International Journal of Scientific & Engineering Research, Volume 6, Issue 8, August-2015 997
ISSN 2229-5518

Existing Site Layout Planning Models and Approaches

Mohamed Nour El-Din, Hesham Bassiouni, Khaled Shawki

Abstract— The field of site layout planning studies have commenced as early as the early 70's, a significant amount of effort has been directed at developing algorithms for identifying optimal construction site layouts which have been addressed separately until now. However, in this study a single framework is made of showing a list of different site layout planning models that can help future research to make a link between different models. The possibility of using a similar approach to find an optimum solution for the planning of construction site layouts under using population based meta-heuristics, trajectory based meta-heuristics and graphical based methods is assessed.

Index Terms— Layout Planning, Optimization

1 Introduction

PROBLEMS that deal with the identification of the optimum location of a number of objects in a predefined area are called Layout planning problems. In many frameworks the solution of layout planning problems has been a frequent issue. For example, construction site management, building design, the location of facilities in urban planning and the design of manufacturing plants [1].

In this study, the construction site layout management was found to be addressed separately in research until now, and different solutions were consequently developed for them. The solutions include the application of different techniques and methods which are classified into Population Based Meta-Heuristics, Trajectory Based Meta-Heuristics and Graphical methods. However, the different site layout planning processes all have similar objective functions which are the minimization of flow costs between the objects in the plan, and the maximization of some measure of closeness ratings.

The hypothesis of this study is to show a list of different site layout planning models that reveals the degree of similarity between the problems. Providing in this study of a framework that provides a list of different site layout planning models is the main objective which can give the opportunity for future knowledge transfer between the currently disconnected problems which may help in the development of new solutions.

This study lists three different existing site layout planning models and approaches:

- Population Based Meta-Heuristics
- Trajectory Based Meta-Heuristics
- Graphical methods

2 Layout Optimization Using Population Based Meta-Heuristics

A research on the use of Annealed Neural Networks by Yeh [2] for construction site layout was performed. Yeh [2] has formulated the problem as a discrete combinatorial optimization problem. This formulation is identical to that presented by Li & Love [3]. Similarly, the model aimed at assigning a set of predetermined facilities on a set of predetermined locations while satisfying a set of layout constraints. Thus the system's method of assignment is classified as a facility to location assignment. The annealed neural network proposed exhibits the rapid convergence of

ISSN 2229-5518

the neural network while preserving the solution quality afforded by simulating annealing [2].

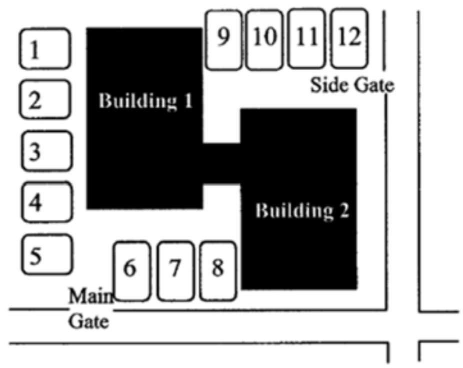

Fig. 1. Site space representation in SitePlan [2].

It was first proposed a research in which a solution for the site-level facilities layout problem using GAs was developed by Li & Love [3]. They hypothesized a facility to location assignment method for the construction site layout problem as laying out predetermined facilities in predetermined locations, (e.g., laying out 11 facilities in 11 locations), so as to minimize the total travel distance between facilities. The algorithm only addressed the static layout problem. The solution generated of the site layout geometry and individual facility size or shape was completely independent. In most of the subsequent studies Tam et al. [4], Zhang & Wang [5], Lam et al. [6] and Gholizadeh et al. [7] this formulation has been implemented.

Later on, Li & Love [8] acknowledged that the representation of the problem as an equal–area problem limited the utility of the algorithm and proposed an alternate model. Therefore by creating a subset of available locations which are smaller than rest of the locations the alternate model defined the problem as an unequal-area problem, say Lp and facilities which cannot be housed in Lp, which is then controlled by applying a genetic constraint to govern the non-assignment requirement between those subsets. In both studies, for effective optimization considering the effect of the size of initial population on convergence it was recommended by the authors that an initial population of 100, and 90-100 GA iterations could be used [9].

A difference in space/topographic conditions of temporary facilities exist due to different functions, the layout problem is often an unequal-area facility layout where the facilities and locations have different sizes/areas. An algorithm in which several GA operators (in addition to the traditional crossover and mutation) were developed by Harmanani et al. [10] and Zouein et al. [11] which were used to solve the site layout problem with unequal size and constrained facilities. These operators include inversion, swap, move, rotation, flip2edge, add missing blocks, fix blocks, and aging. In Alagarsamy [9], the positioning a few rectangular blocks (fixed dimensions) within the available site, where the layout objects can take two orientations (0˚, 90˚) while satisfying the proximity, overlap, and orientation constraints which characterizes the layout problem. the generation of a set of feasible positions for a temporary facility in the neighborhood of a randomly selected location, was made by the Find-a-Set-of-Possible-

- *M.Sc. Candidate, Dept. of Construction and Building Engineering, Univ. of Arab Academy for Science, Technology and Maritime Transport. Email: Mohamed.abushamma@aast.edu*
- *Professor, Dept. of Construction and Building Engineering, Univ. of Arab Academy for Science, Technology and Maritime Transport. Email: hbassiouny2000@yahoo.com*
- *Assistant Professor, Dept. of Construction and Building Engineering, Univ. of Arab Academy for Science, Technology and Maritime*

Positions (Find-ASPP) function and was raised by several GA operators to evolve an initial population. a given location is taken by Find-ASPP function as an input and returns a set of four rectangles or less that describe feasible positions of the center-point of the temporary facilities.

Hegazy & Elbeltagi [12], presented their model for site layout planning. Their work was much more comprehensive and generic than that performed by Li & Love [2]. The Evosite is a spread sheet based site utilization planning tool, which was developed by Hegazy & Elbeltagi [12] that allows the user to define the space requirement for each facility as a group of unit areas (grids). These grids combine to take a user-specified shape which is not limited to rectangular or square shape, allowing for more flexibility in the placement of the facilities and a realistic representation of the site geometry. Also fixed facilities can be marked as excluded areas in the layout as not to be used while allocating temporary facilities. Project manager's preference in positioning the facilities are determined using a qualitative method which is governed while developing and designing the objective function to meet their desired closeness relationships between different temporary facilities on site. Theses qualitative measures are then mapped to a quantitative weight that can be used in optimization as shown in Table 1.

Tam et al. [4], aimed to limit the study to a particularly defined area of construction: which is the structural concrete-frame construction stage of public housing projects. Optimization of the tower crane and supply locations is targeted, as they are the major site facilities for high-rise building construction. A site layout genetic algorithm model is developed and a practical example was presented. The optimization results of the example were very promising and demonstrated the application value of the model.

A formulation using GA was developed by Zouein et al. [11], for solving the site layout problem with unequal-size and constrained facilities. Their research focused more on

TABLE 1
CLOSENESS RELATIONSHIP VALUES [12]

Desired relationship between facilities	Proximity weight
Absolutely necessary	$6^5 = 7,776$
Especially important	$6^4 = 1,296$
Important	$6^3 = 216$
Ordinary closeness	$6^2 = 36$
Unimportant	$6^1 = 6$
Undesirable	$6^0 = 1$

the investigation of the modified GA than on developing an integrated site layout planning system. The strengths and limitations of their proposed GA were tested in the case of:

1. Loosely vs. tightly constrained layouts with equal levels of interactions between facilities.

2. Loosely vs. tightly packed layouts with variable levels of interactions between facilities.

3. Loosely vs. tightly constrained layouts.

Mawdesley et al. [13], described the formulation of the problem of positioning temporary facilities on a construction site as a genetic algorithm. A crossover and mutation operators to allow the operation of the genetic algorithm were provided. The fitness function can be drawn up to include a range of measures of the layout offering the ability to include transport, setup, and removal costs. It can also include other less tangible measures such as environmental and safety aspects. A rectangular grid was used which has made the problem easy to specify and solve. The smaller the grid size, the more accurate the solution but the greater the computational effort required.

An application was presented by Lam et al. [6] about the entropy technique and genetic algorithms to construction site layout planning of medium-size project. An objective function was created with the attributes of the governing factors and the closeness relationships between site facilities of medium-size projects. By introducing an entropy measure and fuzzy arithmetic, an index or weights of governing factors and closeness indices for the relationships between site facilities were deduced and such that the quantitative problem of the importance of weights can be solved in layout planning.

Jang et al. [14] focused on the floor-level construction material layout which is required for multiple-floor building where multiple construction works occur simultaneously in close proximity. By minimizing excessive repositioning of construction materials, the floor-level construction material layout would assist in finding sufficient space for construction materials in urban areas where space is limited around the building sites. The floor-level construction material layout provides project managers with a valuable technique for developing efficient sequences of works that optimally defines how to efficiently position the construction materials and minimize the travel distance between work spots and specific construction materials in a multiple-floor space. Jang et al. [14] compared total distances of construction material handling between an actual case and the output of Genetic Algorithm (GA). Comparative analysis of the output generated by the GA and the actual case study reveals that inefficiencies in positioning of construction materials at the floor-level can lead to an increase in the construction labor material handling distance by 14%.

Zhang & Wang [5] used Particle Swarm Optimization algorithm that simulates social behaviors such as bird flocking together to develop a solution to the unequal-area layout planning problem. In the Particle Swarm Optimization based algorithm, a solution approach is developed using priority-based particle representation of the layout solutions, transformation to the specific layout in consideration of non-overlay and geometric constraints, and framework for implementation. Also a comparative study was performed of the solutions of GA based approach, the PSO adopted solutions required fewer iterations to find the optimal solution than GA based solutions as a result.

A modified GA (MMAS-GA) formed by conjoining MMAS (Max-Min Ant System) to the step of initialization of GA is proposed by Lam, et al. [6] to solve construction site layout planning problems. In order to show the computational capability of MMAS-GA to solve construction site layout planning problems, the results of MMAS-GA and traditional GA are compared by solving an equal-area construction site layout planning problem. The results showed that the proposed MMAS-GA algorithm provided a better optimal solution under the objective function of minimizing the transportation flows between the site facilities. The proposed MMAS-GA algorithm could assist project managers and planners to design optimal construction site layout, and thus to reduce construction costs.

Wong et al. [15] compared a genetic algorithm model that was developed for the search of a near-optimal layout solution and another approach using mixed-integer programming which has been developed to generate optimal facility layout of a precast standardized modular units that requires the establishment of an on-site precast yard. The study has highlighted that mixed-integer programming can perform better than GA in site facility layout problems in which the site facilities and locations can be represented by a set of integer variables.

A site layout algorithm based on ACO was presented by Ning et al. [16] and Ning et al. [17], in which the planning problem is conceptualized as a dynamic multi-objective optimization problem. The authors chose to address the dynamic aspect of the problem by dividing the project duration into smaller layout intervals and generating a layout for each of the layout interval. The evaluation function is designed to find a layout that minimizes the likelihood of accidents (improve safety) and minimizes the total handing cost of interaction flows between the facilities associated with the construction site layout.

3 Layout Optimization Using Trajectory based Meta-Heuristics

To enable the escape from a local optimum Simulated Annealing and Tabu Search algorithms are two methods commonly used. Simulated Annealing is a probabilistic optimization method which works by emulating the physical processes whereby a solid is slowly cooled so that its structure is finalized at a minimum energy configuration. Yeh [2] used annealed neural networks to solve the site layout optimization problem.

Kuppusamy [18], proposed three variants based on the Simulated Annealing model, which are the SA I, SA II and SA COMBO. SA I is an adaptation of Simulated Annealing for dynamic layout problem. SA II is just like SA I but with reheating strategy. The third heuristic, SA COMBO, is the combination of the pair-wise exchange heuristic with time windows, SA and the backward pass pair-wise exchange heuristic.

Liu [19], also presented three models based on the tabu search. The adaptation of tabu search heuristic for the dynamic layout problem is made by the TSbasic. The frequency-based memory and diversification/intensification strategies with the tabu search are incorporated with the TSall. Candidates for the tabu search are discreetly selected by the Probabilistic tabu search heuristic (PTS).

Liang & Chao [20] proposed an algorithm based on Tabu Search (TS) to layout temporary facilities. The problem of allocating ‘n’ facilities to ‘n’ locations with the objective of minimizing the travel distance among the facilities was conceptualized by them. TS include two main processes, to avoid local optima, intensification (to explore the solution space from similarity) and diversification (to modify the move strategy to become more efficient in the solution search). These studies formulated the optimization as a static, one-to one (i.e., space as discrete objects) problem with the single objective of minimizing the cost / distance traveled, which is like the existing formulation of the problem.

4 Graphical Site Layout Methods

Due to the fact that the site boundaries, existing permanent structures, the structure to be constructed, and temporary facility locations all occupy space in three dimensions the layout of temporary facilities is inherently graphical in nature. Due to the inherent human ability to conceptualize space and inter-relationships between spaces in two or three dimensions the layout planning can be done effectively graphically. This idea was utilized by many notable studies [9].

Cheng and O'Connor [21] developed the ArcSite, which is an automated site layout system that utilizes the capabilities of GIS integrated with Database Management Systems (DBMS) for temporary facilities to assist designers in solving the layout planning problem. Knowledgeable users can easily modify the project attributes and perform ‘What-If’ analysis with little effort which is the key benefit of the tool proposed in this study. Osman [22] developed a system that achieves four sub objectives:

1. Obtain the knowledge and procedures that project managers use in laying out site facilities.
2. Model the experts’ knowledge and experience of site planning and express it in a systematic form.
3. To identify the suitable location for the facility define the dominant variables and develop an evaluation method.
4. To replace manual methods develop a GIS based site layout system.

ISSN 2229-5518

Osman [22] developed the procedures in the research to acquire and represent site layout knowledge which are classified into three phases:

1. For the site layout, compiling the experts' knowledge and experience.
2. The knowledge is interpreted into the knowledge base.
3. The knowledge base is translated into the ArcSite implementation forms.

A different hybrid approach in which GA is integrated within the computer aided design AutoCAD® environment to optimize the location of temporary facilities onsite was developed by Osman et al [23]. While the aim of achieving one or more goals (typically minimization of cost) under problem-specific constraints are made by most systems that use mathematical techniques. In contrast, the AutoCAD® drawing (e.g., site boundaries, permanent facilities, obstacles) is used by the hybrid system which performs the optimization based on the geometric data provided. To identify the space available for placing temporary facilities, it is performed only once by the space detection task. While in every cycle of the optimization process the constraint satisfaction task is performed. Finally, to detect space and ensure constraint satisfaction (facilities placed within site boundaries and non-overlap) the drawing is used.

A temporary facility layout planning tool aimed at building on existing research on site layout planning was presented by Alagarsamy [9]. A user friendly, mathematically robust optimization tool that enables the user to model geometric, temporal and project specific requirements is presented in this thesis. This tool uses an optimization engine based on genetic algorithms. The tool provides an option to conventional distance measurement formulas (i.e., Euclidean and Manhattan). The tool is designed to enable the user to specify project specific constraints such as unusable areas, use of offsite locations for temporary facilities, eliminating double handling of materials by locating the required temporary facilities (e.g., laydown areas) within the reach of a user defined crane location. The tool also has the capability to use data extracted from REVIT Building Information Modeling (BIM) models. This tool is designed to be user friendly, mathematically robust and practical.

5 Conclusion

A framework is made in this study that provides a list of different site layout planning models is the main objective which can give the opportunity for future knowledge transfer between the currently disconnected problems which may help in the development of new solutions.

In order to control the complexity of the problem, most studies consider site layout planning as a single objective problem involving minimization of cost or minimization of distance travelled. While the previously mentioned models address site layout with different assumptions, they suffer from one or more of the following shortcomings:

1. The optimization process is limited to minimization of travel effort. As distance is concerned only so far these models useful. In practice, features including safety and security are other features where the efficiency of a layout is judged, which are not a function of travel effort. The problem should be defined as a multi-objective problem where the optimization objectives would be to reduce layout cost while simultaneously meeting safety requirements.

2. Neglecting user interaction. Site planners prefer to alter decisions made by a computer system, based on their knowledge and experience. Preventing user interference, does not allow the utilization of users' experience and knowledge in designing a site layout, and more importantly, does not allow their contribution to the knowledge of the model.

3. Most of the studies reviewed in this study have interpreted the site layout to be static (single layout for the entire project duration). But the space available for laying out temporary facilities may change with time due to the very nature of the construction process. So considering the construction site layout planning as a dynamic/temporal problem is so important. This dynamic aspect of creating a layout has been explicitly addressed by only a few researchers.

ACKNOWLEDGMENT

I humbly wish to express my sincere gratitude to the Construction and Building Engineering Department of College of Engineering and Technology, Coimbatore for their moral and technical support for publication of these findings.

REFERENCES

[1] M. Andayesh and F. Sadeghpour, "Minimum Potential Energy for Site Layout Optimization," in *Proceedings, Int.Symposium on Automation and Robotics in Construction*, Seoul, Korea, 2011.

[2] I.-C. Yeh, "Construction site-layout using annealed neural network," *Journal of Computing in Civil Engineering,* vol. 9, no. 3, pp. 201-208, 1995.

[3] H. Li and P. E. D. Love, "Site level facilities layout using genetic algorithm," *Journal of Computing in Civil Engineering,* vol. 12, no. 4, pp. 227-231, 1998.

[4] C. M. Tam, T. K. L. Tong, A. W. T. Leung and G. W. C. Chiu, "Site Layout Planning Using Nonstructural Fuzzy Decision Support System," *Journal of Construction Engineering and Management, ASCE,* vol. 128, no. 3, pp. 220-231, 2002.

[5] H. Zhang and J. Y. Wang, "Particle Swarm Optimization for Construction Site Unequal-Area Layout," *Journal of Construction Engineering and Management, ASCE,* vol. 134, no. 9, pp. 739-748, 2008.

[6] K.-C. Lam, X. Ning and M. C.-K. Lam, "Conjoining MMAS to GA to Solve Construction Site Layout Planning Problem," *Journal of Construction Engineering and Management, ASCE,* vol. 135, no. 10, pp. 1049-1057, 2009.

[7] R. Gholizadeh, G. G. Amiri and B. Mohebic, "An alternative approach to a harmony search algorithm for a construction site layout problem," *Canadian Journal of Civil Engineering,* vol. 37, no. 12, pp. 1560-1571, 2010.

[8] H. Li and P. E. D. Love, "Genetic search for solving construction site-level unequal-area facility layout problems," *Automation in Construction,* vol. 9, no. 2, pp. 217-226, 2000.

[9] K. Alagarsamy, "CONSITEPLAN – A Multi-Objective Construction Site Utilization Planning Tool," Master of Science, 2012.

[10] H. Harmanani, P. Zouein and A. Hajar, "An Evolutionary Algorithm for Solving the Geometrically Constrained Site Layout Problem," *Computing in Civil and Building Engineering,* pp. 1442-1449, 2000.

[11] P. P. Zouein, H. Harmanani and A. Hajar, "Genetic algorithm for solving site layout problem with unequal size and constrained facilities," *Journal of Computing in Civil Engineering,* vol. 16, no. 2, pp. 143-151, 2002.

[12] T. Hegazy and E. Elbeltagi, "EvoSite - Evolution-Based Model for Site Layout Planning," *Journal of Computing in Civil Engineering,* vol. 13, no. 3, pp. 198-206, 1999.

[13] M. J. Mawdesley, S. H. Al-Jibouri and H. Yang, "Genetic algorithms for construction site layout in project planning," *Journal of Construction Engineering and Management,* vol. 128, no. 5, pp. 418-426, 2002.

[14] H. Jang, S. Lee and S. Choi, "Optimization of f loor-level construction material layout using Genetic Algorithms," *Automation in Construction,* p. 531–545, 2007.

[15] C. K. Wong, W. H. Fung and C. M. Tam, "Comparison of Using Mixed-Integer Programming and Genetic Algorithms for Construction Site Facility Layout Planning," *Journal of Construction Engineering & Management, ASCE,* vol. 136, pp. 1116-1128, October 2010.

[16] X. Ning, K.-C. Lam and M. C.-K. Lam, "A decision-making system for construction site layout planning," *Automation in Construction,* 2010a.

[17] X. Ning, K.-C. Lam and M. C.-K. Lam, "Dynamic construction site layout planning using max-min ant system," *Automation in Construction,* vol. 19, no. 1, pp. 55-65, 2010b.

[18] S. Kuppusamy, Simulated annealing heuristics for the dynamic facility layout problem, West Virginia University: Master's thesis, 2001.

[19] W.-H. Liu, Tabu search for the dynamic facility layout problem, Master's thesis ed., West Virginia University, 2005.

[20] L. Y. Liang and W. C. Chao, "The strategies of tabu search technique for facility layout optimization," *Automation in Construction,* vol. 17, no. 6, pp. 657-669, 2008.

[21] M. Cheng and J. O'Connor, "Arcsite - Enhanced GIS for construction site layout.," *Journal of Construction Engineering and Management,* vol. 122, no. 4, pp. 329-336, 1997.

[22] H. M. Osman, "CAD-Based dynamic layout planning of construction sites using genetic algorithms," Master of Science, 2002.

[23] H. M. Osman, M. E. Georgy and M. E. Ibrahim, "A hybrid CAD-based construction site layout planning system using genetic algorithms," *Automation in Construction,* vol. 12, no. 3, pp. 749-764, 2003.