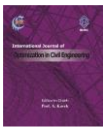
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APPLICATION OF THE MOUTH BROODING FISH ALGORITHM FOR CONSTRUCTION SITE LAYOUT OPTIMIZATION IN INDUSTRIAL PROJECTS

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ABSTRACT

Deciding where to place temporary facilities on a construction site is one of the more consequential choices a project team makes, since that arrangement shapes how materials and people move around the site, how accessible different zones are, and how smoothly logistics run overall. This paper examines whether the Mouth Brooding Fish (MBF) algorithm can handle a standard construction site layout planning problem. The goal is to minimize the total distance that must be traveled between facilities that interact with each other. A well-known benchmark involving eleven facilities and eleven predetermined locations is solved with MBF and compared against Genetic Algorithm (GA), Ant Colony Optimization (ACO), Colliding Bodies Optimization (CBO), and Enhanced Colliding Bodies Optimization (ECBO). Fifty independent runs are performed, each with 200 iterations. The best solution obtained by MBF yields a total travel distance of 12,538, while the mean, worst, and standard deviation values are 12,608, 12,888, and 96, respectively. These figures place MBF in a competitive position relative to the other methods on this particular benchmark. The study does not claim direct field validation for oil and gas projects; rather, it demonstrates that the optimization framework works on a benchmark whose structure is relevant to industrial construction logistics. Further work that incorporates project-specific constraints and actual field data is recommended.

Keywords: Construction site layout planning; Mouth Brooding Fish algorithm; Metaheuristic optimization; Industrial construction; Oil and gas projects; Facility arrangement optimization.

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1. INTRODUCTION

Large industrial projects, refineries, petrochemical plants, and oil and gas facilities involve a complex web of activities, resources, equipment, and temporary facilities. Where those facilities are placed has a direct bearing on material transport, workforce movement, accessibility, and overall site logistics. In energy projects the challenge is especially pronounced: storage areas, workshops, fabrication zones, offices, equipment yards, and restricted access routes all compete for limited space, and an inefficient arrangement quickly translates into unnecessary movement and operational friction.

Construction site layout planning (CSLP) is commonly framed as a combinatorial optimization problem. As the number of facilities grows, the number of possible assignments rises rapidly, rendering exhaustive enumeration impractical for most realistic instances. Metaheuristic algorithms are therefore widely employed to explore large solution spaces and produce high-quality layouts within acceptable computational times. Earlier CSLP studies have drawn on Genetic Algorithms, Ant Colony Optimization, Particle Swarm Optimization, Charged System Search, Colliding Bodies Optimization, and a range of other nature-inspired methods [1–16].

Recent work has also underlined that a metaheuristic's performance is not determined solely by its search mechanism; parameter selection can materially affect the balance between exploration and exploitation and, consequently, the quality of the solutions obtained. Kaveh and Eskandari [29] proposed a multi-stage framework for parameter adjustment and demonstrated its influence across mathematical, engineering, and structural optimization problems. A subsequent study applied the same general idea to the African Vultures Optimization Algorithm for structural optimization [30]. These findings are relevant to CSLP because they emphasize the importance of appropriate parameter settings whenever different metaheuristic methods are compared.

The MBF algorithm was selected for the present study for a specific methodological reason rather than on any assumption that it is universally superior to other metaheuristics. MBF is a population-based algorithm with a relatively simple search structure and a limited set of controlling mechanisms. It has already been applied to several engineering optimization problems, including structural design and other civil-engineering applications [15, 17–23]. This combination of comparatively straightforward implementation, prior engineering use, and the opportunity to examine its behavior on a CSLP problem provides a reasonable basis for its selection. The broader literature on metaheuristic optimization also shows that different algorithms can exhibit substantially different behavior depending on the problem structure and the parameter settings employed [27, 28]. Accordingly, the present study treats MBF as an algorithm to be evaluated through a controlled benchmark comparison, not as a universally best optimization method.

The objective of this study is to apply MBF to a standard CSLP benchmark and to compare its performance with GA, ACO, CBO, and ECBO under the same problem definition. The focus is on minimizing total travel distance between interacting facilities. Although the numerical experiments are conducted on a benchmark problem, the underlying decision structure remains relevant to industrial construction logistics. The contribution of the study is therefore the evaluation of MBF for this CSLP formulation together with a discussion of its potential extension to more detailed industrial and oil-and-gas site-layout

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models.

The specific objectives of the study are as follows:

1. To apply the Mouth Brooding Fish algorithm to the construction site layout planning problem.
2. To evaluate the algorithm using a recognized benchmark CSLP problem.
3. To compare the obtained results with GA, ACO, CBO, and ECBO.
4. To discuss the potential applicability of the framework to industrial and oil and gas construction environments.

In general form, the optimization problem may be stated as finding the design-variable vector $X = [x_1, x_2, \ldots, x_n]$ that minimizes the merit function Mer(X), subject to inequality constraints $g_j(X) \leq 0$ (j = 1, 2, …, m) and bound constraints $x_{imin} \leq x_i \leq x_{imax}$. The merit (or pseudo-objective) function is defined as:

$$\text{Mer}(X) = = F(X) \times f_{penalty}(X) = F(X) \times \left(1 + \gamma \times \sum_{k=1}^{m} max(0, g(x))\right) \quad (1)$$

where F(X) is the original objective function, γ is a penalty parameter, and $f_{penalty}(X)$ is the penalty term [23].

Construction site layout planning aims to determine the optimal arrangement of construction facilities within a predefined project area. The principal objective is to identify a layout configuration that improves construction efficiency by reducing unnecessary transportation, enhancing accessibility, and facilitating the movement of materials, equipment, and personnel.

In large-scale industrial construction projects—such as oil and gas facilities, refineries, and petrochemical plants—the arrangement of temporary facilities is a critical planning decision. These projects generally include multiple interacting facilities, among them material storage areas, workshops, fabrication zones, equipment yards, administrative offices, and supporting service facilities. The location of each facility influences the movement requirements between different areas and can significantly affect construction logistics performance.

In the present study, the CSLP problem is formulated as a single-objective optimization problem whose objective is to minimize the total transportation distance between facilities. This formulation is consistent with previous CSLP studies in which the efficiency of a layout is evaluated on the basis of the interaction frequency between facilities and the distance between their assigned locations. The problem considers a construction site consisting of several facilities and a set of available locations. Each facility must be assigned to an appropriate location while satisfying the layout requirements. The optimization algorithm searches for the arrangement that yields the minimum total weighted distance among facilities.

Although the mathematical formulation is based on a general construction site layout problem, the objective represents an important aspect of industrial construction logistics, where reducing unnecessary movement is a key factor affecting project performance. The construction site consists of a number of facilities that must be assigned to predefined

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locations. Each facility has a specific interaction relationship with other facilities, expressed by the required movement frequency or material-flow intensity. The optimization algorithm searches for an arrangement that minimizes the total transportation distance while satisfying the layout constraints. The objective function is expressed as:

$$\text{Minimize } Z = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij}\, d_{ij}$$

where Z denotes the total transportation distance, f_{ij} represents the interaction frequency or movement requirement between facilities i and j, d_{ij} is the distance between the assigned locations of facilities i and j, and n is the total number of facilities considered in the layout problem.

The objective function evaluates the quality of each generated layout by taking into account both the interaction intensity between facilities and the corresponding transportation distance. A lower value of Z indicates a more efficient arrangement with reduced movement requirements. From an industrial construction perspective, this formulation constitutes a simplified model of construction logistics optimization. In real oil and gas projects, the interaction factor f_{ij} may represent different types of movement requirements, including material transportation, equipment transfer, fabrication activities, and workforce circulation. Likewise, the distance component d_{ij} reflects the spatial relationship among project facilities. Although the present study focuses on the basic CSLP formulation, the mathematical framework can be extended for practical industrial applications by incorporating additional constraints such as safety separation distances, hazardous-area limitations, crane accessibility requirements, emergency routes, and site-specific operational restrictions. Consequently, the proposed optimization model supplies a fundamental framework for evaluating facility arrangements while retaining the flexibility needed for future adaptation to more complex industrial construction environments.

2. MOUTH BROODING FISH (MBF) ALGORITHM

The Mouth Brooding Fish (MBF) algorithm is a metaheuristic optimization method inspired by the reproductive behavior of mouth-brooding fish, which protect their offspring inside their mouths. Emulating this behavior, the algorithm proceeds through the following principal stages:

- Initialization, an initial population of solutions is generated at random.
- Brooding phase, the most promising solutions within the current population are selected and safeguarded, while the remaining solutions are discarded.
- Spawning phase, the protected solutions generate new candidate solutions by combining and mutating their characteristics.
- Evaluation, the newly created solutions are assessed according to the objective function of the problem under consideration.
- Selection, the best-performing solutions are retained to form the subsequent population, which then undergoes another iteration of the brooding and spawning phases.

MBF was chosen for this study because it offers a relatively simple population-based

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search mechanism and has already been examined in several engineering optimization applications [15, 17–23]. Its search process incorporates mechanisms intended to preserve promising solutions while continuing to explore the search space. These characteristics make MBF suitable for a controlled evaluation on the CSLP benchmark. The selection should not be interpreted as a claim that MBF is inherently superior to all other metaheuristics. As emphasized throughout the broader optimization literature, algorithm performance depends on problem structure, parameter settings, and implementation details [27–30].
The principal components of the algorithm are the primary movements, the supplementary movements, crossover, and the shark-attack operator [15].

2.1. The Main Movements

The main movements of each cichlid are calculated as follows:

$$A_{sp} = SP \times \text{Cichlids.Movements} \tag{2}$$

$$SP = SP \times SP_{damp} \tag{3}$$

$$A_{lb} = Dis \times (\text{Cichlids.Best} - \text{Cichlids.Position}) \tag{4}$$

$$A_{gb} = Dis \times (\text{Global.Best} - \text{Cichlids.Position}) \tag{5}$$

$$\text{New N·F·P} = 10 \times SP \times \text{NatureForce.Position(Selected Cells)} \tag{6}$$

$$A_{nf} = Dis \times (\text{New N·F·P} - \text{NatureForce.Position}) \tag{7}$$

$$ASDP = 0.1 \times (\text{VarMax} - \text{VarMin}), \quad ASDN = -ASDP \tag{8}$$

$$\text{Cichlids.Movements} = -\text{Cichlids.Movements} \tag{9}$$

where SP denotes the mother's source point, SP_damp is a damping factor varying between 0.85 and 0.95, Dis is a user-defined dispersion parameter, Cichlids.Best is the best position attained by the individual, Global.Best is the best position of the colony, and VarMin / VarMax are the variable bounds. A mirror effect is applied when a position falls outside the search space, and every position is checked against the bounds so that no cichlid leaves the feasible region [23].

2.2. The Additional Movements

The mother can retain only as many cichlids as its mouth capacity permits; the emaining members are termed left out cichlids. Their number is given by

$$nm = 0.04 \times nFish \times SP^{-0.431} \tag{10}$$

where nFish is the population size. These individuals execute a more extensive displacement controlled by the probability-of-dispersion parameter P_{dis} ($0 \le P_{dis} \le 1$). The number of cells to be altered is:

$$NCC = [nVar \times P_{dis}] \tag{11}$$

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The dispersion limits for left-out cichlids are multiplied by four:

$$\text{UASDP} = 4 \times \text{ASDP} \,.\, \text{UASDN} = -\text{UASDP} \tag{12}$$

The second component of the movement is then:

$$\text{LeftCichlids.Position} = \text{UASDP} \pm \text{Cichlids.P(SelectedCells)} \tag{13}$$

where Cichlids.P(SelectedCells) denotes the randomly chosen cells and leftCichlids. Position is the updated position [23].

2.3. Crossover

Mouth-brooding fish allow their best individuals to mate. Correspondingly, the MBF algorithm selects a pair of parents by means of a probability distribution or roulette-wheel selection. A single-point crossover is performed in which the offspring inherits 65 percent of its genetic material from the better parent and 35 percent from the other parent. The newly generated cichlids replace their parents and begin with zero movement. Before the fitness of the offspring is evaluated, a check is performed to ensure that the new position lies inside the search space [23].

2.4. Shark Attack

The number of cichlids subjected to a shark-attack effect is:

$$\text{nshark} = 0.04 \times \text{nFish} \tag{14}$$

Shark attack modifies the position and movement of four percent of the population according to:

$$\text{Cichlids.NewPosition} = \text{SharkAttack} \times \text{Cichlids.Position} \tag{15}$$

where SharkAttack is a matrix that records which cells are altered and how many times they change [23].

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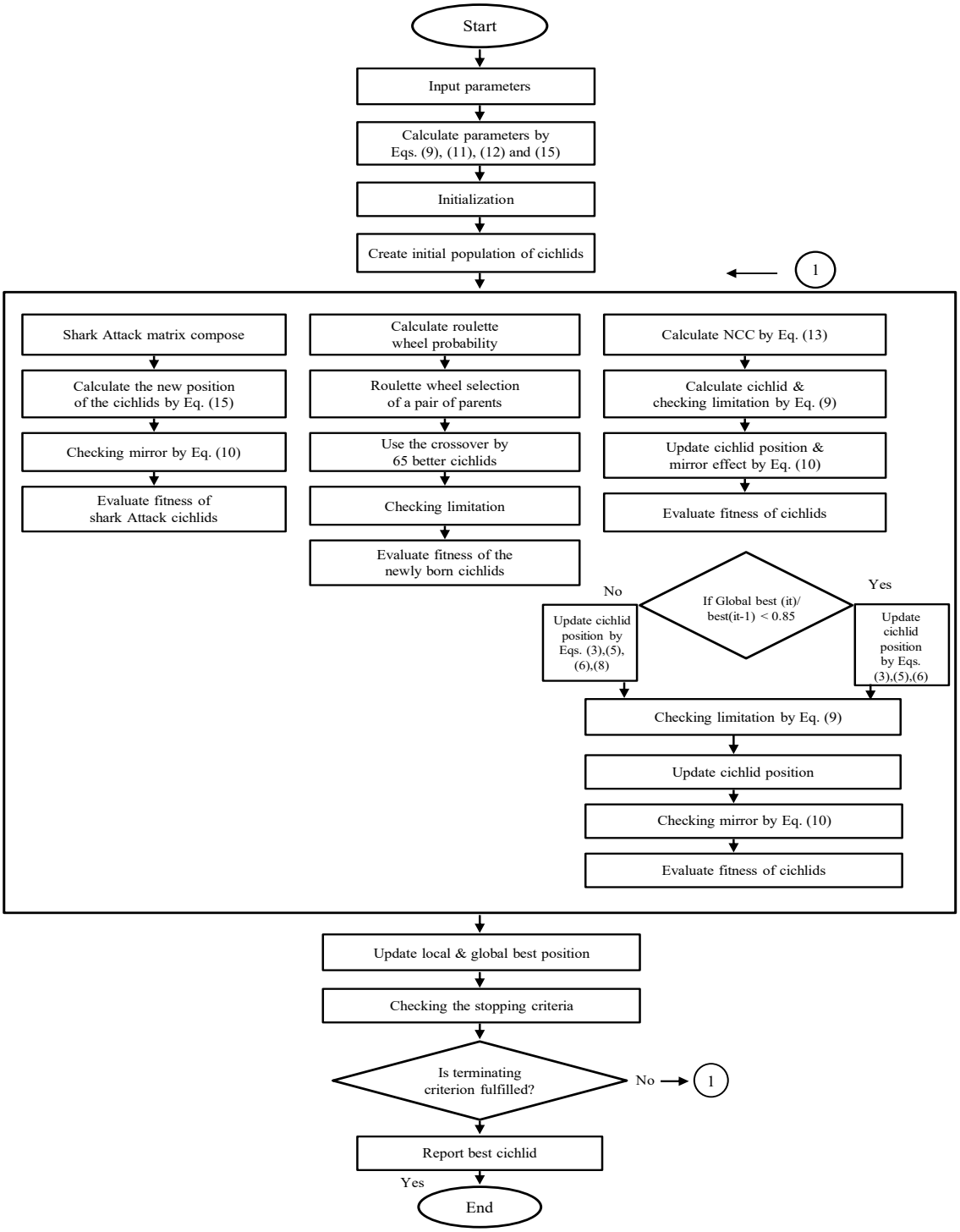


Figure 1: Flowchart of the MBF Algorithm [23]

3. CASE STUDY

To evaluate the performance of the Mouth Brooding Fish algorithm on the construction site layout planning problem, a benchmark consisting of eleven construction facilities is examined. The case is a medium-sized project taken from Kaveh et al. (2016) [18]. The task is to assign the eleven facilities to eleven predetermined locations on the site. This benchmark has been employed extensively in earlier CSLP studies to assess the ability of optimization algorithms to produce efficient facility arrangements. The site contains facility types representative of a typical construction environment—temporary offices, storage areas, workshops, equipment-related zones, and other support facilities. The objective of the layout optimization is to determine an arrangement that minimizes the total transportation distance among interacting facilities.

Although the benchmark does not depict a specific oil and gas project, the underlying layout problem captures an important aspect of industrial construction logistics. Large-scale industrial projects such as refineries, petrochemical plants, and oil and gas facilities likewise require efficient arrangements of temporary facilities to support material movement, equipment access, workforce circulation, and construction activities. Consequently, the optimization of facility locations and the reduction of unnecessary transportation remain relevant challenges across a wide spectrum of complex construction projects.

In the present study the benchmark layout problem is solved with the MBF algorithm and the results are compared with those of previously published optimization methods. Algorithm performance is assessed by the minimum total travel distance achieved. Computational experiments are conducted over multiple independent runs in order to examine the consistency and reliability of the solutions. The use of a benchmark provides a controlled environment for evaluating the optimization capability of the proposed method. Practical implementation in industrial and oil and gas projects would, however, require the incorporation of additional project-specific constraints such as safety distances, hazardous-area requirements, equipment accessibility, and site-specific operational limitations.

Table 1 lists the eleven facilities together with their index numbers. Two assumptions are adopted for the layouts:

1. Each of the predetermined locations is capable of accommodating any of the facilities.
2. The main gate and the side gate are treated as special facilities and are fixed at predetermined locations.

Table 1: Facilities and their corresponding index numbers for the case study [24]

INDEX NUMBER	SITE FACILITIES	NOTE
1	Site office	Not fixed
2	False work workshop	Not fixed
3	Labor residence	Not fixed
4	Storeroom 1	Not fixed
5	Storeroom 2	Not fixed
6	Carpentry workshop	Not fixed
7	Reinforcement steel workshop	Not fixed
8	Side gate	Fixed to 1
9	Electrical, water and other utilities control room	Not fixed
10	Concrete batch workshop	Not fixed
11	Main gate	Fixed to 10

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3.1. Objective Function

The objective of the case study is to minimize the total traveling distance of site personnel between facilities. Following Kaveh et al. (2016) [24] and Li and Love [25], the total travel distance TD is expressed as:

$$\text{Minimize (TD)} = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{l=1}^{n}\sum_{k=1}^{n} x_{ik} \times x_{jl} \times f_{ij} \times d_{kl} \tag{16}$$

subject to $\sum_{i=1}^{n} X_{ij} = 1$ for every facility i and , $\sum_{j=1}^{n} X_{ij} = 1$ for every location k, where x_{ik} equals 1 when facility i is assigned to location k and equals 0 otherwise, f_{ij} is the daily frequency of trips between facilities i and j, and d_{kl} is the distance between locations k and l. Thus TD represents the total daily traveling distance of construction personnel.

3.2. Travel Distance Between Site Locations

The distances between the predetermined locations, taken from Li and Love (1998) [25], are reported in Table 2.

Table 2: Travel distance between predetermined locations [24]

DISTANCE		LOCATION										
		1	2	3	4	5	6	7	8	9	10	11
LOCATION	1	0	15	25	33	40	42	47	55	35	30	20
	2	15	0	10	18	25	27	32	42	50	45	35
	3	25	10	0	8	15	17	22	32	52	55	45
	4	33	18	8	0	7	9	14	24	44	49	53
	5	40	25	15	7	0	2	7	17	37	42	52
	6	42	27	17	9	2	0	5	15	35	40	50
	7	47	32	22	14	7	5	0	10	30	35	40
	8	55	42	32	24	17	15	10	0	20	25	35
	9	35	50	52	44	37	35	30	20	0	5	15
	10	30	45	55	49	42	40	35	25	5	0	10
	11	20	35	45	53	52	50	40	35	15	10	0

3.3. Trip Frequency Between Facilities

The frequency of trips between facilities influences both the layout itself and the preferred proximity of facilities. Table 3, drawn from Li and Love (1998) [25], presents the daily trip frequencies.

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Table 3: Trip frequency between facilities [24]

TRIP FREQUENCY		FACILITY										
		1	2	3	4	5	6	7	8	9	10	11
	1	0	5	2	2	1	1	4	1	2	9	1
	2	5	0	2	5	1	2	7	8	2	3	8
	3	2	2	0	7	4	4	9	4	5	6	5
	4	2	5	7	0	8	7	8	1	8	5	1
	5	1	1	4	8	0	3	4	1	3	3	6
FACILITY	6	1	2	4	7	3	0	5	8	4	7	5
	7	4	7	9	8	4	5	0	7	6	3	2
	8	1	8	4	1	1	8	7	0	9	4	8
	9	2	2	5	8	3	4	6	9	0	5	3
	10	9	3	6	5	3	7	3	4	5	0	5
	11	1	8	5	1	6	5	2	8	3	5	0

3.4. Computational Procedure

To assess the consistency of the MBF results, the benchmark problem was solved in fifty independent runs, each comprising 200 iterations. Table 4 summarizes the resulting statistics. The mean, worst, and standard-deviation values obtained by MBF are 12,608, 12,888, and 96, respectively. The fifty-run experiment is used to gauge robustness across independent stochastic runs; no claim of statistical significance is advanced, because no formal inferential test is reported.

Table 4: Results of 50 independent runs for the example

ALGORITHM	BEST	AVERAGE	WORST	DIFFERENCE BEST AVERAGE SOLUTION	DIFFERENCE BEST WORST SOLUTION	STD
CBO [24]	12,546	12,558	12,768	0.096	1.769	45.51
ECBO [24]	12,546	12,555	12,746	0.072	1.594	32.11
MBF *	12538	12608	12888	0.006	0.028	96

** Current study*

Table 5 presents a comparative analysis of the present results and those reported in earlier studies of the same case. The best objective value achieved in this work is 12,538, which is lower than the best values previously published for CBO, ECBO, GA and ACO. These findings indicate that MBF produced a competitive solution for the construction site layout planning problem under consideration.

Table 5: Comparison of the final solution obtained in the present work with previously reported results

Alg.	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	TOTAL DIST.
CBO [24]	9	11	6	5	7	4	3	1	2	8	10	12,546
ECBO [24]	9	11	4	5	7	6	3	1	2	8	10	12,546
MBF*	9	11	6	5	7	2	4	1	3	8	10	12,538
GA [25]	11	5	8	7	2	9	3	1	4	6	10	15,090
ACO [26]	9	11	6	5	7	2	4	1	3	8	10	12,546

** Current study. Layout entries indicate the location index assigned to each facility (F1–F11).*

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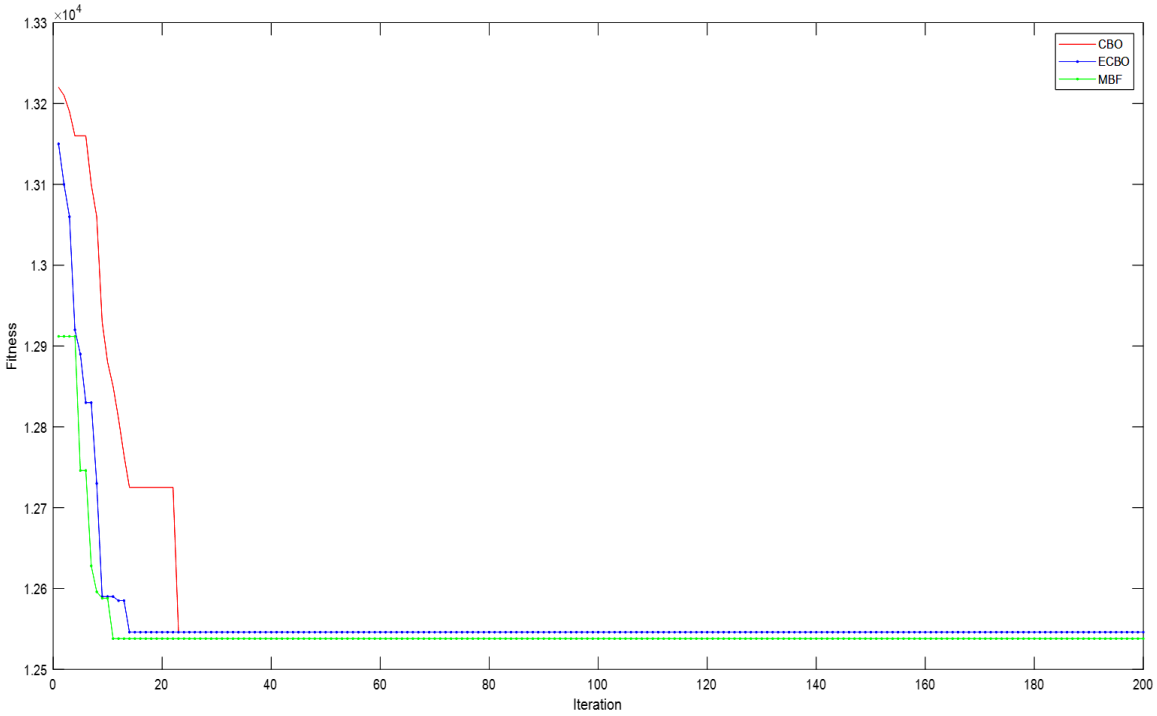


Figure 2: Convergence history of the MBF algorithm

4. RESULTS AND DISCUSSION

The MBF algorithm was applied to the benchmark CSLP problem using the objective function defined earlier. In the best of the fifty independent runs, MBF attained a total travel distance of 12,538. The result demonstrates that the algorithm was able to identify a low-cost facility arrangement for the problem under consideration.

From a construction-management standpoint, reducing total travel distance is relevant because the spatial arrangement of site facilities governs the movement of materials, equipment, and personnel. A layout that yields shorter weighted travel distances can therefore support more efficient construction logistics. This consideration is especially pertinent to industrial projects, where storage areas, workshops, fabrication zones, equipment yards, and administrative facilities may interact frequently.

The results must, however, be interpreted strictly within the scope of the benchmark problem. The numerical analysis does not constitute field validation on an actual oil and gas construction site. In a practical application the model would need to incorporate project-specific facility dimensions, material-flow rates, access routes, safety distances, hazardous-area restrictions, emergency access, and other operational constraints. The present study therefore supplies methodological evidence for the benchmark CSLP formulation rather than direct evidence of field performance on a specific industrial project.

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5. CONCLUSIONS

This study investigated the application of the Mouth Brooding Fish algorithm to a standard construction site layout planning problem. The benchmark comprised eleven facilities assigned to eleven predetermined locations, and the objective was to minimize the total travel distance between interacting facilities. Fifty independent runs were performed, each with 200 iterations. MBF obtained a best total travel distance of 12,538; the corresponding mean, worst, and standard-deviation values were 12,608, 12,888, and 96. These results show that MBF can generate competitive solutions for the considered benchmark and furnish a reasonable basis for further investigation of the algorithm in CSLP applications.

6. INDUSTRIAL AND OIL AND GAS APPLICABILITY

The proposed framework possesses potential relevance to large-scale industrial construction projects, including oil and gas facilities. Such projects frequently require the simultaneous coordination of temporary offices, storage areas, workshops, equipment yards, fabrication areas, and other support facilities. In these settings, layout decisions can affect material-handling distances, equipment movement, accessibility, and construction logistics. The MBF-based framework can serve as a decision-support tool for generating and comparing alternative facility arrangements during the planning stage. For practical implementation, however, the current benchmark model should be extended to incorporate project-specific safety, accessibility, hazardous-area, emergency-response, and operational constraints.

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