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A Hybrid Ant Lion Optimizer (ALO) Algorithm for Construction Site Layout Optimization

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ABSTRACT

A well-planned layout will contribute to saving time and site congestion as well as minimize travel distance, material handling effort, and operational cost. However, most of developed mathematical optimization procedures only work for small-scale problems and often falls into either local or global optima which do not guarantee the further convergence. Therefore, this study is motivated to propose a Hybrid Ant Lion Optimizer (ALO) algorithm inspired by ant lions' predatory behavior, combining optimization techniques and heuristic methods to overcome a limitation of previous research. The validation has demonstrated that the proposed algorithm is able to provide very competitive results in terms of improved exploration, local optima avoidance, exploitation, and convergence. The hybrid ALO algorithm also finds superior optimal solutions for the majority of site layout problems employed, showing that this algorithm has merits in solving constrained problems with diverse search spaces. The optimal results obtained for the site layout optimization demonstrate the applicability of the proposed algorithm in solving real problems with unknown search spaces as well.

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1. Introduction

The arrangement of the construction site layout has a significant impact on the project's expenses, productivity, safety, and other aspects [1]. However, the site layout plan is frequently created without regard for the project's objectives and, in some cases, no specific site layout plan in practice [2]. As a result, it leads to a long project duration, expensive costs on the construction and the quality of the project is compromised. The limitation of existing space on the construction site compared to materials and equipment [1] confirms the need for proper site layout planning to save time and lessen site congestion. Thus, minimizing travel distance, material handling effort, and operational cost [3]. The organizing process referred to as production factors, is also considered part of operational strategies to achieve a more efficient system [4]. Besides, workers and site personnel spend most of their time on construction sites. Therefore, if they can move around the site easily and quickly, it will improve productivity [5].

In planning a construction site layout, variables such as workspace and the number of interactions between locations are considered to minimize construction conflicts and optimize the workspace [5,6]. Optimization techniques and heuristics methods are employed to address the problem. Mathematical optimization procedures have been developed to obtain optimal solutions. However, they only apply to small-scale problems while artificial intelligence techniques have been implemented for an actual problem. Thus, optimization techniques are applied to generate the optimal arrangement [7]. Through time, an improved model of the optimization algorithms has proven faster in producing the outcome than manually determining the information [8]. In addition, creating better material flow on site has proven to reduce 10-30% of material handling cost [9] and shows the performance of the model. In contrast, heuristic methods have produced an approximate rather than an ideal solution for large-scale problems and often produce a good solution in a reasonable time.

The metaheuristic algorithms' model is often used to provide a solution for site layout problems. Furthermore, a hybrid algorithm such as *a hybrid AI-based particle Bee Algorithm (BA)* for facility layout optimization [6] and *a hybrid Whale Optimization Algorithm (WOA) – Colliding Bodies Optimization (CBO)* was implemented [10]. Nevertheless, the Ant Lion Optimizer (ALO) algorithm has not been fully utilized despite its consistency in other studies that require an optimization approach. Moreover, it also has a simplicity to generate high-quality solutions [11]. However, a Hybrid Ant Lion Optimizer (ALO) algorithm is necessary for producing a more optimal solution with better run-time. Combining optimization technique and heuristic method to increase its accuracy or precision level within the timeframe for the optimal solution of the site layout problem.

Given the drawbacks of previous researches, this study is motivated by creating a Hybrid version of the Ant Lion Optimizer (ALO) algorithm to improve the accuracy and convergence level of the initial model introduced by Mirjalili in 2015 [12]. Opposition-Based Learning (OBL) is applied to achieve the objective, followed by Mutation and Crossover Strategy (MCS).

Furthermore, the Roulette Wheel Selection method used by the ALO was replaced by Tournament Selection (TS) method. The performance of the developed algorithm is evaluated by comparing its performance for three actual case studies [13] with the addition of a new case study to ensure its performance.

2. Literature review

Engineering and management of construction projects can be challenging. Numerous people and resources are involved in a construction site, making it a complex workplace. It is important to optimize the construction or related operation to maintain minimum cost, duration, and overall productivity [14–16]. Considering the dynamics and risks within the site, planning construction site layout is vital. The well-planned site layout significantly contributes to time and cost-saving, especially operational costs. In addition, creating an efficient system and safer workplace with smooth material, equipment, and workflow [17–21]. Specifically, reducing potential conflicts of material handling, site congestion, and travel distance can decrease operational costs by approximately 20% to 50% [22].

Various decision tools have been used to aim for an effective and efficient optimization process. For the construction site layout problems, many studies focus on applying artificial intelligence to find optimal solutions. Metaheuristic algorithms are often used to find the solution. In 2018, a study was conducted to compare the performance of three algorithms for three case studies. Those three algorithms are the *Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), and Symbiotic Organisms Search (SOS)* algorithm [13]. The model was used to determine an optimal arrangement of site layout by minimizing workers' traveling distance between each location given the traveling frequency. In addition, a *hybrid Whale Optimization Algorithm (WOA) – Colliding Bodies Optimization (CBO)* algorithm was implemented, 2018 [10], and a *Hybrid Symbiotic Organisms Search with Local Operators (HSOS-LO)* algorithm, 2020 [22], with the same objective to produce a more stable and efficient solution. The total travel distance (TD) is determined as follows [13,22]:

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

Subjected to:

$$\sum_{j=1}^{n} x_{ij} = 1, i = 1,2,3, \dots n \quad (2)$$

$$\sum_{j=1}^{n} x_{ij} = 1, j = 1,2,3, \dots n \quad (3)$$

$$x_{ij} \in \{0; 1\}, i = 1,2,3, \dots n;\ j = 1,2,3, \dots n \quad (4)$$

where n is the number of facilities, the f_{ij} and d_{ij} represent frequency and distance between locations i and j, respectively.

x_{ij} and x_{kl} are members of facility–location assignment matrix (x_{ij} = 1 if facility i is assigned to location j; x_{ij} = 0 otherwise; x_{kl} = 1 if facility k is assigned to location l, x_{kl} = 0 otherwise); f_{ik} is the frequencies of trips of construction personnel between facilities *i* and *k*; and d_{jl} is the distances between locations *j* and *l*.

Furthermore, Ant Lion Optimizer (ALO) algorithm has shown that it is worth considering as an optimization tool by showing its outstanding and comparative performance to seven popular algorithms: PSO, GA, SMS, BA, FPA, CS, and FA [12]. However, it requires long run-time to produce a result and a better selection method to enhance computational efficiency [23,24]. It also requires further research to escalate the effectiveness of other random walks and improve ALO algorithm performance [12]. A number of studies successfully improved the performance, such as implementing Laplace distribution and opposition-based learning for a wider exploration area [25] and replacing the roulette wheel method with tournament selection to obtain more accuracy, convergence, and better run time [26,27].

The author also carried out an extensive analysis of multi-objective algorithmic strategies to show the article's research ability. A hybrid model called as the adaptive opposition slime mold approach for the TCQS trade-off optimization in construction building in India (AOSMA) [28]. Application a Hybrid Sine Cosine Optimization Algorithm to the routing of cement transport vehicles [29]. Hybrid multi-verse optimizer model for a significant discrete time-cost trade-off problem [30]. Development an original time-series Wolf-Inspired Optimized Support Vector Regression (WIO-SVR) model to predict 48-step-ahead energy consumption in buildings [31]. For construction projects, utilizing the slime mold algorithm to improve time, cost, and quality [32]. A water distribution system's design was enhanced [33] using an AI algorithm. Reducing the price of building supplies by using the Particle Swarm Optimization function of the Dragonfly Algorithm [34]. Developed the Slime Mold Algorithm (SMA) to address the time, cost, and quality trade-off issue in a building project [35].

Regardless of the potential, there is limited research utilizing the ALO algorithm or its improved version for site layout problem. Considering the aforementioned, this study proposed a hybrid ALO algorithm by utilizing tournament selection to increase the convergence level of each iteration. Furthermore, raise the probability of finding the optimal solution by using OBL and MCS. The proposed model is expected to become a decision tool with more stable and better performance in providing an outcome compared to the other algorithm as it produces an optimum site arrangement with optimum total traveling distance between facilities.

3. Development and application of algorithm

Original Ant Lion Optimizer (ALO) algorithm modeled based on the hunting scheme of Antlion. Methods such as opposition-based learning were implemented along with mutation and crossover. In addition, tournament selection is applied to create a hybrid version suitable to solve the issue. Fig. 1 depicts a scheme of the proposed algorithm with an initial current iteration equal to 0.

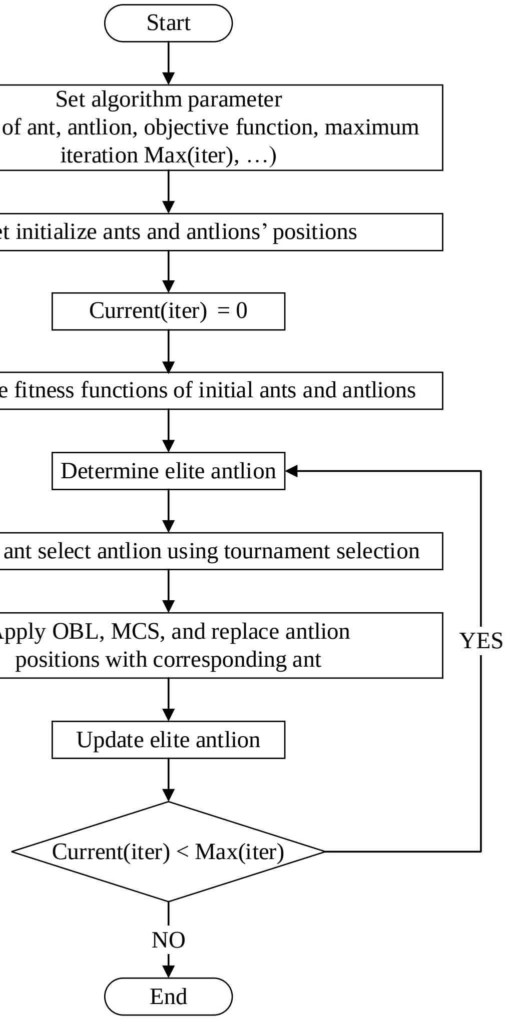

Fig. 1. Flowchart of Hybrid Ant Lion Optimizer (ALO) Algorithm.

3.1. Ant lion algorithm

Antlion is an insect species in the Neuropteran family, Myrmeleontidae. Its predatory behavior started since larvae by creating a circular moving path to dig a conical pit with its enormous jaws and remove the sand out of the pit to draw passing prey. The antlion larvae then wait as they hide deep inside the trap. Commonly, its prey is passing ants.

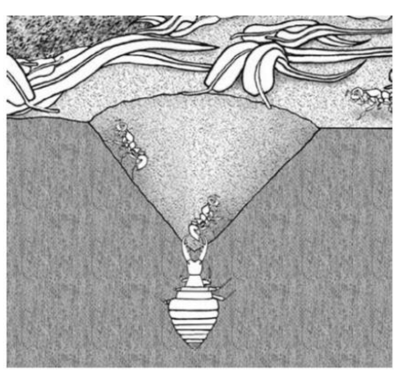

Fig. 2. Antlion's pit trap and predatory behavior [23].

The algorithm of ALO captures the interaction of the passing ants that moves through the search space and the predatory behavior of the antlion by using pit traps. Naturally, ants move randomly to go after food. Therefore, its random movement can be modelled as the equation below [36]:

$$X(t)=[0,cumsum(2r(t_1)-1), cumsum(2r(t_2)-1),\dots,cumsum(2r(t_2)-1)] \quad (5)$$

with *cumsum* as the cumulative summation; *n* as the maximum number of iterations; and *t* as iteration index; as for the random function, r(*t*):

$$r(t) = \begin{cases} 1 \ if \ rand > 0.5 \\ 0 \ if \ rand \leq 0.5 \end{cases} \quad (6)$$

where *rand* is a randomly generated number in [0,1], the illustration of three ants' random walk with over 500 iterations is shown in Fig. 3. The figure further demonstrates the significant deviation of random walk around the initial position represented by red, the upsurge represented by black, or the downturn blue.

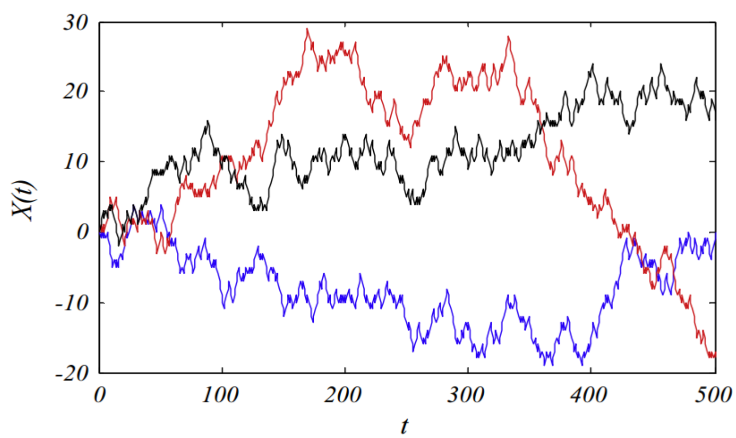

Fig. 3. Three ants' random walk iterations [12].

3.2. Tournament selection

Tournament selection substitutes the roulette wheel method to enhance efficiency and shorten long run-time in the optimization process [26]. The tournament selection method compares the values of the objective function by generating k elements at random and selecting any that have an improved objective function's value [37]. Hence, improving the competence to obtain the optimal value. The determined value of k =10 for this study. It means that the chances of finding a suitable candidate are raised ten times. The overall selection focuses on the sampling and selecting process.

3.3. Opposition-based learning

More than half of cases for predicted solutions differ from the globally optimal solution based on probability theory compared to using OBL. The Opposition-based learning concept is to generate a solution opposite the original one. Besides, this method is applicable for an initial and new solution created by the algorithm until it produces the optimum solution. Hence, initiating the opposite forecast to accelerate the convergence [38].

3.4. Mutation and crossover

Frequently used operations through different optimization stages are mutation and crossover. The mathematical model for one vector n dimensions of each $x_i = \{x_{i1}, x_{i2}, \dots, x_{in}\}$.

Step 1: Mutation

The mutation algorithm randomly selects components from vectors x_a, x_b, x_c $(a \neq b \neq b \neq i)$ to produce a mutation vector u_i (see Fig. 4). The model consists of F as a random number that represents various sizes of the mutation with the range of (0;1), and the formula is as follows:

$$u_i = x_a + F(x_b - x_c) \quad (7)$$

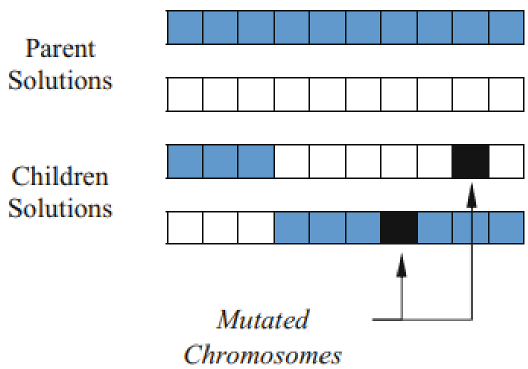

Fig. 4. Theoretical illustration of mutation.

Step 2: Crossover

The crossover produces a trial vector v_i by crossovers the mutation vector (see Fig. 5). The trial vector is then formed by choosing random elements of vector u_i based on the probability factor p_c and target vector x_i as represented by the formula below:

$$v_{ij} = \begin{cases} u_{ij} & ; rand \leq p_c \text{ or } j = j_o \\ x_{ij} & ; otherwise \end{cases} \quad (8)$$

The probability factor is represented by p_c. It controls the population's diversity and lessens the localized optimum risk. The determined value of $p_c = 0.3$ for this study. Meanwhile, j_0 represents an index [1,2,3,....,n] which guarantees vector v_i at least inherited an element from the mutant of vector u_i.

4. Case studies

The proposed algorithm is applied in three case studies (1-3) obtained from a study by Prayogo [13]. The outcome was then compared to those of PSO, ABC, and SOS algorithms from the reference with 30 populations (*popsize*) and 30 iterations (*maxiter*) as parameters. In addition, one practical case study (case study 4) was also included. Eq. (1-4) from the literature review and the proposed hybrid ALO algorithm are used to reduce the total travel distance of workers between facilities.

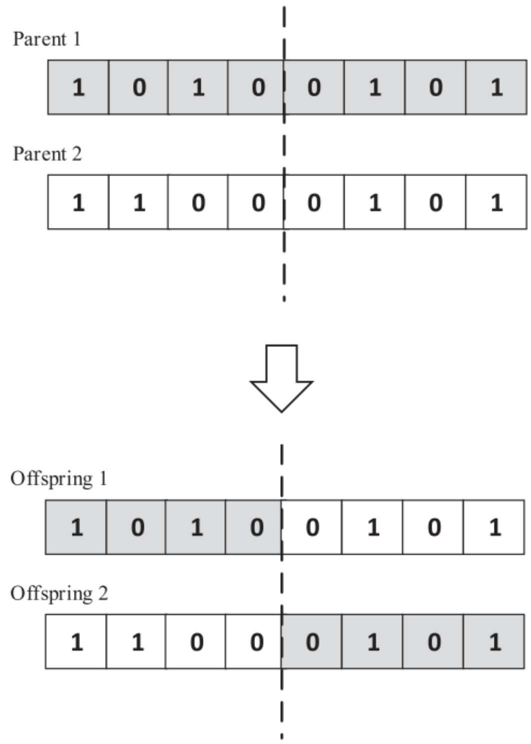

Fig. 5. Conceptual illustration of crossover.

4.1. Case study 1

Case study 1 contains 11 locations for 11 facilities. In this case, the site gate (SG) and the main gate (MG) are permanently placed in locations 1 and 10, respectively. The initial site layout is shown in Fig. 6. Table 1 shows the information for the initial location of the facilities. Meanwhile, Table 2 shows the traveling distance, and

Table **3** shows the frequencies of the trip made by workers between locations.

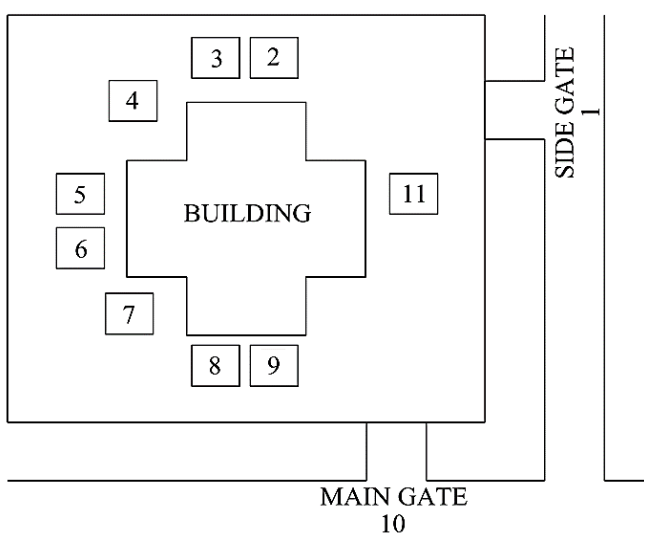

Fig. 6. The initial layout of Case 1 [13].

Table 1
Prearranged information of case study 1.

Location	Facilities	Note
1	Site gate (SG)	Permanent
2	Site office (SO)	-
3	Falsework shop (FS)	-
4	Labor residence (LR)	-
5	Storeroom 1 (S1)	-
6	Storeroom 2 (S2)	-
7	Carpentry workshop (CW)	-
8	Reinforcement steel workshop (RW)	-
9	Electrical, water, and utility control room (UR)	-
10	Main gate (MG)	Permanent
11	Concrete batch workshop (BW)	-

Table 2
Between-locations distance of case study 1 (in meters).

Location	1	2	3	4	5	6	7	8	9	10	11
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

Table 3
The trip frequency between locations of case study 1.

Facility	SO	FS	LR	S1	S2	CW	RW	SG	UR	BW	MG
SO	0	5	2	2	1	1	4	1	2	9	1
FS	5	0	2	5	1	2	7	8	2	3	8
LR	2	2	0	7	4	4	9	4	5	6	5
S1	2	5	7	0	8	7	8	1	8	5	1
S2	1	1	4	8	0	3	4	1	3	3	6
CW	1	2	4	7	3	0	5	8	4	7	5
RW	4	7	9	8	4	5	0	7	6	3	2
SG	1	8	4	1	1	8	7	0	9	4	8
UR	2	2	5	8	3	4	6	9	0	5	3
BW	9	3	6	5	3	7	3	4	5	0	5
MG	1	8	5	1	6	5	2	8	3	5	0

Table 4 compares results for 30 iterations, while Table 5 shows the solution for location based on the optimum traveling distance. The proposed algorithm's lowest average and standard deviation indicate better consistency than the result of PSO, ABC, and SOS algorithms with similar optimum traveling distances, 12546 meters. The layout design for case study 1 is based on the result of the hybrid ALO algorithm shown in Fig. 7 and Fig. 8.

Table 4
A comparison of total traveling distance for case study 1.

Methods	Min. (m)	Max. (m)	Ave. (m)	St. Dev. (m)
PSO	12546	12840	12583	70,321
ABC	12546	13190	12812,07	169,552
SOS	12546	12714	12560,07	39,953
NH-ALO	12546	12600	12559,73	23.186

Table 5
Location-based on optimum traveling distance for case study 1.

Methods	SO	FS	LR	S1	S2	CW	RW	SG	UR	BW	MG	Traveling Distance (m)
PSO	9	11	5	6	7	2	4	1	3	8	10	12546
ABC	9	11	4	5	7	6	3	1	2	8	10	12546
SOS	9	11	4	6	7	5	3	1	2	8	10	12546
NH-ALO	9	11	6	5	7	4	3	1	2	8	10	12546

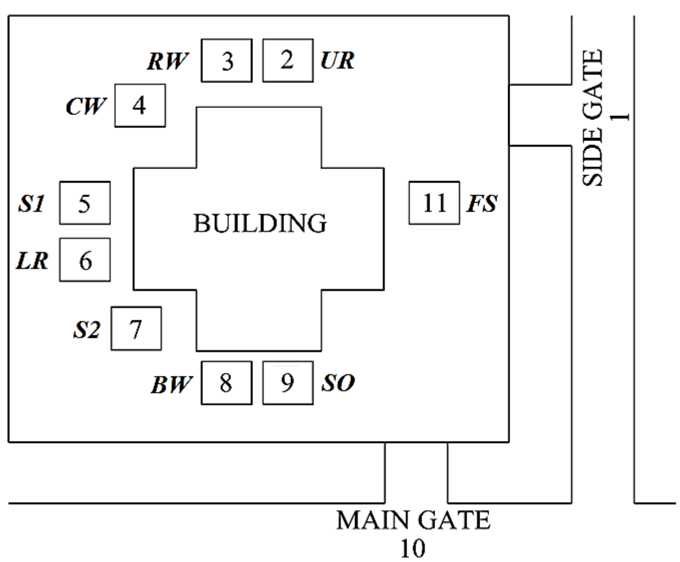

Fig. 7. The site layout design of H-ALO for case study 1.

The algorithm runs through 200 iterations (maxiter) with 50 populations (popsize) to better evaluate the performance. The convergence curve of the proposed algorithm shows the comparison between the previous study of the WOA-CBO algorithm [10]. The hybrid ALO obtained the optimal solution faster as the objective function value represents the optimal travel distance achieved before the WOA-CBO.

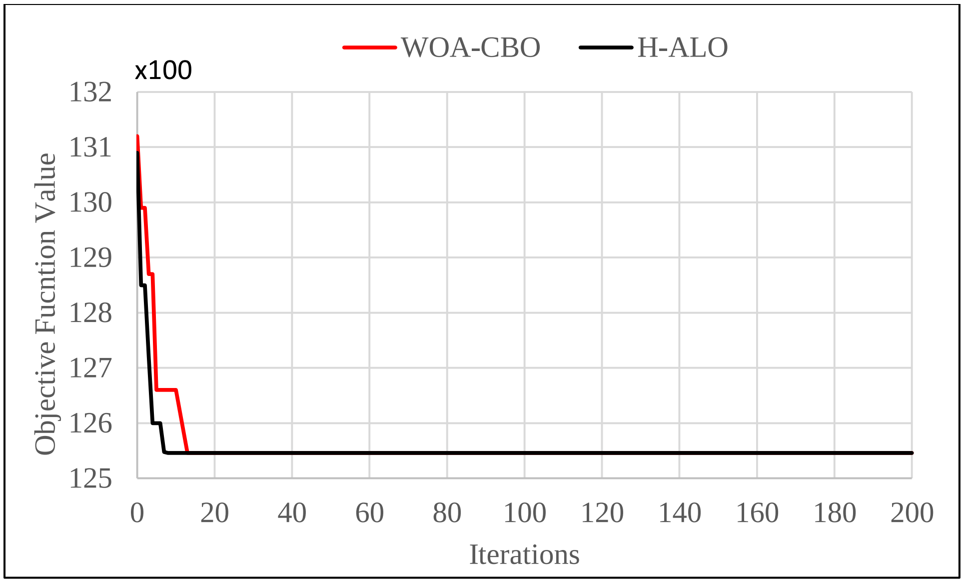

Fig. 8. The convergence curve of WOA-CBO and H-ALO.

4.2. Case study 2

The second case consists of 10 locations for 10 facilities from an apartment construction project in Surabaya, Indonesia. The entrance gate (EG) and guard post (GP) locations are fixed in locations 4 and 5 (see Fig. 9). Table 6 provides information on prearranged location; meanwhile, Table 7 and Table 8 both show the traveling distance and frequency between each location sequentially. The original layout is as follows:

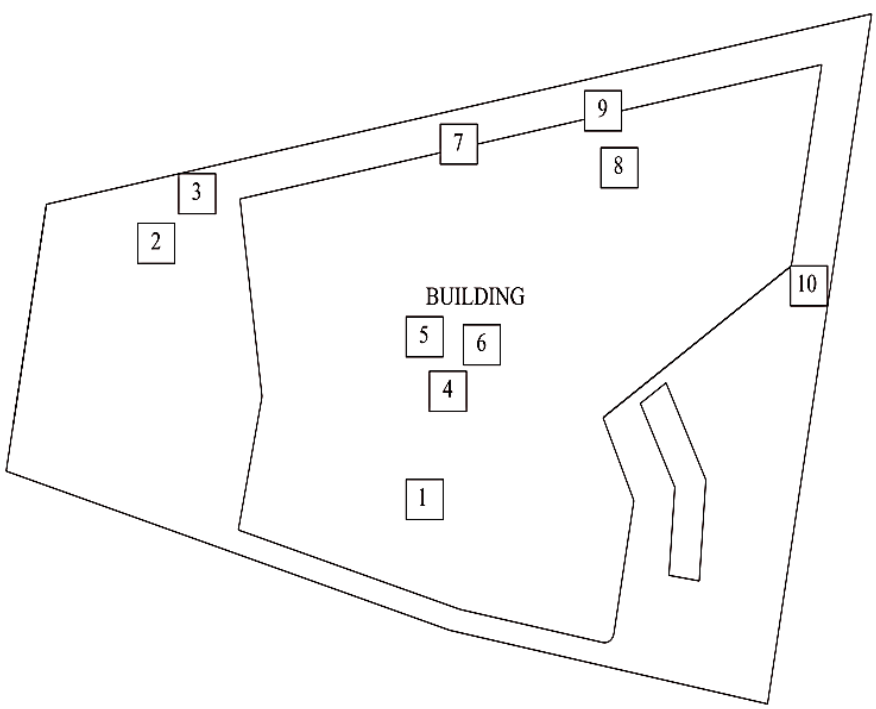

Fig. 9. The initial layout of Case 2 [13].

Table 6
Prearranged information of case study 2.

Location	Facilities	Note
1	Batching plant (BP)	-
2	Site office (SO)	-
3	Formwork workshop (FW)	-
4	Entrance gate (EG)	Permanent
5	Guard post (GP)	Permanent
6	GRC fabrication (GF)	-
7	Contractor office (CO)	-
8	Steel storage (SS)	-
9	Steel fabrication 1 (SF1)	-
10	Steel fabrication 1 (SF2)	-

Table 7
Between-locations distance of case study 2 (in meters).

Location	1	2	3	4	5	6	7	8	9	10
1	0	139	156	33	39	49	139	170	174	150
2	139	0	19	106	100	112	128	160	165	188
3	156	19	0	125	119	131	112	144	148	207
4	33	106	125	0	12	23	111	143	147	123
5	39	100	119	12	0	12	99	131	135	111
6	49	112	131	23	12	0	89	121	125	101
7	139	128	112	111	99	89	0	32	36	104
8	170	160	144	143	131	121	32	0	9	42
9	174	165	148	147	135	125	36	9	0	102
10	150	188	207	123	111	101	104	42	102	0

Table 8
The trip frequency between locations of case study 2.

Facility	BP	SO	FW	EG	GP	GF	CO	SS	SF1	SF2
BP	0	10	8	9	3	9	0	0	0	0
SO	10	0	8	12	8	9	11	5	0	1
FW	8	8	0	4	3	8	0	0	0	0
EG	9	12	4	0	6	15	10	10	8	5
GP	3	8	3	6	0	9	5	3	2	1
GF	9	9	8	15	9	0	0	0	0	0
CO	0	11	0	10	5	0	0	7	7	10
SS	0	5	0	10	3	0	7	0	25	27
SF1	0	0	0	8	2	0	7	25	0	16
SF2	0	1	0	5	1	0	10	27	16	0

The result of the proposed algorithm and the comparison with PSO, ABC, and SOS algorithms from Ref. [13] are shown in Table 9. Despite the similarity of site layout arrangement according to the optimum traveling distance, the proposed algorithm produces the lowest average and standard deviation. Hence, the proposed algorithm is better for achieving consistency. The site layout design for the proposed algorithm is shown in Fig. 10 based on data from Table 10.

Table 9
A comparison of total traveling distance for case study 2.

Methods	Min. (m)	Max. (m)	Ave. (m)	St. Dev. (m)
PSO	319184	40736	39327,07	303,011
ABC	319184	46698	41733,77	2013,849
SOS	319184	40666	39243,4	274,206
NH-ALO	39184	39926	39238.13	187.820

Table 10
Location-based on optimum traveling distance for case study 2

Methods	BP	SO	FW	EG	GP	GF	CO	SS	SF1	SF2	Traveling Distance (m)
PSO	2	6	3	4	5	1	10	7	9	8	319184
ABC	2	6	3	4	5	1	10	7	9	8	319184
SOS	2	6	3	4	5	1	10	7	9	8	319184
NH-ALO	2	6	3	4	5	1	10	7	9	8	39184

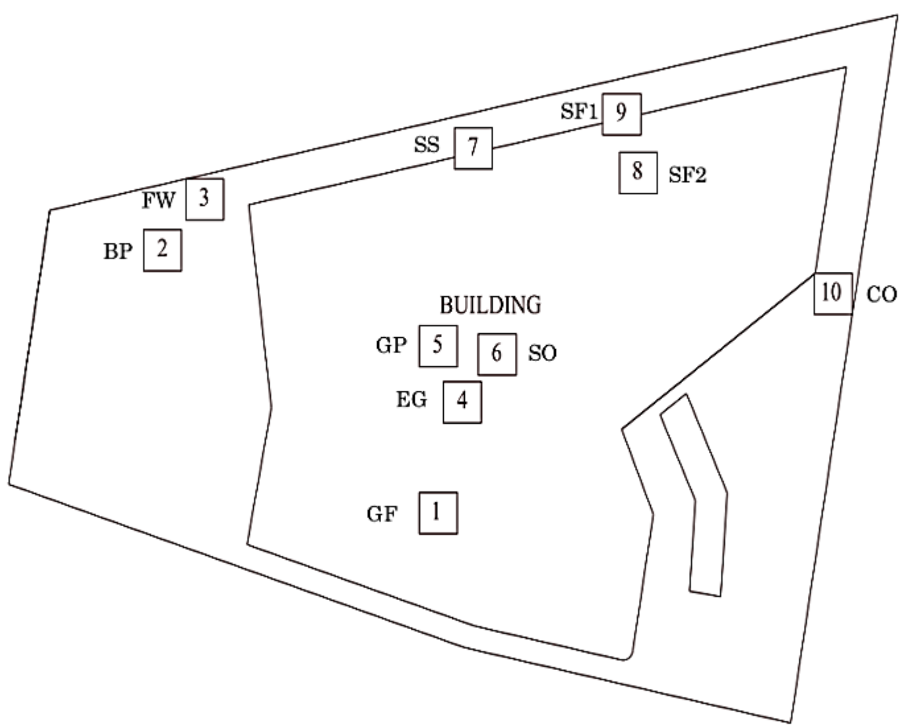

Fig. 10. The site layout design of H-ALO for case study 2.

4.3. Case study 3

This case is a construction site layout of a hotel project in Surabaya, Indonesia, as shown in Fig. 11. The location of the main gate (MG), site gate (SG), tower crane (TC), and the power source (PS) are permanent. The locations are 1, 2, 7, and 9 sequentially. Data obtained for the third case are summarized in Table 11, Table 12, and Table 13, with 14 locations and 14 facilities.

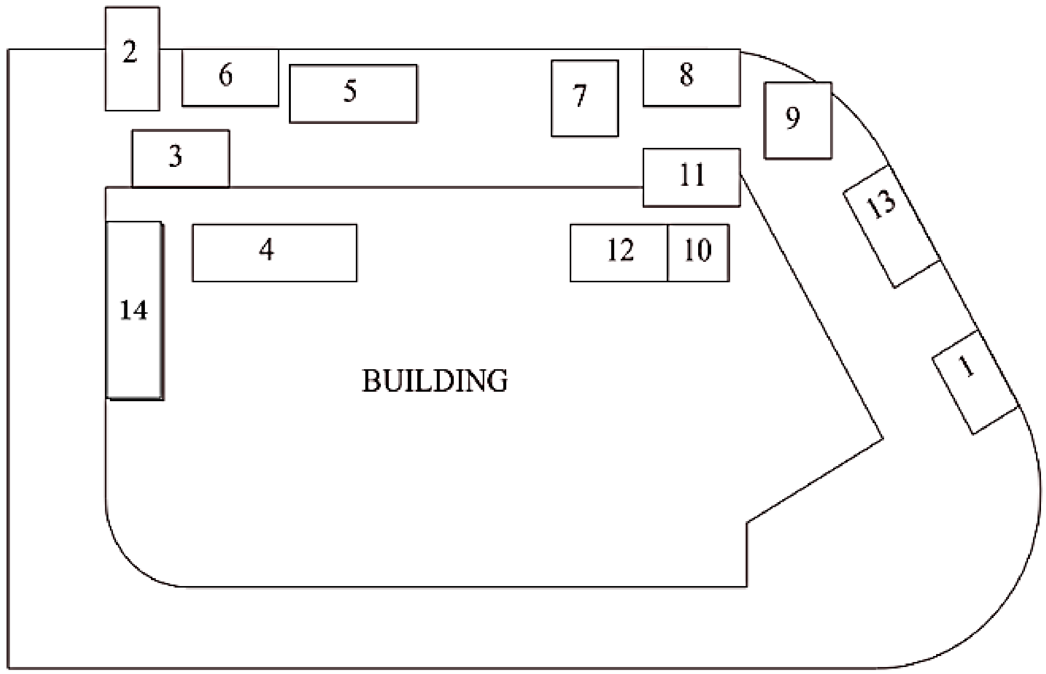

Fig. 11. The initial layout of Case 3 [13].

Table 11
Prearranged information of case study 3.

Location	Facilities	Note
1	Main gate (MG)	Permanent
2	Site gate (SG)	Permanent
3	Guard post (GP)	-
4	Office (O)	-
5	Workers toilet 1 (WT1)	-
6	Wiremesh storage (WS)	-
7	Tower crance (TC)	Permanent
8	Workers toilet 2 (WT2)	-
9	Power source (PS)	Permanent
10	Health post (HP)	-
11	Material storage (MS)	-
12	Workers barrack (WB)	-
13	Reinforcement fabrication (RF)	-
14	Formwork fabrication (FF)	-

Table 12
Between-locations distance of case study 3 (in meters)

Location	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	65	60	43	38	37	25	17	10	8	11	17	0	51
2	65	0	7	14	15	7	23	33	51	45	40	36	47	15
3	60	7	0	7	12	4	20	30	43	37	31	28	45	8
4	43	14	7	0	9	9	12	23	26	20	15	11	32	6
5	38	15	12	9	0	2	4	14	22	23	15	14	34	18
6	37	7	4	9	2	0	8	18	26	25	19	18	35	12
7	25	23	20	12	4	8	0	2	10	10	6	10	12	28
8	17	33	30	23	14	18	2	0	8	9	5	13	10	38
9	10	51	43	26	22	26	10	8	0	12	5	15	1	42
10	8	45	37	20	23	25	10	9	12	0	1	9	6	36
11	11	42	34	15	15	19	6	5	5	1	0	6	4	36
12	17	36	28	11	14	18	10	13	15	9	6	0	15	27
13	0	47	45	32	34	35	12	10	1	6	4	15	0	51
14	51	15	8	6	18	12	28	38	42	36	36	27	51	0

Table 13
The trip frequency between locations of case study 3.

Facility	MG	SG	GP	O	WT1	WS	TC	WT2	PS	HP	MS	WB	RF	FF
MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SG	0	0	1	1	1	30	1	1	1	3	15	2	2	0
GP	0	1	0	1	0	0	1	1	1	1	1	1	1	0
O	0	1	1	0	3	1	1	1	1	2	2	3	2	2
WT1	0	1	0	3	0	0	1	0	0	2	0	4	0	0
WS	0	30	0	1	0	0	0	1	0	4	2	4	4	0
TC	0	1	1	1	1	0	0	1	1	1	0	1	0	0
WT2	0	1	1	1	0	1	1	0	1	2	2	2	2	2
PS	0	1	1	1	0	0	1	1	0	0	0	1	0	0
HP	0	3	1	2	2	4	1	2	0	0	3	3	2	2
MS	0	15	1	2	0	2	0	2	3	3	0	2	15	2
WB	0	2	1	3	4	4	1	2	3	3	2	0	2	2
RF	0	2	1	2	0	4	0	2	2	2	15	2	0	0
FF	0	0	0	2	0	0	0	2	2	2	2	2	0	0

The result comparison between the hybrid ALO with PSO, ABC, and SOS algorithms is shown in the tables below. The output from the proposed model is the lowest average and standard deviation, which indicate consistency and accuracy compared to the other three algorithms. Fig. 12 shows the layout design based on the result of the proposed algorithm.

Table 14
A comparison of total traveling distance for case study 3.

Methods	Min. (m)	Max. (m)	Ave. (m)	St. Dev. (m)
PSO	4276	4973	4553,933	159,392
ABC	4391	4932	4662,467	157,698
SOS	4281	4531	4398,4	67,027
NH-ALO	4064	4230	4167.800	61.187

Table 15
Location-based on optimum traveling distance for case study 3.

Methods	MG	SG	GP	O	WT1	WS	TC	WT2	PS	HP	MS	WB	RF	FF	Traveling Distance (m)
PSO	1	2	8	5	10	3	7	12	9	4	6	11	14	13	4276
ABC	1	2	6	11	12	3	7	10	9	4	5	8	14	13	4391
SOS	1	2	5	8	13	6	7	12	9	4	3	11	14	10	4281
NH-ALO	1	2	14	10	11	3	7	8	9	4	6	12	5	13	4064

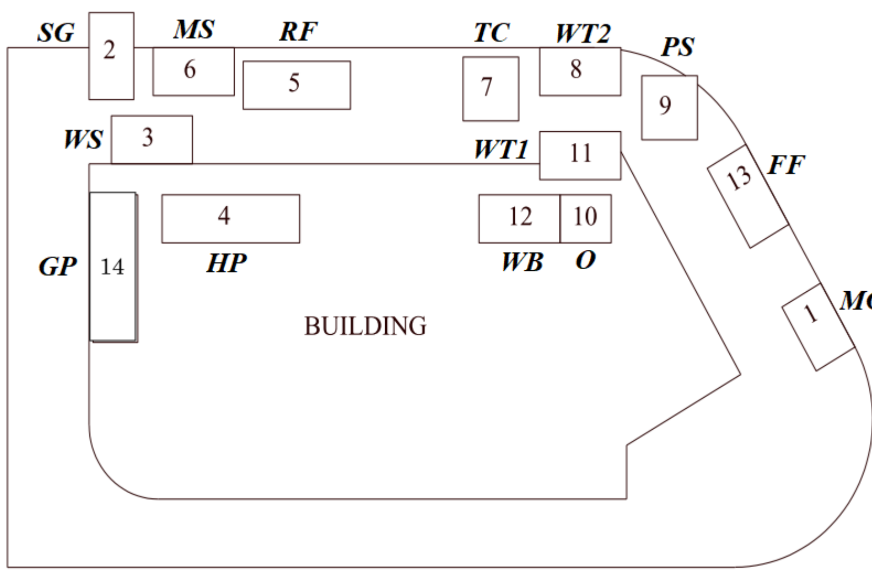

Fig. 12. The site layout design of H-ALO for case study 3.

4.4. Case study 4

An additional practical case with 11 locations for 11 facilities (Fig. 13). The data was obtained from a shopping mall construction project in Jambi, Indonesia, where the main gate (MG) location is fixed. Table 16 provide information on prearranged location. Table 17 and Table 18 show the traveling distance and frequency between locations.

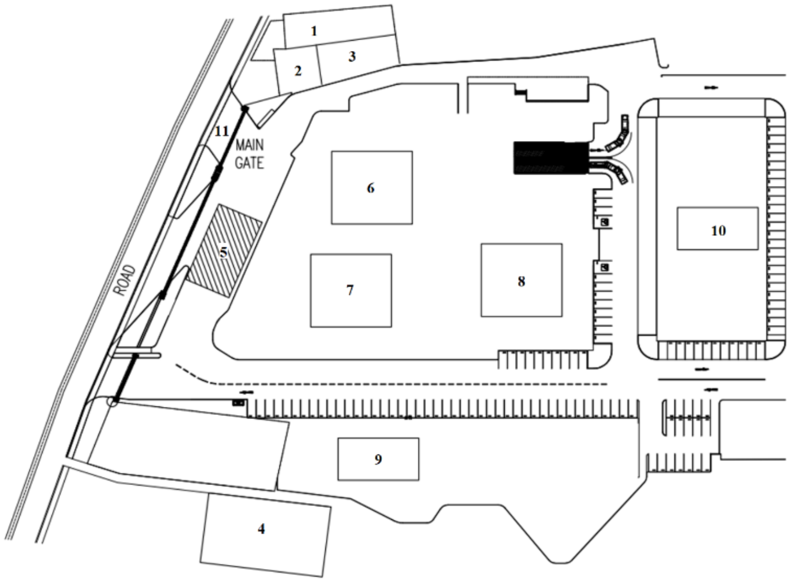

Fig. 13. The initial layout of Case 4.

Table 16
Prearranged information of case study 4.

Location	Facilities	Note
1	Labor residence (LR)	-
2	Storeroom (SR)	-
3	Site office (SO)	-
4	Mess (M)	-
5	Bar bender workshop (BBW)	-
6	Masonry and concrete workshop (MCW)	-
7	Plafond workshop (PW)	-
8	MEC workshop (MW)	-
9	Carpentry workshop (CW)	-
10	Reinforced steel workshop (RSW)	-
11	Main gate (MG)	Permanent

Table 17
Between-locations distance of case study 4 (in meters).

Location	1	2	3	4	5	6	7	8	9	10	11
1	0	15	84	192	79	89	100	135	147	182	47
2	15	0	80	183	70	80	91	126	138	173	38
3	84	80	0	202	66	37	65	76	112	109	42
4	192	183	202	0	192	202	160	248	260	295	105
5	79	70	66	192	0	44	35	81	70	134	32
6	89	80	3	202	44	0	29	48	76	95	42
7	100	91	65	160	35	29	0	47	48	101	53
8	135	126	76	248	81	48	47	0	63	55	88
9	147	138	112	260	70	76	48	63	0	111	100
10	182	173	109	295	134	95	101	55	111	0	135
11	47	38	42	105	32	42	53	88	100	135	0

Table 18
The trip frequency between locations of case study 4.

Facility	LR	SR	SO	M	BBW	MCW	PW	MW	CW	RSW	MG
LR	0	1	1	0	8	8	8	8	8	8	8
SR	1	0	3	3	2	2	2	2	2	2	4
SO	1	3	0	6	6	6	6	6	6	6	2
M	0	3	6	0	0	0	0	0	0	0	6
BBW	8	2	6	0	0	0	0	0	0	0	8
MCW	8	2	6	0	0	0	0	0	0	0	8
PW	8	2	6	0	0	0	0	0	0	0	8
MW	8	2	6	0	0	0	0	0	0	0	8
CW	8	2	6	0	0	0	0	0	0	0	8
RSW	8	2	6	0	0	0	0	0	0	0	8
MG	8	4	2	6	8	8	8	8	8	8	0

The proposed algorithm for case study 4 shows that the average total travel distance is 27973.33 meters with a standard deviation of 1246.546 meters. The layout design for this case study is shown in Fig. 14.

Table 19
A comparison of total traveling distance for case study 4.

Methods	Min. (m)	Max. (m)	Ave. (m)	St. Dev. (m)
NH-ALO	26680	29234	27973.33	1246.546

Table 20.
Location-based on optimum traveling distance for case study 4.

Methods	LR	SR	SO	M	BBW	MCW	PW	MW	CW	RSW	MG	Traveling Distance (m)
NH-ALO	6	1	7	4	3	8	10	2	9	5	11	26680

5. Discussion

In general, this study aims to expand the Ant Lion Optimizer (ALO) algorithm application for site layout optimization through iterative computations related to specified criteria instead of making excessive hypotheses about the optimization problem. By combining with other technical, the proposed hybrid ALO emphasize that it balances exploration and exploitation with global and local searches. Hence, the developed novel hybrid Ant Lion Optimizer (ALO) algorithm is expected to become a useful decision instrument to generate an optimal solution for the site layout arrangement of the actual construction site with minimum total traveling distance.

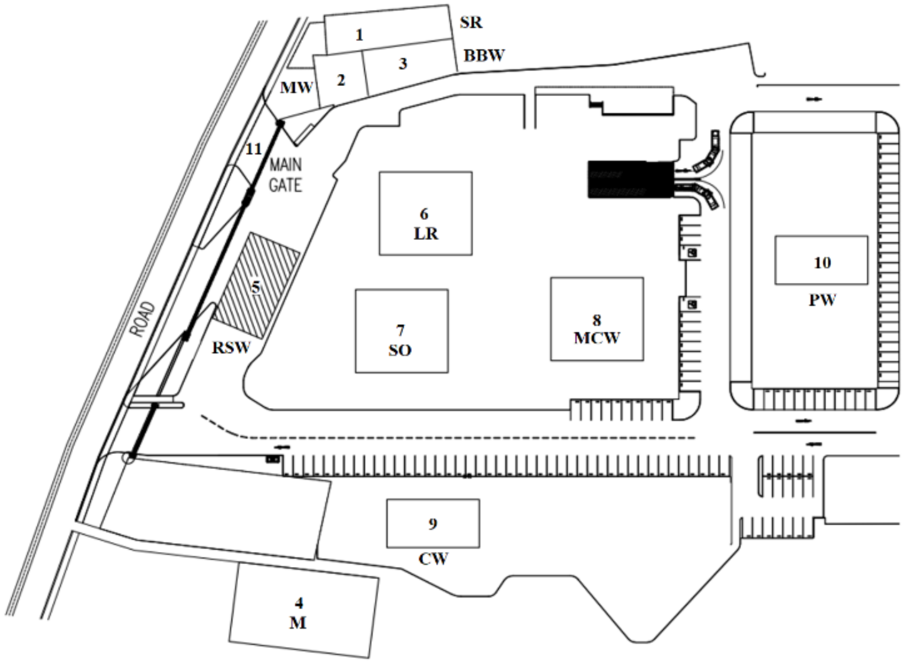

Fig. 14. The site layout design of H-ALO for case study 4.

6. Conclusions

The construction site layout planning has significant impact on the productivity, budget, and timeline of the project. A well-planned layout will contribute to saving time, site congestion, minimize travel distance, material handling effort, and operational cost. Increasing the efficiency, safety, and a better workflow. Artificial intelligence-based solutions, such as metaheuristic algorithms, have been studied in depth for the construction site planning problem. Optimization techniques have been applied to find the solution. Moreover, generating optimal solutions contribute to reducing material handling cost by about 10-30% due to better material flow.

A hybrid ALO algorithm is developed to generate an optimal solution for construction site layout problems, where improvement was made by applying OBL, and MCS to increase the probability of producing optimal solution. In addition, replacing the Roulette Wheel Selection with Tournament Selection to enhance both efficiency and shorten long run-time during the optimization process. The proposed algorithm is compared to a previous study using PSO, ABC, and SOS algorithms for three case studies. Moreover, produce both optimum total travel distance and the site layout arrangement for one practical case study. The overall outcome signified that the hybrid ALO algorithm has better consistency, accuracy, and convergence as it shows the lowest average and standard deviation compared to the other algorithm. Thus, reliable in providing optimal solutions and suitable as an alternative for decision tool for this particular problem.

Nonetheless, for further study, the proposed model can be improved by considering the dimension of the facility, cost factor, and construction stages to have a more realistic depiction of the problem. It is encouraged to use both the ALO algorithm and the hybrid ALO algorithm to solve the problem that requires an optimization approach.

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Conflicts of interest

The authors declare no conflict of interest.

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