	12	4	6	10	2	8	11	3
P5	Mean	1.469E+03	1.462E+03	1.362E+03	1.827E+03	1.820E+03	1.719E+03	1.665E+03	1.704E+03	1.460E+03	1.551E+03	1.623E+03	1.390E+03	1.525E+03	1.653E+03	**1.357E+03**
	Stdev	6.376E+01	5.975E+01	4.637E+01	3.792E+01	5.444E+01	4.297E+01	7.545E+01	5.625E+01	4.999E+01	8.781E+01	5.436E+01	6.158E+01	6.844E+01	6.807E+01	**7.930E+01**
	Best	1.335E+03	1.335E+03	1.269E+03	1.770E+03	1.712E+03	1.659E+03	1.505E+03	1.590E+03	1.397E+03	1.406E+03	1.517E+03	1.265E+03	1.393E+03	1.527E+03	**1.204E+03**
	Worst	1.582E+03	1.558E+03	1.439E+03	1.892E+03	1.935E+03	1.807E+03	1.829E+03	1.821E+03	1.577E+03	1.713E+03	1.725E+03	1.516E+03	1.670E+03	1.751E+03	**1.487E+03**
	Rank	6	5	2	15	14	13	11	12	4	8	9	3	7	10	1
P6	Mean	6.900E+02	6.830E+02	6.862E+02	7.113E+02	7.120E+02	7.074E+02	6.878E+02	7.008E+02	6.880E+02	6.780E+02	6.880E+02	6.850E+02	6.710E+02	6.890E+02	**6.470E+02**
	Stdev	6.520E+00	5.783E+00	2.964E+00	4.085E+00	4.012E+00	3.261E+00	6.890E+00	4.820E+00	6.560E+00	7.220E+00	3.590E+00	4.650E+00	6.290E+00	5.120E+00	**8.027E+00**
	Best	6.720E+02	6.735E+02	6.804E+02	7.044E+02	7.059E+02	7.023E+02	6.730E+02	6.940E+02	6.749E+02	6.620E+02	6.840E+02	6.750E+02	6.590E+02	6.790E+02	**6.340E+02**
	Worst	7.020E+02	7.009E+02	6.913E+02	7.210E+02	7.192E+02	7.135E+02	6.977E+02	7.112E+02	6.961E+02	6.940E+02	6.950E+02	6.930E+02	6.860E+02	7.000E+02	**6.640E+02**
	Rank	11	4	6	14	15	13	7	12	8	3	8	5	2	10	1
P7	Mean	1.824E+03	2.462E+03	2.113E+03	3.756E+03	3.451E+03	4.045E+03	2.364E+03	2.833E+03	2.261E+03	2.256E+03	2.541E+03	2.718E+03	2.231E+03	2.626E+03	**1.753E+03**
	Stdev	5.628E+01	1.197E+02	1.551E+02	1.930E+02	1.940E+02	1.134E+02	1.513E+02	1.141E+02	1.290E+02	1.139E+02	1.130E+02	1.940E+02	1.300E+02	1.140E+02	**5.277E+01**
	Best	1.696E+03	2.279E+03	1.822E+03	3.389E+03	3.085E+03	3.737E+03	2.179E+03	2.664E+03	2.077E+03	2.001E+03	2.326E+03	2.380E+03	2.033E+03	2.472E+03	**1635E+03**
	Worst	1.919E+03	2.789E+03	2.392E+03	4.165E+03	3.762E+03	4.214E+03	2.735E+03	3.117E+03	2.502E+03	2.478E+03	2.703E+03	3.033E+03	2.486E+03	2.856E+03	**1.859E+03**
	Rank	2	8	3	14	13	15	7	12	6	5	9	11	4	10	1
P8	Mean	1.944E+03	1.853E+03	1.914E+03	2.320E+03	2.317E+03	2.248E+03	2.054E+03	2.135E+03	1.914E+03	1.929E+03	2.034E+03	1.905E+03	1.872E+03	2.012E+03	**1.719E+03**
	Stdev	7.922E+01	7.282E+01	6.496E+01	6.276E+01	5.192E+01	7.164E+01	9.488E+01	5.302E+01	7.450E+01	8.115E+01	7.137E+01	4.955E+01	6.158E+01	5.247E+01	**9.668E+01**
	Best	1.820E+03	1.681E+03	1.793E+03	2.177E+03	2.224E+03	2.082E+03	1.853E+03	2.021E+03	1.785E+03	1.745E+03	1.902E+03	1.803E+03	1.773E+03	1.880E+03	**1.551E+03**
	Worst	2.121E+03	2.008E+03	2.024E+03	2.437E+03	2.395E+03	2.364E+03	2.198E+03	2.216E+03	2.025E+03	2.020E+03	2.138E+03	2.022E+03	1.965E+03	2.089E+03	**1.889E+03**
	Rank	8	2	6	15	14	13	11	12	5	7	10	4	3	9	1
P9	Mean	7.171E+03	3.081E+04	4.412E+04	6.858E+04	6.702E+04	6.546E+04	4.937E+04	5.450E+04	**4.751E+03**	3.367E+04	4.712E+04	4.507E+04	3.250E+04	4.759E+04	5.683E+04
	Stdev	5.536E+03	7.121E+03	7.545E+03	4.187E+03	5.081E+03	3.889E+03	6.930E+03	5.416E+03	**7.333E+03**	7.049E+03	3.886E+03	5.616E+03	6.412E+03	4.385E+03	8.213E+03
	Best	3.963E+03	1.954E+04	3.307E+04	5.874E+04	5.570E+04	5.838E+04	3.469E+04	4.371E+04	**3.686E+04**	2.193E+04	4.104E+04	3.539E+04	2.015E+04	4.034E+04	3.861E+04
	Worst	1.355E+04	4.363E+04	6.160E+45	7.612E+04	7.431E+04	7.429E+04	6.231E+04	6.718E+04	**6.497E+04**	4.808E+04	5.524E+04	5.522E+04	4.625E+04	5.946E+04	6.772E+04
	Rank	2	3	6	15	14	13	10	11	1	5	8	7	4	9	12
P10	Mean	2.019E+04	2.112E+04	**1.661E+04**	2.705E+04	2.702E+04	2.424E+04	2.585E+04	2.682E+04	2.321E+04	2.490E+04	2.478E+04	1.876E+04	2.701E+04	2.732E+04	2.365E+04
	Stdev	1.672E+03	9.471E+02	**1.452E+03**	1.546E+03	1.484E+03	1.018E+03	1.392E+03	1.662E+03	1.079E+03	1.863E+03	1.522E+03	8.330E+02	1.437E+03	1.641E+03	1.499E+03
	Best	1.738E+04	1.941E+04	**1.436E+04**	2.285E+04	2.456E+04	2.191E+04	2.365E+04	2.406E+04	2.103E+04	2.181E+04	2.185E+04	1.693E+04	2.476E+04	2.475E+04	2.147E+04
	Worst	2.311E+04	2.278E+04	**1.947E+04**	2.902E+04	3.055E+04	2.611E+04	2.840E+04	3.138E+04	2.472E+04	2.882E+04	2.884E+04	1.999E+04	3.079E+04	3.013E+04	2.648E+04
	Rank	3	4	1	14	13	7	10	11	5	9	8	2	12	15	6

TABLE 7 (continued): The mean, standard deviation, best and worst of the objective function value for problem no. 11 to 20 (with dimension = 100)

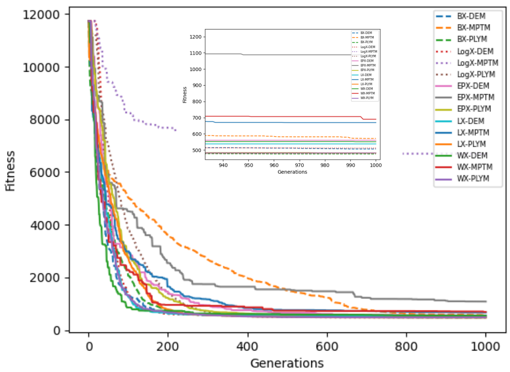
Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P11	Mean	4.648E+04	3.886E+04	**7.842E+04**	8.693E+05	3.532E+05	1.710E+06	1.559E+05	1.446E+04	1.677E+05	9.035E+04	6.236E+04	2.337E+04	1.807E+05	1.510E+05	1.113E+05
	Stdev	1.314E+04	9.035E+03	**1.853E+03**	9.321E+05	1.369E+05	5.067E+06	4.197E+04	3.662E+04	5.216E+04	2.723E+04	1.010E+04	7.142E+03	4.843E+04	3.022E+04	2.546E+04
	Best	2.823E+04	2.492E+04	**4.564E+03**	1.553E+05	1.641E+05	2.495E+05	9.127E+04	8.767E+04	1.169E+05	5.634E+04	4.088E+04	1.149E+04	1.032E+05	1.084E+05	6.388E+04
	Worst	8.150E+04	6.003E+04	**1.160E+04**	3.234E+06	6.727E+05	2.311E+07	2.745E+05	2.099E+05	3.084E+05	1.563E+05	8.005E+04	3.491E+04	2.603E+05	2.049E+05	1.591E+05
	Rank	5	4	1	14	13	15	10	8	11	7	6	3	12	9	8
P12	Mean	2.031E+10	1.192E+10	**1.551E+09**	6.872E+11	9.375E+11	9.930E+11	3.269E+10	1.426E+11	6.686E+09	3.550E+10	5.087E+10	2.010E+09	8.897E+10	1.134E+11	4.176E+09
	Stdev	6.980E+09	3.929E+09	**2.861E+08**	1.373E+11	1.089E+11	1.338E+11	1.120E+10	2.823E+10	2.216E+09	1.736E+10	1.040E+10	4.072E+08	2.202E+10	1.643E+10	1.234E+09
	Best	8.799E+09	7.502E+09	**1.214E+09**	4.759E+11	6.983E+11	7.007E+11	1.867E+10	1.014E+11	2.817E+09	8.115E+09	3.376E+10	1.236E+09	5.765E+10	8.351E+10	2.565E+09
	Worst	3.069E+10	2.303E+10	**2.357E+09**	1.018E+12	1.139E+12	1.217E+12	5.719E+10	1.973E+11	1.024E+11	8.304E+10	7.477E+10	2.727E+09	1.349E+12	1.510E+11	6.689E+09
	Rank	6	5	1	13	14	15	7	12	4	8	9	2	10	11	3
P13	Mean	1.302E+09	4.128E+08	**4.152E+06**	2.388E+11	2.954E+11	3.278E+11	5.000E+09	1.866E+10	9.322E+07	3.447E+09	3.314E+09	3.947E+07	2.207E+10	1.603E+10	1.342E+08
	Stdev	7.360E+08	1.780E+08	**1.106E+06**	6.458E+10	2.823E+10	3.318E+10	3.054E+09	4.539E+09	2.802E+07	1.265E+09	1.099E+09	9.216E+06	1.282E+10	3.667E+09	3.493E+07
	Best	3.574E+08	1.359E+08	**2.364E+06**	1.320E+11	2.343E+11	2.704E+11	1.261E+09	9.403E+09	5.762E+07	1.429E+09	1.458E+09	2.226E+07	8.498E+10	9.001E+08	7.331E+07
	Worst	2.833E+09	8.301E+08	**6.563E+06**	3.618E+11	3.515E+11	3.924E+11	1.077E+10	2.971E+10	1.772E+08	5.667E+09	5.610E+09	5.529E+07	6.313E+10	2.308E+10	2.158E+08
	Rank	6	5	1	13	14	15	9	11	3	8	7	2	12	10	4
P14	Mean	5.834E+06	1.331E+06	1.123E+06	6.878E+07	6.316E+07	4.973E+07	1.408E+07	6.285E+06	1.439E+06	1.358E+07	2.739E+06	1.445E+06	1.679E+07	4.066E+06	**9.914E+05**
	Stdev	1.963E+06	4.932E+05	3.493E+05	3.784E+07	2.646E+07	2.356E+07	6.252E+06	2.438E+06	5.413E+05	5.547E+06	1.135E+06	5.926E+05	4.380E+06	8.853E+05	**3.968E+05**
	Best	3.603E+06	6.784E+05	6.207E+05	2.455E+07	1.724E+07	1.720E+07	3.915E+06	3.202E+06	5.834E+05	4.190E+06	1.239E+06	2.945E+05	8.628E+06	2.727E+06	**4.862E+05**
	Worst	1.122E+07	2.319E+06	1.989E+06	1.701E+08	1.140E+08	1.014E+08	2.783E+07	1.141E+07	2.628E+06	2.281E+07	5.337E+06	2.405E+06	2.468E+07	5.435E+06	**1.678E+06**
	Rank	8	3	2	15	14	13	11	9	4	10	6	5	12	7	1
P15	Mean	1.288E+08	6.107E+06	**2.283E+05**	1.681E+11	1.879E+11	1.897E+11	2.040E+09	2.534E+09	1.761E+07	5.125E+08	2.098E+08	5.404E+06	7.773E+09	2.103E+09	2.463E+07
	Stdev	1.074E+08	3.223E+06	**8.059E+04**	4.226E+10	3.255E+10	3.260E+10	1.859E+09	9.444E+08	6.707E+06	2.936E+08	7.028E+07	1.462E+06	4.231E+09	6.713E+08	7.086E+06
	Best	1.316E+07	1.288E+06	**1.139E+05**	9.177E+10	1.308E+11	1.057E+11	2.781E+08	1.033E+09	8.517E+06	1.699E+08	9.668E+07	2.903E+06	1.738E+09	1.314E+09	1.246E+07
	Worst	3.766E+08	1.326E+07	**3.874E+05**	2.307E+11	2.524E+11	2.411E+11	8.070E+09	4.418E+09	2.958E+07	1.252E+09	3.263E+08	7.858E+06	1.506E+10	3.579E+09	4.239E+07
	Rank	6	3	1	13	14	15	9	11	4	8	7	2	12	10	5
P16	Mean	8.021E+03	6.991E+03	**6.402E+03**	1.942E+04	2.111E+04	2.264E+04	9.307E+03	1.148E+04	7.240E+03	9.176E+03	1.018E+04	6.890E+03	1.002E+04	1.028E+04	6.432E+03
	Stdev	8.250E+02	9.682E+02	**4.985E+02**	2.384E+03	2.417E+03	1.952E+03	5.930E+02	1.002E+03	5.660E+02	9.710E+02	9.360E+02	4.730E+02	7.630E+02	6.970E+02	8.110E+02
	Best	6.674E+03	5.563E+03	**5.162E+03**	1.444E+04	1.515E+04	1.965E+04	7.992E+03	9.567E+03	6.225E+03	7.549E+03	8.275E+03	5.913E+03	8.551E+03	8.918E+03	4.893E+03
	Worst	9.477E+03	8.828E+03	**7.223E+03**	2.301E+04	2.487E+04	2.751E+04	1.018E+04	1.387E+04	8.261E+03	1.056E+04	1.203E+04	7.735E+03	1.149E+04	1.139E+04	7.665E+03
	Rank	6	4	1	13	14	15	8	12	5	7	10	3	9	11	2
P17	Mean	**7.070E+03**	7.319E+03	7.420E+03	7.560E+03	7.290E+03	8.240E+03	8.242E+03	8.380E+03	7.700E+03	7.522E+03	8.060E+03	7.930E+03	7.730E+03	7.458E+03	7.466E+03
	Stdev	**6.402E+02**	6.622E+02	6.823E+02	7.047E+02	7.066E+02	9.638E+02	9.033E+02	8.177E+02	9.200E+02	7.034E+02	8.067E+02	8.565E+02	6.955E+02	6.900E+02	6.923E+02
	Best	**6.308E+03**	6.709E+03	6.820E+03	6.839E+03	6.367E+03	7.304E+03	7.323E+03	7.564E+03	6.821E+03	6.894E+03	7.105E+03	7.087E+03	7.004E+03	6.749E+03	6.790E+03
	Worst	**7.770E+03**	7.806E+03	8.020E+03	8.263E+03	7.902E+03	8.900E+03	9.108E+03	8.820E+03	8.284E+03	7.945E+03	8.158E+03	8.232E+03	8.017E+03	8.197E+03	8.034E+03
	Rank	1	3	4	8	2	13	14	15	9	7	12	11	10	5	6
P18	Mean	6.394E+06	2.229E+06	**1.963E+06**	1.104E+08	8.516E+07	9.719E+07	7.715E+06	6.249E+06	2.314E+06	6.792E+06	4.043E+06	2.164E+06	1.557E+07	5.719E+06	2.214E+06
	Stdev	2.687E+06	6.929E+05	**4.289E+05**	5.072E+07	2.715E+07	4.551E+07	2.234E+06	1.725E+06	8.437E+05	3.095E+06	1.451E+06	6.033E+05	8.889E+06	2.611E+06	8.083E+05
	Best	2.985E+06	1.288E+06	**1.293E+06**	4.741E+07	3.520E+07	3.476E+06	4.006E+06	4.033E+06	8.005E+05	2.415E+06	1.987E+06	1.325E+06	4.850E+06	1.659E+06	9.066E+05
	Worst	1.372E+07	4.052E+06	**2.885E+06**	2.105E+08	1.291E+08	2.335E+08	1.121E+07	9.912E+06	4.399E+06	1.526E+07	7.817E+06	3.361E+06	3.283E+07	1.275E+07	3.611E+06
	Rank	9	4	1	15	13	14	11	8	5	10	6	2	12	7	3
P19	Mean	4.107E+08	8.391E+06	**9.653E+05**	2.411E+11	2.575E+11	2.521E+11	1.319E+09	2.498E+09	2.788E+07	7.819E+08	2.388E+08	7.819E+06	7.318E+09	2.095E+09	5.090E+07
	Stdev	5.155E+08	3.935E+06	**4.196E+05**	6.797E+10	4.448E+10	3.288E+10	9.286E+08	8.903E+08	1.355E+07	5.512E+08	9.709E+07	4.206E+06	7.181E+09	5.295E+08	2.396E+07
	Best	2.223E+07	3.523E+06	**4.129E+05**	9.440E+10	1.418E+11	1.972E+11	4.092E+08	1.157E+09	9.966E+06	1.758E+08	1.174E+08	4.075E+06	2.159E+09	1.244E+09	1.854E+07
	Worst	2.057E+09	1.999E+07	**1.979E+06**	3.162E+11	3.069E+11	3.049E+11	4.062E+09	5.267E+09	5.502E+07	2.468E+09	4.330E+08	2.242E+07	3.384E+10	3.098E+09	1.105E+08
	Rank	7	3	1	13	15	14	9	11	4	8	6	2	12	10	5
P20	Mean	3.860E+03	3.606E+03	**3.482E+03**	5.209E+03	5.398E+03	4.809E+03	4.708E+03	4.093E+03	4.421E+03	4.906E+03	4.448E+03	4.829E+03	4.389E+03	4.109E+03	3.998E+03
	Stdev	4.478E+02	3.924E+02	**3.082E+02**	3.282E+02	3.980E+02	4.077E+02	4.986E+02	4.442E+02	4.623E+02	4.200E+02	4.313E+02	4.977E+02	4.634E+02	4.841E+02	4.012E+02
	Best	3.395E+03	3.200E+03	**3.106E+03**	4.827E+03	4.976E+03	4.309E+03	4.268E+03	3.507E+03	3.905E+03	4.521E+03	4.000E+03	4.378E+03	3.856E+03	3.623E+03	3.508E+03
	Worst	4.379E+03	4.054E+03	**3.866E+03**	5.603E+03	5.821E+03	5.397E+03	5.345E+03	4.500E+03	5.003E+03	5.486E+03	4.964E+03	5.362E+03	4.869E+03	4.603E+03	4.482E+03
	Rank	3	2	1	14	15	11	10	5	8	13	9	12	7	6	4

TABLE 7 (continued): The mean, standard deviation, best and worst of the objective function value for problem no. 21 to 30 (with dimension = 100)

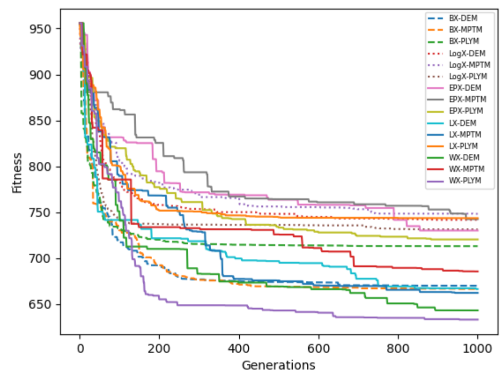
Problems		BX-DEM	BX-MPTM	BX-PLYM	LogX-DEM	LogX-MPTM	LogX-PLYM	EPX-DEM	EPX-MPTM	EPX-PLYM	LX-DEM	LX-MPTM	LX-PLYM	WX-DEM	WX-MPTM	WX-PLYM
P21	Mean	**3.328E+03**	3.602E+03	4.140E+03	4.727E+03	4.331E+03	4.862E+03	3.609E+03	3.810E+03	3.506E+03	3.608E+03	3.703E+03	4.085E+03	3.510E+03	3.656E+03	3.818E+03
	Stdev	**1.060E+02**	8.966E+01	2.719E+02	1.988E+02	1.591E+02	1.930E+02	1.089E+02	7.236E+01	1.140E+02	1.220E+02	6.134E+01	1.090E+02	1.050E+02	8.144E+01	1.057E+02
	Best	**3.031E+03**	3.432E+03	3.876E+03	4.343E+03	4.118E+03	4.546E+03	3.438E+03	3.698E+03	3.304E+03	3.458E+03	3.558E+03	3.887E+03	3.325E+03	3.510E+03	3.571E+03
	Worst	**3.474E+03**	3.811E+03	4.862E+03	5.032E+03	4.569E+03	5.295E+03	3.893E+03	3.942E+03	3.818E+03	3.913E+03	3.780E+03	4.281E+03	3.846E+03	3.842E+03	3.971E+03
	Rank	1	4	12	14	13	15	6	9	2	5	8	11	3	7	10
P22	Mean	2.426E+04	2.285E+04	**2.169E+04**	2.991E+04	3.039E+04	2.840E+04	2.955E+04	2.976E+04	2.738E+04	2.242E+04	2.523E+04	2.237E+04	2.988E+04	3.006E+04	2.777E+04
	Stdev	1.323E+03	4.308E+03	**1.348E+03**	9.469E+02	1.152E+03	8.395E+02	1.203E+03	1.079E+03	1.497E+03	9.284E+03	4.438E+03	1.041E+03	9.640E+02	1.485E+03	1.582E+03
	Best	2.162E+04	8.486E+03	**1.954E+04**	2.781E+04	2.881E+04	2.656E+04	2.781E+04	2.779E+04	2.346E+04	4.072E+03	1.132E+04	2.005E+04	2.819E+04	2.827E+04	2.278E+04
	Worst	2.690E+04	2.591E+04	**2.507E+04**	3.157E+04	3.341E+04	2.956E+04	3.226E+04	3.202E+04	2.965E+04	3.032E+04	2.865E+04	2.364E+04	3.165E+04	3.407E+04	3.022E+04
	Rank	5	4	1	13	15	9	10	11	7	3	6	2	12	14	8
P23	Mean	4.403E+03	4.575E+03	5.787E+03	5.773E+03	5.451E+03	6.576E+03	4.357E+03	4.660E+03	4.455E+03	4.353E+03	4.590E+03	5.831E+03	4.197E+03	4.464E+03	**4.035E+03**
	Stdev	1.335E+02	2.470E+02	4.677E+02	3.952E+02	2.652E+02	4.720E+02	1.349E+02	1.136E+02	1.781E+02	1.420E+02	1.080E+02	4.770E+02	1.070E+02	1.050E+02	**1.910E+02**
	Best	4.143E+03	4.198E+03	4.846E+03	5.030E+03	5.067E+03	5.621E+03	4.156E+03	4.458E+03	4.200E+03	4.078E+03	4.388E+03	4.975E+03	3.972E+03	1.125E+03	**3.725E+03**
	Worst	4.628E+03	5.345E+03	6.523E+03	6.549E+03	6.023E+03	7.349E+03	4.632E+03	4.878E+03	4.778E+03	4.615E+03	4.827E+03	6.676E+03	4.420E+03	4.256E+03	**4.406E+03**
	Rank	5	8	13	12	11	15	4	10	6	3	9	14	2	7	1
P24	Mean	5.585E+03	5.224E+03	4.932E+03	7.504E+03	7.249E+03	1.042E+04	5.224E+03	6.069E+03	5.456E+03	5.326E+03	6.156E+03	7.527E+03	5.809E+03	5.689E+03	**4.818E+03**
	Stdev	2.400E+02	2.000E+02	2.773E+02	5.138E+02	4.440E+02	6.935E+02	2.005E+02	2.210E+02	2.640E+02	2.252E+02	2.530E+02	9.880E+02	1.720E+02	1.401E+02	**2.030E+02**
	Best	5.056E+03	4.972E+03	4.146E+03	6.803E+03	6.418E+03	9.391E+03	4.870E+03	5.540E+03	5.080E+03	5.046E+03	5.582E+03	5.901E+03	5.843E+03	5.512E+03	**4.515E+03**
	Worst	5.975E+03	5.705E+03	5.471E+03	8.538E+03	8.180E+03	1.180E+04	5.676E+03	6.414E+03	6.054E+03	5.784E+03	6.618E+03	9.336E+03	6.243E+03	5.978E+03	**5.241E+03**
	Rank	7	3	2	13	12	15	3	10	6	5	11	14	9	8	1
P25	Mean	4.588E+03	5.683E+03	3.603E+03	1.873E+04	1.792E+04	2.154E+04	5.432E+03	8.076E+03	3.966E+03	4.993E+03	6.258E+03	**3.596E+03**	5.964E+03	7.510E+03	3.661E+03
	Stdev	1.820E+02	3.570E+02	6.590E+01	2.017E+03	1.450E+03	1.855E+03	2.986E+02	4.639E+02	1.270E+02	2.750E+02	3.720E+02	**6.880E+01**	4.430E+02	5.650E+02	5.046E+01
	Best	4.299E+03	4.857E+03	3.527E+03	1.536E+04	1.574E+04	1.802E+04	4.865E+03	7.128E+03	3.693E+03	4.607E+03	5.695E+03	**3.470E+03**	5.133E+03	5.704E+03	3.588E+03
	Worst	5.019E+03	6.378E+03	3.759E+03	2.150E+04	2.184E+04	2.472E+04	6.073E+03	8.980E+03	4.196E+03	5.649E+03	7.296E+03	**3.689E+03**	6.878E+03	8.506E+03	3.781E+03
	Rank	5	8	2	14	13	15	7	12	4	6	10	1	9	11	3
P26	Mean	1.123E+04	1.909E+04	**7.239E+03**	4.377E+04	4.196E+04	4.749E+04	2.168E+04	2.987E+04	2.404E+04	1.014E+04	2.471E+04	1.215E+04	1.957E+04	2.742E+04	1.895E+04
	Stdev	6.751E+03	5.404E+03	**5.271E+03**	3.084E+03	2.757E+03	1.642E+03	3.271E+03	1.542E+03	3.051E+03	4.479E+03	3.084E+03	7.916E+03	3.196E+03	2.073E+03	6.496E+03
	Best	6.256E+03	9.641E+03	**4.833E+03**	3.556E+04	3.521E+04	4.365E+04	1.494E+04	2.625E+04	1.482E+04	7.020E+03	1.806E+04	4.801E+03	1.190E+04	2.325E+04	5.239E+03
	Worst	2.714E+04	2.674E+04	**2.376E+04**	4.857E+04	4.618E+04	4.991E+04	2.636E+04	3.247E+04	2.743E+04	2.743E+04	2.926E+04	2.543E+04	2.484E+04	3.021E+04	2.328E+04
	Rank	3	6	1	14	13	15	8	12	9	2	10	4	7	11	5
P27	Mean	**3.200E+03**	3.200E+03	3.200E+03	3.200E+03	4.088E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.318E+03	3.200E+03	3.200E+03	4.326E+03
	Stdev	**1.070E-04**	8.900E-05	8.490E-05	1.280E-04	9.330E+02	8.090E-05	8.710E-05	1.140E-04	9.290E-05	1.320E-04	1.340E-04	2.970E+02	1.640E-04	1.550E-04	5.470E+02
	Best	**3.200E+03**	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.509E+03
	Worst	**3.200E+03**	3.200E+03	3.200E+03	3.200E+03	6.498E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	3.200E+03	4.149E+03	3.200E+03	3.200E+03	5.541E+03
	Rank	1	3	5	4	14	12	6	7	11	8	9	13	10	2	15
P28	Mean	6.098E+03	3.415E+03	3.779E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.400E+03	7.099E+03	3.762E+03	3.300E+03	**3.300E+03**	7.537E+03
	Stdev	5.950E+02	2.400E+02	4.285E+01	1.280E-04	8.720E-05	6.770E-05	1.050E-04	1.500E-04	1.030E-04	4.480E+02	1.720E+03	1.660E+02	9.410E-05	**1.210E-04**	5.920E+02
	Best	5.106E+03	3.300E+03	3.696E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	**3.300E+03**	6.723E+03
	Worst	7.295E+03	3.975E+03	3.854E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	3.300E+03	5.307E+03	8.820E+03	3.937E+03	3.300E+03	**3.300E+03**	8.746E+03
	Rank	13	10	12	4	5	3	7	8	6	9	14	11	2	1	15
P29	Mean	8.930E+03	**8.820E+03**	9.039E+03	9.178E+03	9.010E+03	9.888E+03	9.979E+03	1.000E+04	9.346E+03	9.756E+03	9.408E+03	9.208E+03	9.732E+03	9.807E+03	9.230E+03
	Stdev	7.800E+02	**7.345E+02**	8.979E+02	9.071E+02	8.072E+02	9.067E+02	9.790E+02	8.972E+02	1.008E+03	8.790E+02	9.867E+02	9.978E+02	9.578E+02	9.797E+02	9.504E+02
	Best	8.107E+03	**8.105E+03**	8.190E+03	8.389E+03	8.176E+03	8.215E+03	9.007E+03	9.108E+03	8.207E+03	8.806E+03	8.464E+03	8.390E+03	8.800E+03	8.792E+03	8.394E+03
	Worst	9.779E+03	**9.785E+03**	9.920E+03	1.006E+04	9.945E+03	1.078E+04	1.089E+04	1.103E+04	1.003E+04	1.045E+04	1.034E+04	1.000E+04	1.093E+04	1.083E+04	1.017E+04
	Rank	2	1	4	5	3	13	14	15	8	11	9	6	10	12	7
P30	Mean	2.859E+08	2.469E+08	**2.005E+07**	3.024E+11	2.978E+11	3.212E+11	1.715E+09	1.032E+10	3.978E+08	1.080E+09	1.864E+09	1.327E+08	5.344E+09	8.336E+09	1.503E+10
	Stdev	2.389E+08	8.187E+07	**5.659E+09**	3.825E+10	1.892E+10	2.652E+10	6.987E+08	2.613E+09	1.279E+08	5.455E+08	4.233E+08	3.947E+07	2.755E+09	1.994E+09	8.079E+09
	Best	4.475E+07	1.070E+08	**9.424E+06**	2.112E+11	2.551E+11	2.756E+11	9.470E+08	5.781E+09	1.700E+08	4.779E+08	1.279E+09	6.905E+07	1.683E+09	5.541E+09	9.000E+08
	Worst	8.296E+08	4.341E+08	**3.227E+07**	3.553E+11	3.366E+11	3.588E+11	3.484E+09	1.488E+10	7.232E+08	2.671E+09	2.721E+09	2.116E+08	1.272E+10	1.183E+10	2.551E+10
	Rank	4	3	1	14	13	15	7	11	5	6	8	2	9	10	12

TABLE 8: Friedman Mean Rank of performed over all 15 RCGAs version

	Dim 10 Friedman Mean Rank	Rank	Dim 30 Friedman Mean Rank	Rank	Dim 50 Friedman Mean Rank	Rank	Dim 100 Friedman Mean Rank	Rank
BX-DEM	11.667	2	7.400	1	10.266	4	10.667	4
BX-MPTM	11.067	1	9.877	4	10.133	3	9.134	2
BX-PLYM	12.134	4	9.466	3	6.733	1	6.467	1
LogX-DEM	26.334	14	26.266	13	26.800	15	25.134	13
LogX-MPTM	26.667	15	27.067	14	26.534	14	25.200	14
LogX-PLYM	24.800	13	27.400	15	26.134	13	26.667	15
EPX-DEM	14.667	10	17.000	11	17.934	11	16.467	8
EPX-MPTM	16.734	12	22.066	12	22.067	12	20.934	12
EPX-PLYM	12.067	3	15.066	9	12.134	7	11.334	6
LX-DEM	12.334	5	11.400	5	11.667	5	13.667	7
LX-MPTM	12.467	6	13.934	7	15.667	8	17.067	9
LX-PLYM	15.934	11	12.534	6	11.800	6	11.067	5
WX-DEM	13.734	7	14.600	8	15.867	9	17.067	9
WX-MPTM	14.067	8	16.133	10	17.667	10	18.400	11
WX-PLYM	14.667	9	9.133	2	8.934	2	10.400	3



(a) Problem 4

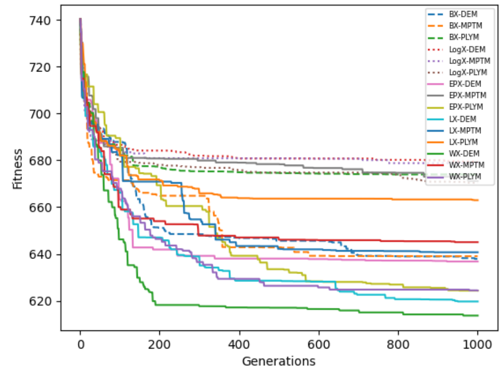


(b) Problem 5

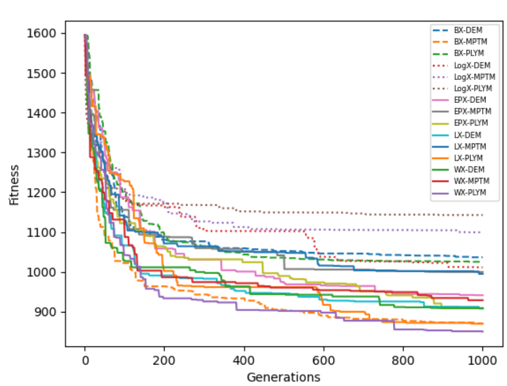
well when the dimension is 10, WX-PLYM performs better when the dimension is 30 and 50, and BX-PLYM and WX-PLYM both perform well when the dimension is 100, and the Friedman mean ranking test is illustrated in Figure 10, and their convergence graph is shown in Figure 5. In the case of hybrid functions, BX-DEM outperforms all other methods when the dimension is 10 and 30. BX-PLYM produces more accurate results when the dimension is 50 and 100, as demonstrated the convergence graph in Figure 6 and their Friedman mean ranking test in Figure 11. LX-DEM works well when the group is a function of composite when the dimension is 10. If the dimensions are 30 and 100, BX-DEM is clearly superior. When the dimension is 50, BX-PLYM outperforms all other algorithms. The convergence graph is displayed in Figure 7 and their Friedman mean ranking test is presented in Figure 12.

VII. ANALYSIS

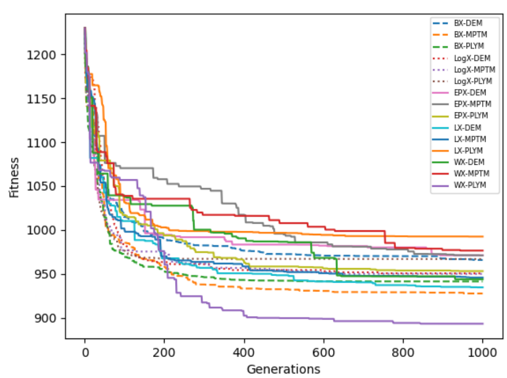
With the increased human population, pollution is also rapidly growing. It is necessary to take appropriate measures to control the ever-increasing pollution. One way is to deploy the smog-free towers. First, China is where the SFT is positioned. With its smog tower in Xian, which has been able to successfully clean 10 million cubic meters of air daily, it has already had remarkable success. Therefore, In China, already SFTs have proved to be an effective measure to control the problem. It is high time India should also adopt it. In this study, we reclaimed that Delhi, the capital of India, should employ SFTs at the earliest. Delhi is approximately 52 km and 49 km long and wide, respectively. To reduce pollution, we want to place the SFT all over Delhi city. In order to place the SFT in Delhi, Kurin system has designed a city cleaner purifier which claims to provide clean air in the 3 km radius around it. Take into account, consider that pollution is uniform everywhere, and the weather is stable. A circular area of the SFT cleans the air. Mostly in Delhi, the Average Quality Index (AQI) is 524, which is almost 93 times the WHO annual air quality guideline. The value for PM2.5 and PM10 levels are 190 to 530 and 160 to 700, respectively, in Delhi, which comes in the hazardous category. A 20–30 percent reduction in pollution may be achieved if SFTs were installed across Delhi. The complete information given by the website India Meteorological Department (IMD) generated Figures 13, 14. In Figure 13a and Figure 14a, which offer a thorough overview of the nationwide distribution of PM2.5 and PM10 levels. These figures highlight the extensive environmental problems by showing the complex pattern of particulate matter concentrations nationwide. On the other hand, Figure 13b and Figure 14b drastically focus on Delhi, the center of the problem. The IMD statistics are a reliable resource maintained by the Government of India's Ministry of Earth Sciences. They help determine the pollution problem and develop a more comprehensive awareness of regional differences. Placing the smog-free tower with the circle packing problem with the help of the Real Coded Genetic Algorithm will give an idea of where to place these towers. Figure 15 demonstrates that, 50 SFTs with a radius of 3 km are required all over Delhi so that the AQI will be reduced by 20 to 30 percent. Setting the radius



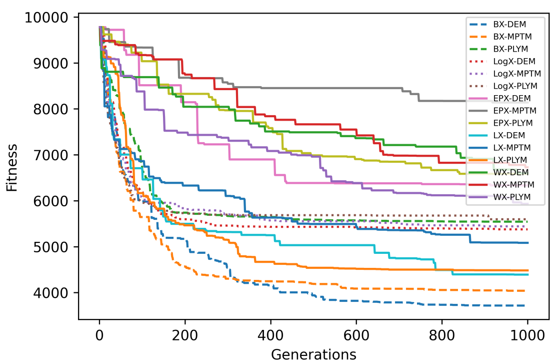
(c) Problem 6



(d) Problem 7

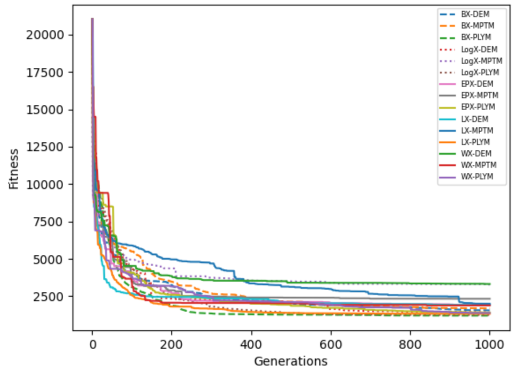


(e) Problem 8

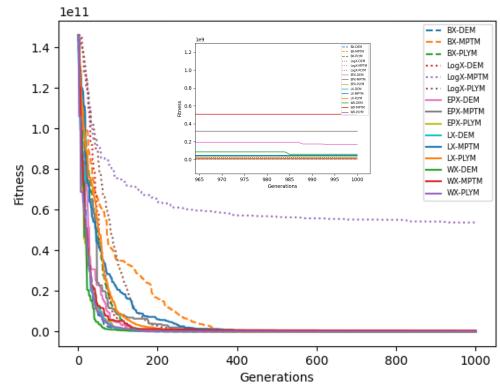


(f) Problem 10

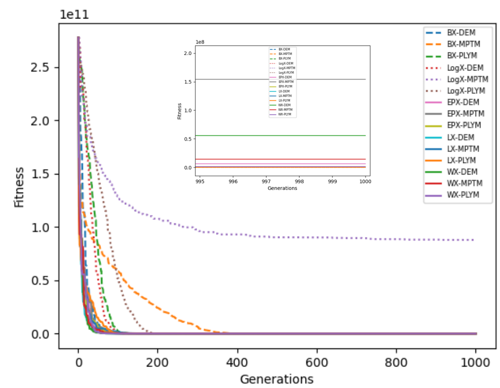
FIGURE 5: Convergence graph for Multimodal functions of CEC-2017 benchmark problem



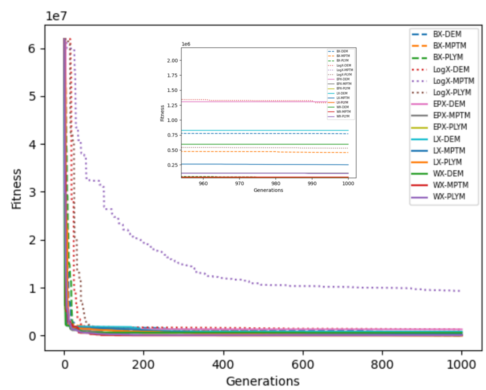
(a) Problem 11



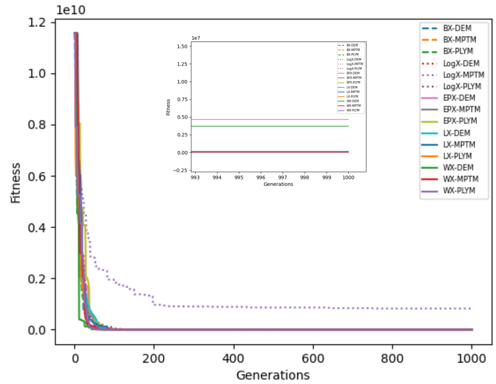
(b) Problem 12



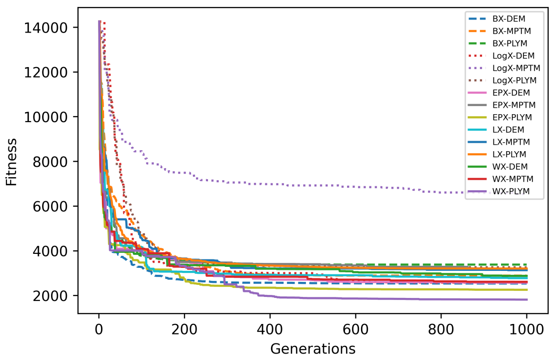
(c) Problem 13



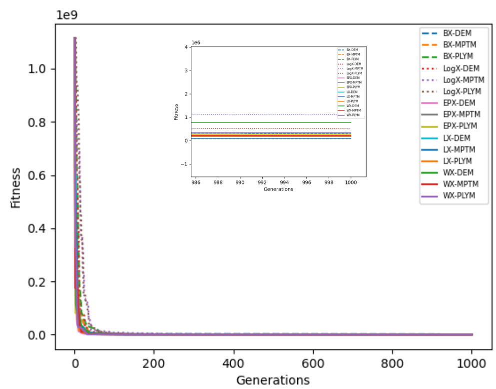
(d) Problem 14



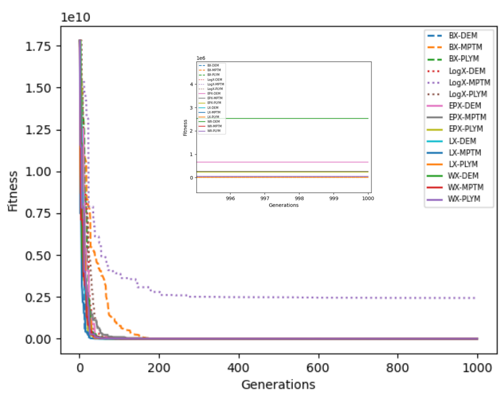
(e) Problem 15



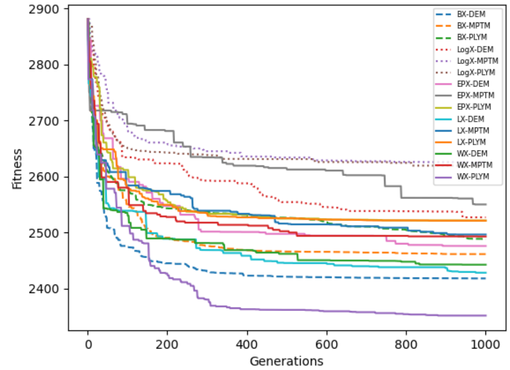
(f) Problem 16



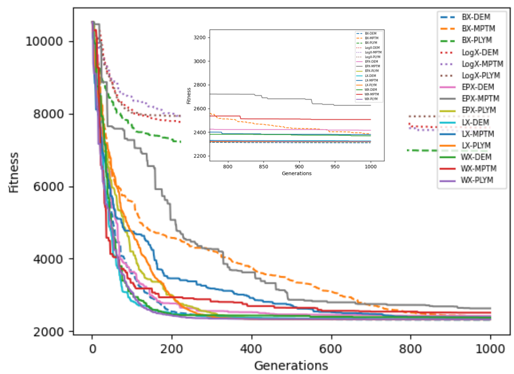
(g) Problem 18



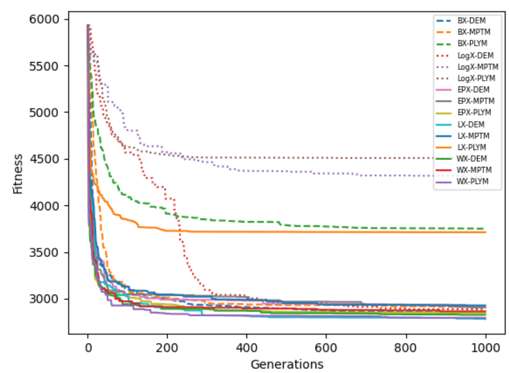
(h) Problem 19



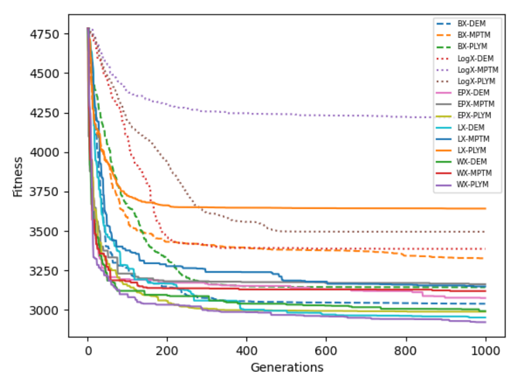
(a) Problem 21



(b) Problem 22

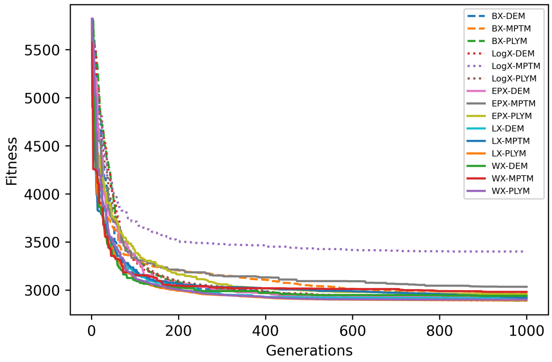


(c) Problem 23

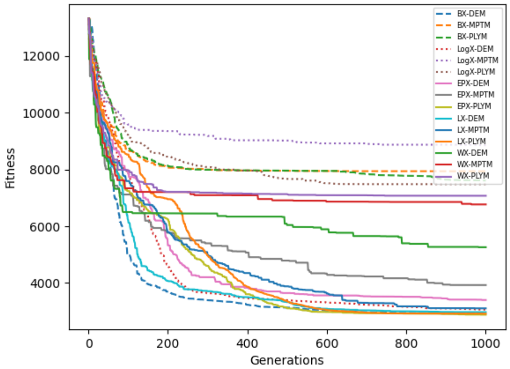


(d) Problem 24

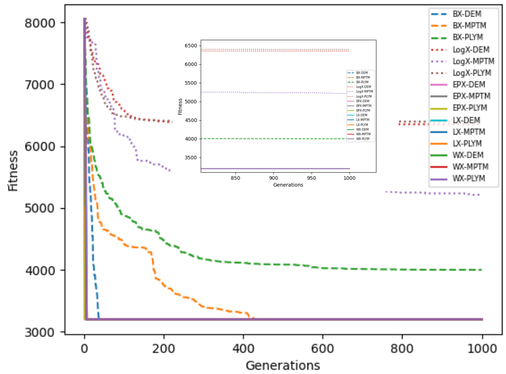
FIGURE 6: Convergence graph for Hybrid functions of CEC-2017 benchmark problem



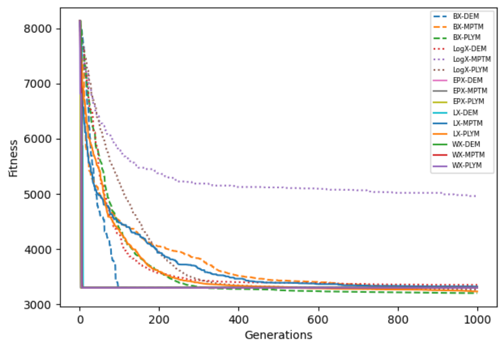
(e) Problem 25



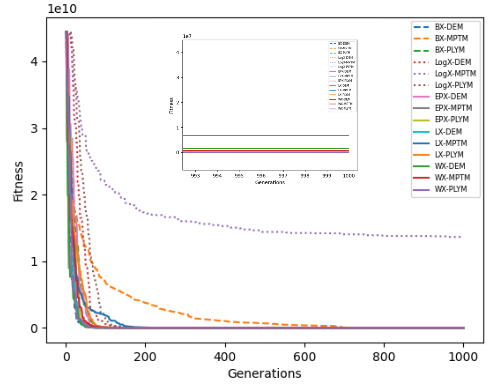
(f) Problem 26



(g) Problem 27



(h) Problem 28



(i) Problem 30

FIGURE 7: Convergence graph for Composite functions CEC-2017 benchmark problem

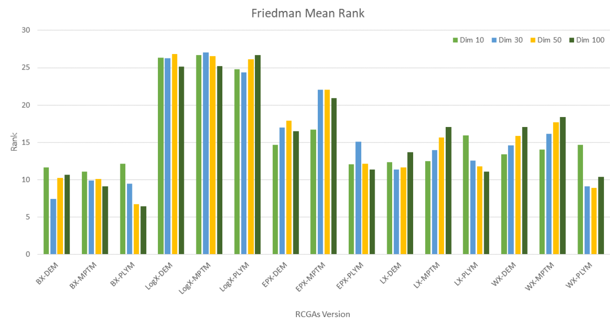


FIGURE 8: Friedman mean ranking of CEC-2017 Functions

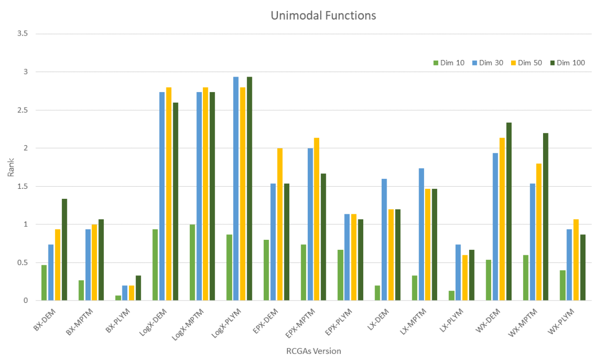


FIGURE 9: Friedman mean ranking of CEC-2017 Unimodal Functions

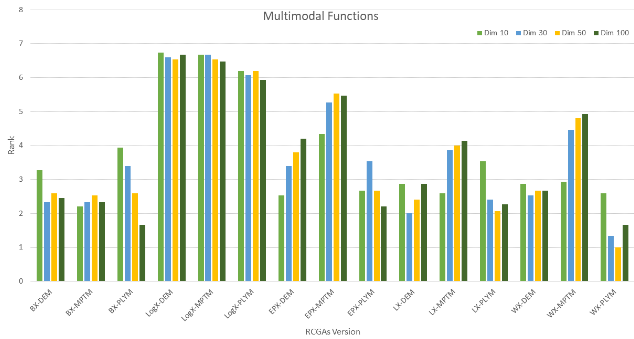


FIGURE 10: Friedman mean ranking of CEC-2017 Multimodal Functions

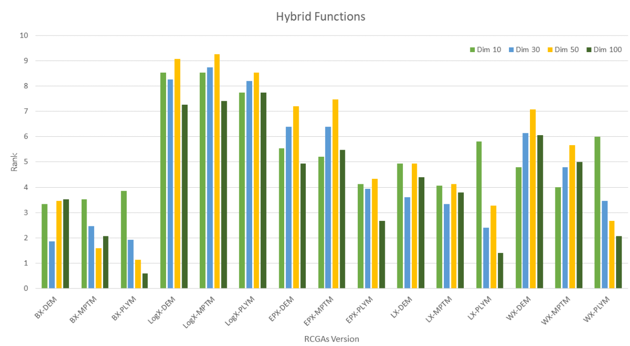


FIGURE 11: Friedman mean ranking of CEC-2017 Hybrid Functions

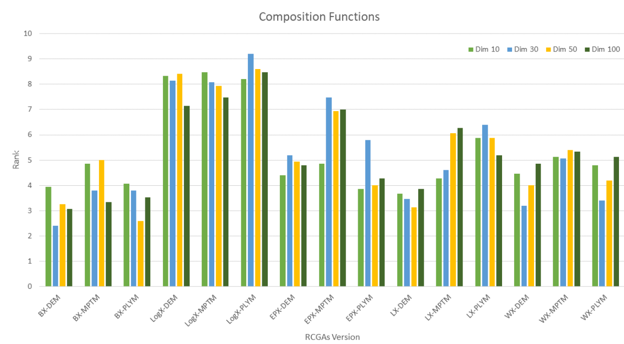
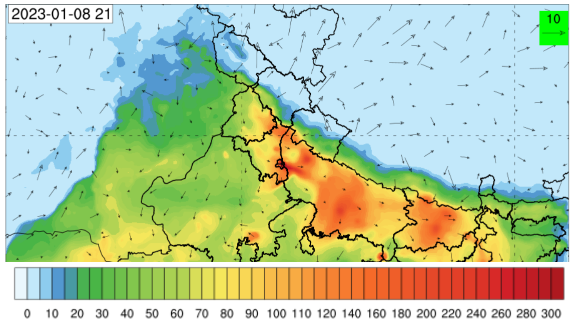
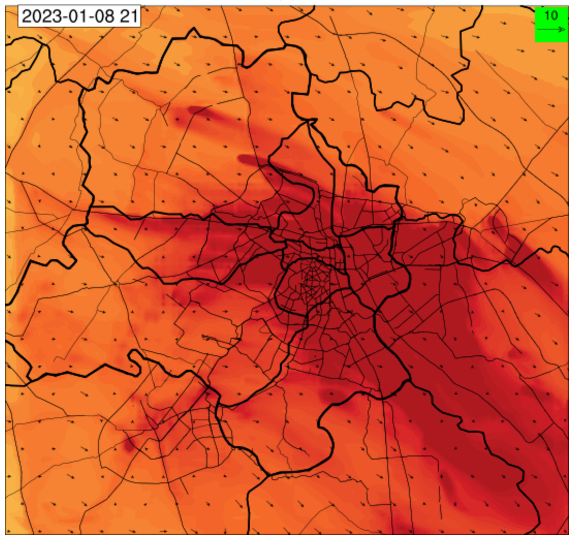


FIGURE 12: Friedman mean ranking of CEC-2017 Composite Functions



(a)



(b)

FIGURE 13: **The Particulate Matter 2.5 level** (a) In India (b) In Delhi

of SFTs at 1.5 km, Figure 16 demonstrates that 188 SFTs are required to achieve a reduction of over 35 percent in the AQI. More improvement can be achieved in AQI if we reduce the radius of the SFTs.

VIII. CONCLUSION

We explored the significance of smog-free towers in decreasing air pollution in this research paper. It will propose the number of SFT(s) necessary in Delhi, India, as well as their positions. For this, we proposed a real coded crossover operator and named it Burr Crossover (BX). This suggested crossover operator is evaluated on the CEC-2017 benchmark problem sets to test the performance. The proposed parent-centric crossover operator is self-adaptive, and the ideology of BX is linked with Burr XII distribution. The spread of offspring generated by BX is controlled by its shape parameter. BX and well-defined existing four crossover operators (LX, WX, EPX, and Log-X) are attached to the existing three well-known mutation operators (DEM, MPTM, and PLYM). The tournament selection operator is used as a selection operator. A thorough evaluation using 30 benchmark problems is used to validate the effectiveness of the BX-DEM, BX-MPTM, and BX-PLYM algorithms (CEC-2017). This assess-

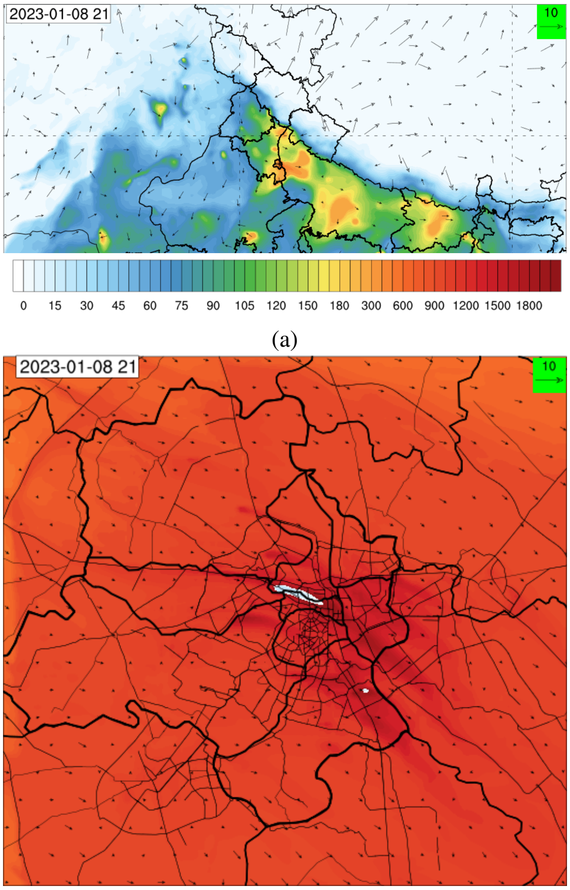


FIGURE 14: **The Particulate Matter 10 level** (a) In India (b) In Delhi

ment provides an adequate basis to evaluate BX's efficiency by benchmarking its performance against some well-known and well-defined crossover operators. The performance of the proposed algorithm is compared with twelve well-known, established, real-coded algorithm versions. All the algorithms are implemented in a similar manner, and simulations are carried out under the same testing environment. All the algorithms are compared on the basis of Friedman's mean rank test. It can be observed that if the dimension is 10 then BX-MPTM outperforms well. BX-DEM performs better than all other algorithms when the size of the dimension is 30. When the dimension is 50 and 100, BX-PLYM performs significantly better than all the algorithms. BX-PLYM is used for solving the circle packing problem to place the smog-free towers in Delhi. The proposed algorithm suggests that 50 SFTs are required to reduce pollution by 20 to 30 percent in Delhi.

This research work is based on a case study in Delhi. However, the mathematical model is likely to change for other cities, depending on geographic, demographic, or environmental characteristics. Therefore, this work is not a generalized model but a particular case study of Delhi. However it can be served as base model for different regions.

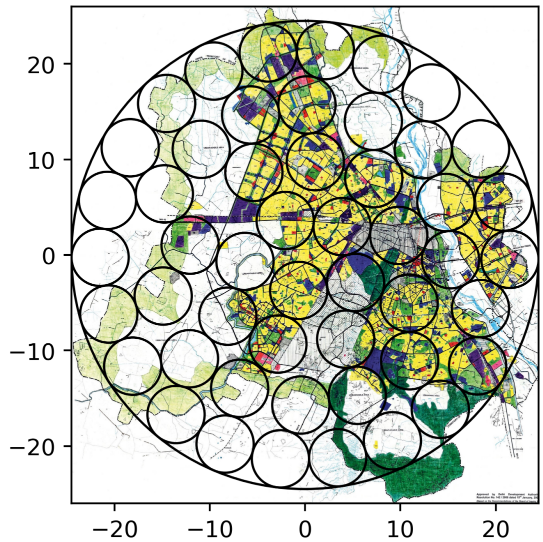


FIGURE 15: 50 Smog Free Towers placed in Delhi

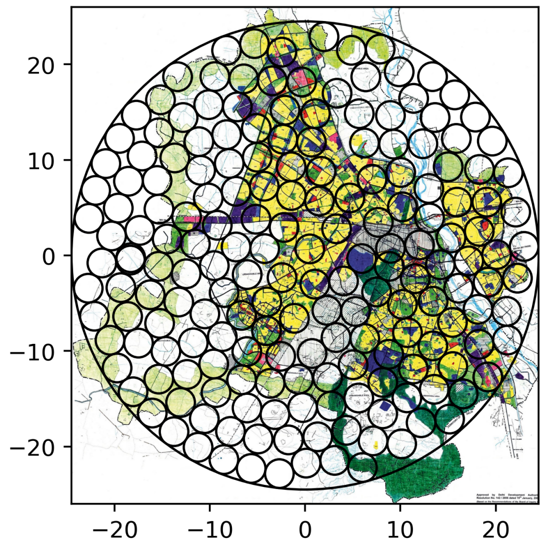


FIGURE 16: 188 Smog Free Towers placed in Delhi

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