

OPTIMAL ARRANGEMENT OF TEMPORARY FACILITIES IN CONSTRUCTION SITES

K.M.Shawki*; **M.E.Abd EL-Razek ****, and **S.A.Maqboly*****

**Assistant Prof., College of Engineering and Technology, AASTMT, Alexandria, Egypt.*

***Prof., College of Engineering and Technology, AASTMT, Cairo, Egypt.*

****M.Sc. Student, College of Engineering and Technology, AASTMT, Alexandria, Egypt*

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Site layout planning requires decision makers to identify the planned location of each temporary construction facility on site. These temporary facilities include site offices, workshops and storage facilities. Their planned locations on site have a direct impact on productivity, cost, and duration of construction. This paper presents a computer model called "GASITE" helps construction decision makers to carefully evaluate all feasible locations for these temporary facilities and select an optimal layout that minimize the cost and travel distance between facilities. The optimization problem has been solved using genetic algorithms as an optimization technique .Application of the model is illustrated using an example .The proposed model is efficient and easy to apply and as such should be of interest to construction engineers and practitioners.

KEYWORDS: *Construction, site layout, genetic algorithm*

INTRODUCTION

Site layout planning consists of identifying the facilities needed to support construction operations, determining their size, shape and positioning them within the boundaries of the available on-site or remote areas [1]. Despite the importance of site space as a resource, site-layout planning is often neglected and the attitude of engineers has been that it will be done as the project progresses. Good site layout, however, is important to promote safe and efficient operations, minimize travel time, decrease material handling and avoid obstructing material and equipment movements, especially in the case of large Projects [2]. In addition, such a problem becomes far from trivial if a construction site is confined due to the lack of available space, or if the site is very large, then traveling between facilities can be considerably time consuming. When temporary site level facilities are required to be located on a construction site, the locations of buildings to be constructed are assumed to be known. These locations are used to define available sites for temporary facilities. Then the problem can be defined as allocation of predetermined facilities like warehouses, job offices, workshops and batch plants so as to optimize an objective subject to layout constraints and requirements. Using such a definition of the problem, formulation in terms of a combinatorial optimization problem has been attempted. A number of studies were conducted in order to improve site layout planning in construction projects. These studies adopted a wide range of methodologies and development tools including neural

networks, simulation, knowledge-based systems, and genetic algorithms. For example, Yeh (1995)[3] used annealed neural networks to arrange a set of predetermined facilities on a set of predetermined locations on construction sites. Several expert systems and knowledge-based systems were also developed to integrate domain knowledge of experts and assist in facility layout planning tasks [4, 5, 6]. Other studies proposed heuristic algorithms including the use of the early commitment criterion to design site layouts [8]; and the utilization of relative significance and ranking of temporary facilities [9]. Dawood and Marasini (2001) [7] used simulation to develop a model that assists managers in designing and managing the layout of stockyards. Tawfik and Fernando (2001a) [8] integrated simulation with genetic algorithms in an attempt to optimize site layouts. Genetic algorithms were also used in several studies to optimize the layouts of construction sites [9, 10, 11]. These genetic algorithms have shown improvements in the search process for near optimal solutions, especially in this type of problem that is characterized by a large search space.

GENETIC ALGORITHMS

GAs are search algorithms that are based on the natural selection and genetics to search through decision space for optimum solutions. GAs employ a random yet directed search for locating the globally optimal solution. In addition, GAs perform an intelligent search for a solution from a nearly infinite number of possible solutions. Typically, GAs require a representation scheme to encode feasible solutions for optimization problems. Usually, a solution is represented as a linear string called chromosome whose length varies from one application to another. Some measures of fitness (objective function) are applied to construct better solutions. Once the chromosome structure and the objective function are set, the GA evolutionary procedure takes place on a population of parent chromosomes. Three genetic operations are required: Reproduction, crossover, and mutation. Reproduction is the process by which chromosomes with better fitness values receive correspondingly better copies in the new generation. As the total number of chromosomes in each generation is kept constant, chromosomes with lower fitness values are eliminated. The second operator; crossover, is the process in which chromosomes are able to mix and match their desirable qualities in a random fashion. Crossover (marriage) is conducted by selecting two parent chromosomes, exchanging their information, and producing off springs. The exchange of information between parent chromosomes is done through a random process. Fig. (1) shows a case of double-point crossover, but single-point crossover may also be used Fig. (2). As an opposite to crossover, mutation, Fig. (3), is a rare process that resembles the process of a sudden generation of an odd offspring that turns out to be genius (Goldberg 1989)[12].

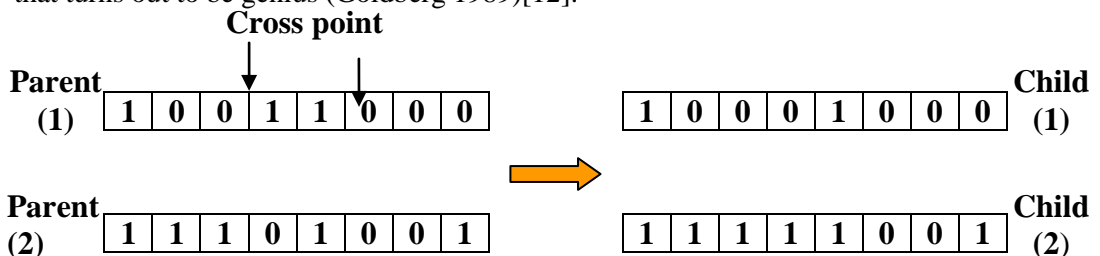


Fig. (1) Two point crossover

The benefit of the mutation process is that it can break any stagnation in the evolutionary process, avoiding local optima.

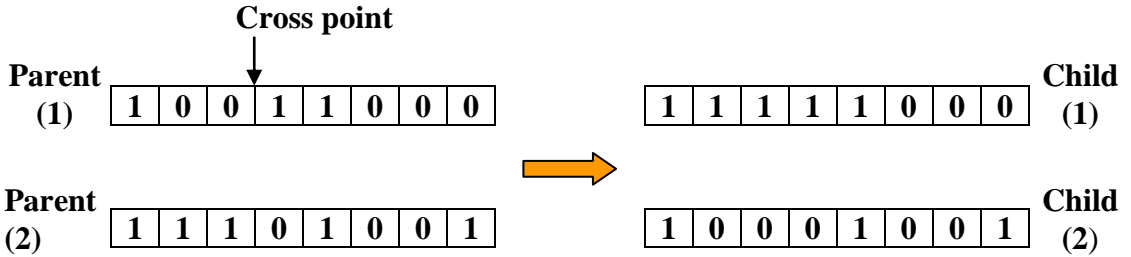


Fig. (2) Single point crossover

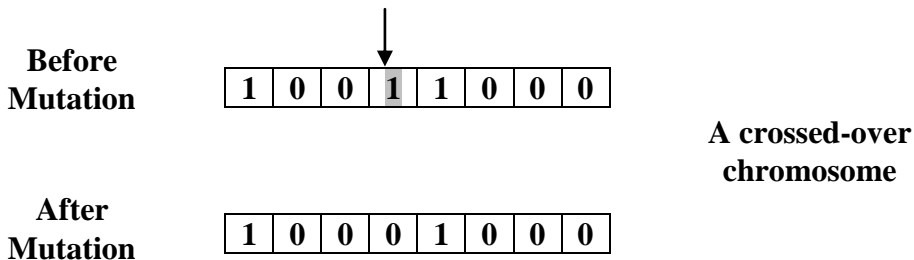


Fig. (3) Mutation

GENETIC ALGORITHMS FORMULATION

The objective function in this present study is to minimize the cost and travel distance between facilities in construction site layout planning. The total travel cost of resources can be calculated and minimized using the objective function shown in Eq. (1).

$$\text{Fitness} = \text{Min.} \left[\sum_{i=1}^n (Q * C_i * d_i) \right] \dots\dots\dots (1)$$

Where :

$$d_i = \left[\sqrt{(X_i - X_b)^2 + (Y_i - Y_b)^2} \right] \dots\dots\dots (2)$$

where C_i = Travel cost rate in EPG/m of distance traveled between facilities i & building ; d_i =distance in meters between facilities i and building ; X_i, Y_i =coordinates of center of gravity of facility i ; X_b, Y_b = coordinates of center of gravity of building ; n = total number of facilities on site and Q = The required Quantity for transport.

OPTIMIZATION CONSTRAINTS

In the present model, two types of constraints, Fig.(4). are imposed on the generated solutions to ensure the development of practical site Layout plans (El-Rayes et al. 2005)[13]:

- (1) Boundary constraints; and

(2) Overlap constraints.

The purpose of boundary constraints is to ensure that temporary facilities are located within the site boundaries, while overlap constraints are required to avoid the overlap of facilities on site.

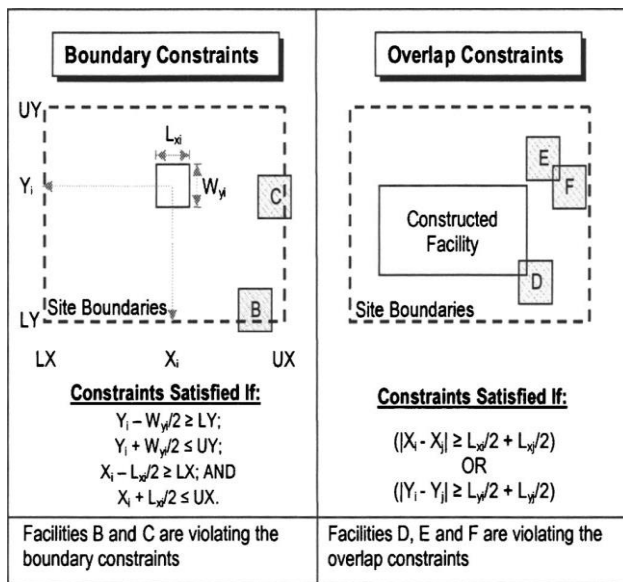


Fig. (4) Optimization constraints

Boundary Constraints

Boundary constraints are examined in this model for each solution using the following four-steps algorithm in order to ensure that each facility is located within the boundaries of the site.

1. For each temporary facility *i*, find the coordinates of its center of gravity (X_i, Y_i), and its length in the X direction (L_{xi}) and width in the Y direction (W_{yi});
2. In the Y direction, examine the following two conditions: (1) the upper boundary of each facility ($Y_i + W_{yi}/2$) is less than the upper boundary of the site space (UY); and (2) the lower boundary of the facility ($Y_i - W_{yi}/2$) is greater than the lower boundary of the site space (LY), as shown in Fig. (1);
3. If both conditions in Step 2 are satisfied, perform a similar examination in the X direction; and
4. If all the conditions in Steps 2 and 3 are satisfied, then facility *i* complies with boundary constraints. Otherwise, the solution is in violation of this type of constraint and therefore it should be precluded.

Overlap Constraints

In order to ensure that no overlap occurs between facilities on site, overlap constraints are examined using the following four steps algorithm.

1. For each temporary facility *i*, find the coordinates of its center of gravity (X_i, Y_i), and its length in the X direction (L_{xi}) and width in the Y direction (W_{yi});

2. To ensure that there are no overlaps between facilities i and j in the X direction, calculate the absolute difference between the X coordinates ($|X_i - X_j|$) of facilities i and j , and compare it to the average length of the two facilities in the X direction ($(L_{xi}/2 + L_{xj}/2)$). If $|X_i - X_j| \geq (L_{xi}/2 + L_{xj}/2)$, then there is no overlap in the X direction;
3. Repeat Step 2 for the Y direction; and
4. If overlaps are encountered in both Steps 2 and 3, then there is an overlap between the two facilities as shown in Fig. (4), and therefore this solution should be precluded. Otherwise, overlap constraints are satisfied.

GA SITE MODEL

In GASITE [14] model the input phase is designed to help the construction planner enter and store all the necessary planning data needed to optimize the site layout plan. GASITE is linked to MATLAB to solve the optimization problem using GA as an optimizer. GA parameters were tuned to suit this problem. These parameters include: (1) the population size; (2) the number of generations; (3) the type of crossover and its probability; (4) the probability of mutation; (5) and the random seed used to randomly initiate the first population of solutions (Deb, K. 2001)[15]. These genetic parameters are utilized by the objective optimization function to control the evolution of the solutions generated during the optimization process which runs until completing the specified number of generations. After completing the optimization process, the results are retrieved and visualized in the output phase.

The input data phase includes four steps as follows:

STEP (1):

Enter facilities data as shown in Fig. (5). This data includes, site name, temporary facility name, dimensions, material quantity and travel cost per meter.

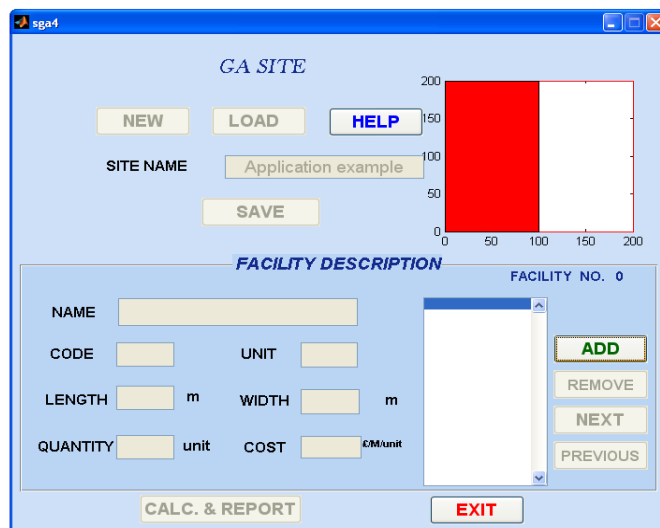


Fig. (5) GASITE main interface

STEP(2):

The main program screen will appear with three options as shown in Figure (6), the options are NEW for starting new project, LOAD for restoring an old project and HELP to learn about GASITE.

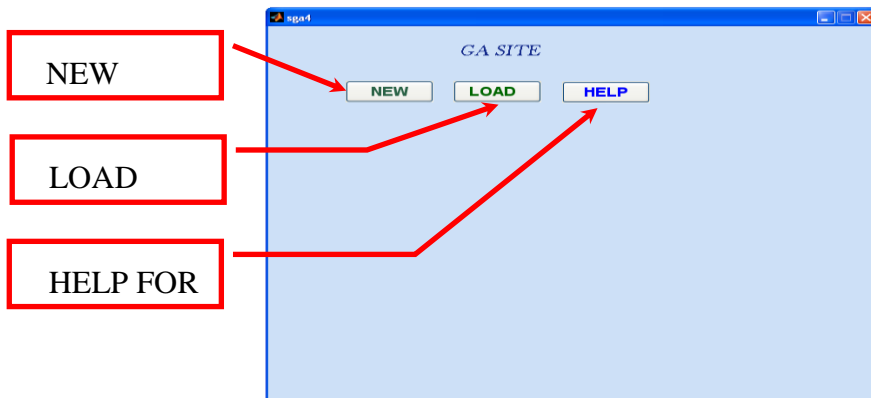


Fig. (6) Editing or opening projects

STEP (3) :

In case of new project, by pressing 'new button' project data window .GA SITE asked the user to define the site coordinates and site name as shown in Fig. (7).

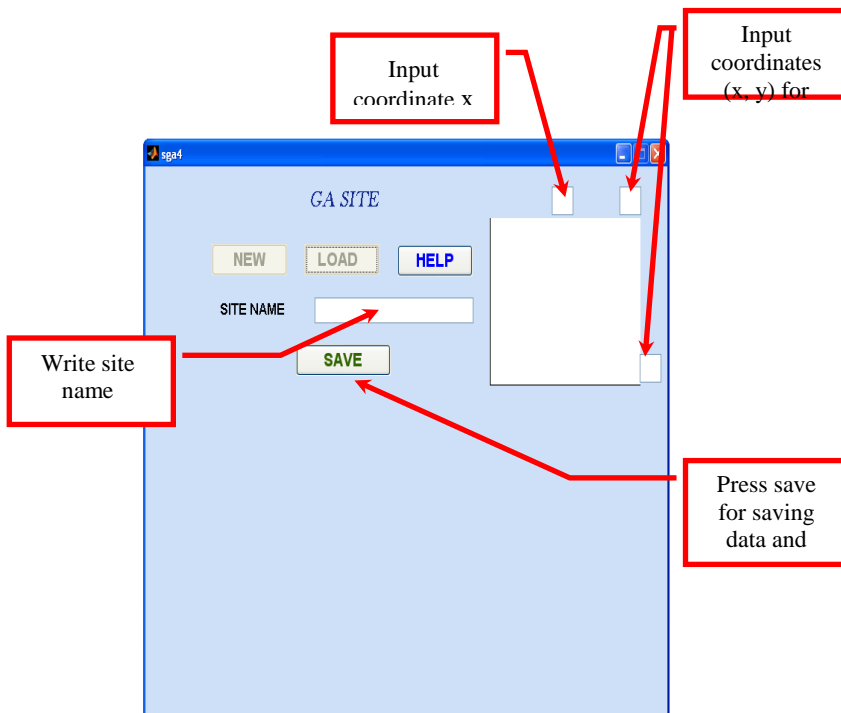


Figure (7) Entering site dimensions

STEP (4):

After finished entering data either than stage 3 or 4 press 'calculation & report button' for show the results. As shown in Fig (8) . After end of analyses process the following items will appear:

- Two edit boxes shows the value of the objective function as shown in Fig (10), best and mean fitness of the problem as shown in Fig.(11)
- Plotted figure shows the distribution of temporary facility on site as shown in Fig. (12).

Excel sheet shows a complete report about the site layout as shown in Fig. (13).

For calculating the data

For exit GA SITE

Fig. (8) Complete GASITE data interface

NUMERICAL EXAMPLE

In this section we present an example for a site as shown in Fig. (9). The application example is analyzed to illustrate the use of the GASITE model and demonstrate its capabilities in optimizing construction site layouts and generating optimal solution for objective function.

The example involves the design of a layout for the site has an area of 40000 m² with dimensions (200 * 200 m) and was required to accommodate the ten temporary facilities listed in Table (1) .

Using GASITE to solve this problem. The locations of temporary facilities, however, need to be properly determined in an attempt to minimizing cost and travel distance between facilities on site. In order to support planners in this important and challenging task, the present model is applied to search for and identify optimal locations for all the temporary facilities.

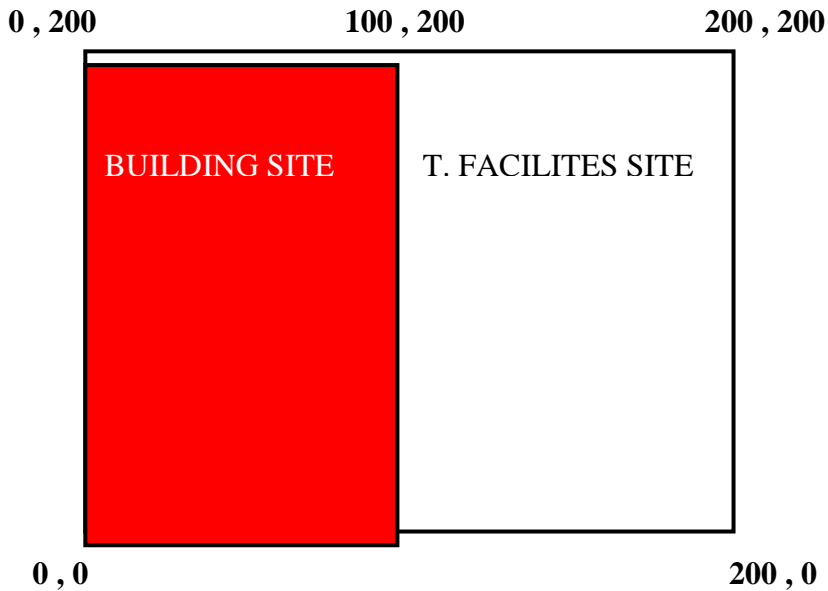


Figure (9) Site dimensions

Table (1) the specification of temporary facilities for application example

Facility no.	Facility name	Facility code	Facility Dimensions		Unit	QTY	Cost EGP/M
			Length m	Wide m			
1	Reinforcing steel shop1	R1	16	8	Ton	80	6.00
2	Reinforcing steel shop2	R2	16	8	Ton	80	6.00
3	Carpentry shop1	C1	12	10	No.	60	1.00
4	Carpentry shop2	C2	12	10	No.	60	1.00
5	Formwork shop1	F1	16	10	M3	120	1.50
6	Formwork shop2	F2	16	10	M3	120	1.50
7	Concrete batch plants	B	16	16	M3	100	1.25
8	Cement storage	CM	12	12	Ton	40	1.00
9	Block storage	BS	10	10	No./1000	70	2.00
10	Warehouse	W	15	15	No.	160	1.00

THE RESULTS

Running GASITE leads to the followings:

- The value of the fitness function.(minimum of the total travelling cot Fig.(10).
- The mean and the best fitness value of the objective function (Fig. (11) .
- Complete report about site layout as shown in Fig.(12).

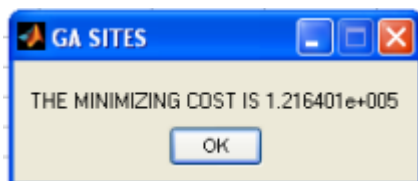


Fig. (10) The Minimizing cost edit box

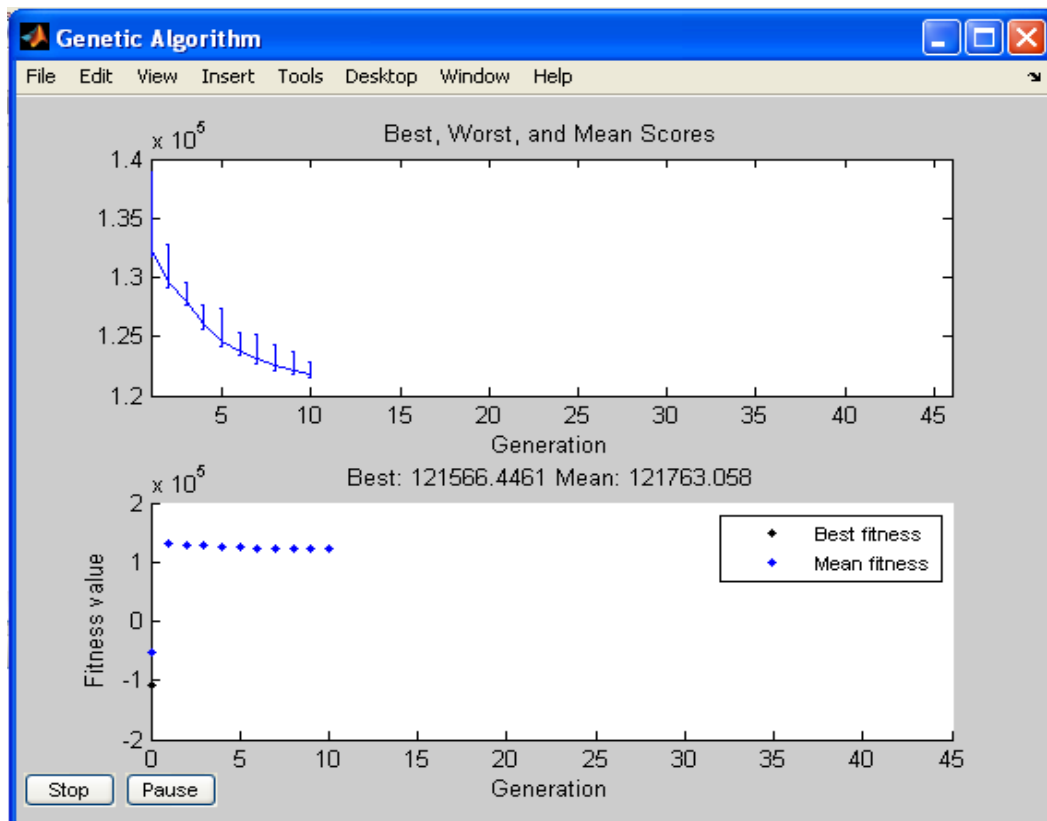


Fig. (11) The best & main Fitness value

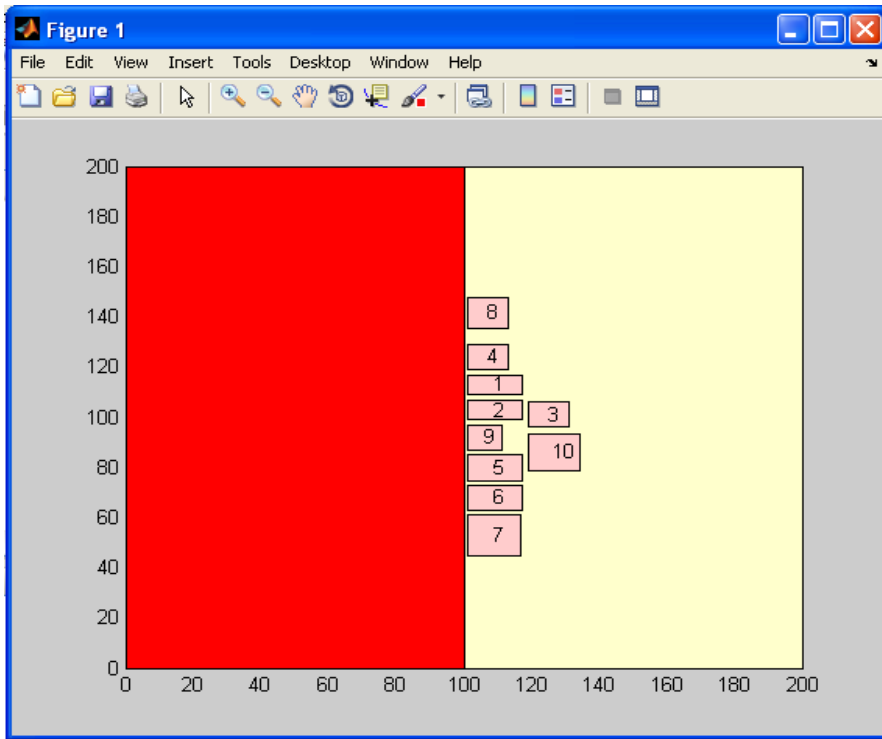


Fig. (12) Distribution of temporary facilities on site

facility	facility	x	y
name	code	center	center
Reinforcing R1		109.0554	112.873
Reinforcing R2		109.0576	102.873
Carpentry C1		125.271	100.9799
Carpentry C2		107.0379	124.0359
Formwork F1		109.0528	79.85111
Formwork F2		109.0559	67.84435
Concrete t B1		109.0205	52.82828
Cement st CM		107.2224	141.6508
Block ston BS		106.1155	91.86146
Warehousi W		126.6493	85.97096

Fig. (13) Output report

CONCLUSION

This paper presents a computer model "GA SITE" used for site layout planning. GASITE was designed to locate the optimal positions for temporary facilities. The selection of the optimal locations for temporary facilities based on minimizing cost and travel distance between facilities. Genetic algorithms were used as an optimization technique. Application example was analyzed to illustrate the use of the model and demonstrate its capabilities in optimizing construction site layouts. In conclusion, the use of GASITE can provide the planner with a good site layout planning.

REFERENCES

- (1) Tommelein, I. D., Levitt, R. E., and Hayes-Roth, B. (1992). "Sight Plan model for site layout." *J. Constr. Eng. Manage.*, 118(4), 749–766.
- (2) Hegazy, T., and Elbeltagi, E. (1999). "EvoSite: Evolution-based model for site layout planning." *J. Computer Civ. Eng.*, 13(3), 198–206.
- (3) Yeh, I.-C. (1995). "Construction-site layout using annealed neural network." *J. Computer. Civ. Eng.*, 9(3), 201–208.
- (4) Li, H., and Love, P. E. D. (1998). "Site-level facilities layout using genetic algorithms." *J. Comput. Civ. Eng.*, 12(4), 227–231.
- (5) Kumara, S. R. T., Kashyap, R. L., and Moodie, C. L. (1988). "Application of expert systems and pattern recognition methodologies to facilities layout planning." *Int. J. Prod. Res.*, 26(5), 905–930.
- (6) Hamiani, A. (1989). "Knowledge representation for the site layout problem." *Sixth Conf. on Computing in Civil Engineering*, New York, 283–289.
- (7) Dawood, N., and Marasini, R. (2001). "Stockyard layout management for precast concrete products using simulation." *Proc., CIB-W78 Int. Conf., IT in construction in Africa*, Mpumalanga, South Africa, 26/1–13.
- (8) Tawfik, H. M., and Fernando, T. (2001). "A simulation environment for construction site planning." *5th Int. Conf. Information Visualisation*, London, U.K.
- (9) Islier, A. A. (1998). "A genetic algorithm approach for multiple criteria facility layout design." *Int. J. Prod. Res.*, 36(6), 1549–1569.
- (10) Harmanani, H., Zouein, P., and Hajar, A. (2000). "An evolutionary algorithm for solving the geometrically constrained site layout problem." *Proc., 8th ASCE Int. Conf. on Computer. Civ. and Build. Eng. (ICCCBE-VIII)*, Stanford University, 1442–1449.
- (11) Mawdesley, M. J., Al-jibouri, S. H., and Yang, H. (2002). "Genetic algorithms for construction site layout in project planning." *J. Constr. Eng. Manage.*, 128(5), 418–426.
- (12) Goldberg, D. E. (1989). *Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison-Wesley.
- (13) K.El-Rayes, et al (2005) "Trade-off between safety and cost in planning construction site layouts" *Journal of construction engineering and management ASCE* November
- (14) Samy Maqboly (2010) , "Minimizing of cost and travel distance between facilities in construction site layout planning of medium projects ", *M. Eng.*

thesis, Arab Academy for Science and Technology and Maritime Transport, Alexandria, Egypt, (In progress).

(16) Deb,K (2001) “Multiobjective optimization using evolutionary algorithms “ Wiley ,New york

التوزيع الأمثل للمنشآت المؤقتة في مواقع التشييد

تعد المساحات المتوفرة بمواقع التشييد للمنشآت المؤقتة مثل المخازن وأماكن تشوين وتصنيع حديد التسليح وأماكن تشوين وتصنيع الشدادات والسقالات ... الخ أحد العناصر الهامة التي كثيراً ما يتم تجاهلها أثناء عمليات التخطيط المبدئي للمشاريع. و لذلك يجب استخدام هذه المساحات بصورة مثالية لوضع هذه المنشآت المؤقتة بحيث يتم تحقيق شرط تقليل تكلفة و مسافة النقل الذي يؤثر تأثيراً كبيراً في تكلفة الإنشاء. ولحل هذه المشكلة فقد تم عمل برنامج حاسب إلي (GASITE) يحتوي علي مجموعة من الشاشات للمدخلات والمخرجات سهلة الاستخدام لمهندسي التشييد . تشمل شاشات المدخلات عدد المنشآت المؤقتة وأسمائها وأبعادها المقترحة وكمية المواد المنقولة منها إلي المبنى المراد أنشاؤه و تكلفة نقل هذه المواد داخل الموقع . وتشمل شاشات المخرجات شكل الموقع العام موضحة علي توزيع هذه المنشآت المؤقتة و تقرير عن إجمالي تكلفة النقل اعتماداً علي داله الهدف التي تحقق اقل مسافة نقل و اقل تكلفة و يتم الحل بحيث يتم استيفاء القيود و هي علي سبيل المثال لا الحصر شرط أن يكون توزيع المنشآت المؤقتة داخل الموقع وأيضاً عدم التداخل بين هذه المنشآتالخ. ولحل داله الهدف تم استخدام الخوارزمات الجينية (GENETIC ALGORITHMS) للحصول علي الحل المثالي لما لها من قوة لحل مثل هذا النوع من الدوال.و قد تم اختبار هذا البرنامج للتأكد من صحته و تم تطبيقه للحصول علي النتائج موضحة بالبحث.