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RELATIVE IMPORTANCE ANALYSIS OF VARIABLES INFLUENCING CONSTRUCTION SITE LAYOUT PLANNING FOR SECURITY AND CRIME PREVENTION

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ABSTRACT

Purpose: This paper investigated the variables influencing construction site layout planning for effective site security. Construction sites are fraught with security and crime risks. To secure the site decisions have to be made on the best layout option on the location of facilities, road network, and access and exit points. A proactive site layout planning can increase productivity, efficiency, security and profitability.
Design/methodology/approach: Survey research method was adopted for the study. Copies of questionnaire were administered on construction/site managers involved in various sizes of construction projects in Akwa Ibom State. A total of 15 variables identified in the literature were evaluated using relative importance index (RII). The analysis also involved the ranking of the values (highest to lowest) of the different variables according to the relative importance indices.
Findings: The results showed that grouped location of facilities, security evaluation, perimeter control measures, access control, positioning of objects for clear lines-of-sight and strategic lighting are the most important variables (ranks 1 – 6 respectively) in construction site layout planning for security and crime prevention.
Research limitations/Implications: The paucity literature on site layout planning for security was a limitation to the study. To overcome this, the study combined variables from Crime Prevention through Environmental Design (CPTED) with site layout planning variables to produce a set of variables for site layout planning for security and crime prevention.
Originality/value: The paper concluded that security and the efficiency and effectiveness of labour and materials management for optimum productivity could be compromise by wrong location and placement of materials laydown areas, plant and equipment, offices and storage facilities and poor access to materials and work areas. It recommended the use of rule-based design checking system to assist human judgement on decision making by designers and construction managers.

Keywords: Crime; crime prevention; planning; security; site layout

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1. INTRODUCTION

Worldwide, the construction industry is considered to be one of the most important sectors in the economy of every country. It has interaction with nearly all areas of human endeavour because most human activities take place within spaces created by construction. The construction industry consists of all works carried out for the physical development and improvement of the environment for the achievement of developmental programmes' goals and objectives. Statistics drawn from 50 largest and most influential construction markets in the world by Construction Intelligence Center indicate that the turnover of the global construction industry was about $7.4 trillion in 2010, $8.5 trillion in 2015 and is projected at $10.3 trillion in 2020 at a growth rate of 3.9% (PR Newswire, 2015). The report predicts that the construction industries in the Middle East and Africa region will be the fastest growing in 2016 - 2020 period. This growth also carries with it some risks and challenges that need to be addressed. For countries in developing nations like Nigeria, the construction industry plays a significant role in boosting the economy and in socio-economic development. Analysis of data from the National Bureau of Statistics (NBS) for 2016 reported that the contribution of Nigeria's construction to GDP was 4% (Samuel, 2017). In real terms, the construction industry's output value increased at a compound annual growth rate (CAGR) of 11.68% between 2011 and 2015, and is estimated to grow at a CAGR of 9.49% over the period 2016 - 2020 (Business Wire, 2016).

The key project objectives of time, cost and quality could be affected by issues relating to security. To a contractor a project is not considered successful if the objective of profit is not achieved. Incidences of theft and losses recorded at construction sites can be extremely costly in terms of time lost, accident induced expenditure, insurance, delays, replacement of damaged, destroyed or stolen materials, and damage done to company's image. This has a great impact and effect on project objectives. Severe loses could lead to abandonment of the project, bankruptcy or poor quality projects. Crime problems on site could result from poor site layout planning. Effective use of site space has a significant impact on safety and security on site (Sadeghpour and Andayesh, 2015). The inability to factor in security needs on construction sites, especially critical infrastructure projects, also leaves the site vulnerable to crime and other security problems. Site layout planning which is often overlooked by many contractors (Kumar and Bansal, 2015) can have a negative impact on security. Every activity and structure on site has the potential of attracting criminal elements. Plant, equipment and materials such as aggregate heaps not properly located can block lines-of-sight of security personnel thereby compromising security. They could constitute concealment and cover for potential offenders.

Issues of crime prevention and security should, therefore, be of prime consideration to construction site layout planners. Planning allows for successful and effective performance of the security functions of a construction site. It involves visualising, projecting, locating and validating proposed activities considered necessary to achieve desired project objectives. Planning bridges the gap between assumptions and action. It determines in advance the course of action to be taken. Studies on site layout planning generally focus on productivity and safety. Site layout planning for security of construction sites is a less explored area. There are many variables involved. This study identifies the variables that can be considered in site layout planning for security and crime prevention. The variables are drawn from crime prevention through environmental design (CPTED), physical security and defensible space models and mapped together with conventional site layout elements. It also identifies core elements and concepts that can be used to develop layout

plans for security of construction and critical infrastructure sites. A proactive site layout planning can increase productivity, efficiency, security and profitability. Contractors will spend more money and time to complete a project if the construction site is not adequately protected.

1.1. The problem

Elements of risk and uncertainty could jeopardise the achievement of project objectives if the contractor does not fully plan and control all aspects of the project. Site security problems can affect the success and the potential profitability of the project. To remain competitive and in business a contractor will generally do everything possible to manage the resources necessary to complete the project. Construction sites today face many of the same social issues and problems as do other institutions. Globally, theft on construction sites is rampant. British Security Industry Association (2012) notes that construction sites are targets of both the opportunistic and carefully planned crimes. The National Equipment Register and National Insurance Crime Bureau joint 2013 annual report on equipment theft indicates that an estimated $300 million to $1 billion worth of registered construction equipment were stolen in 2013 in the United States and only about 21% recovered (Verisks Crime Analytics, 2014). This was based on 11,846 reported cases and excludes theft of tools, building materials and loses due to vandalism. Site security is a major contribution to site theft. Research by Verisks Crime Analytics (2017) indicates that increase in construction works correlates with higher numbers of construction equipment in an area attracting attention from thieves thereby increasing the risk of theft. The site location that the equipment spends the most time and the level of site security are indicated, among others, as factors that increase equipment theft.

The 2012/2013 construction site theft report by Mobile Mini (2015) indicates that the construction industry in the UK loses hundreds of millions of pounds yearly due to construction site theft. According to the report, there were an estimated 6,000 cases of site theft between September 2012 and September 2013. An assessed 35% of the cases involved forced entry while 21% of the cases occurred in unsecure sites. It noted that plant equipment, metals and tools were commonly targeted. Others include building materials, diesel, electrical and plumbing fittings and fixtures, vehicles, scaffold, office equipment and cash. Data was compiled from the responses of 27 police forces.

In Nigeria and other developing nations, it is difficult to get acceptable estimates because of poor records and statistics. Most thefts are not discovered, and those uncovered are not reported or recorded. A study of 42 construction firms in Lagos, Nigeria by Farinloye, Odusami and Adewumi (2013) reveal that a particular construction firm experienced more than 50 cases of theft on her sites in five years and 7.3% loses of over N10 million. Badejo (2015), drawing from interviews with Nigerian construction industry professionals, reports on the growing concern over construction site theft in Nigeria resulting in shortage of materials, poor quality work, increase in project cost and site management conflicts. Nasarawa state police, Nigeria, arrested seven persons in connection with a hospital construction site theft of a Mikano generator, 600 bags of cement and other items worth millions on Naira (Emmanuel, 2016). The results of poor security measures on site include costly job delays, loss of production, disruption of the planned schedule of work, down time for operators, and higher insurance premium. These issues also negatively impact on effectiveness and efficiency of labour productivity on site, making construction site layout planning for security crucial for construction companies.

2. REVIEW OF RELATED LITERATURE

2.1. Site layout planning for security

Construction site layout planning refers to the arrangement and allocation of available, limited space within the boundaries of a site for placement of site objects (temporary facilities, materials, plant and equipment, storage areas, workshops and outdoor materials preparation areas, access roads, sidewalks and utilities). These objects should be identified, grouped, sized and optimally positioned. There is a distinction between conventional site layout planning and security site layout planning. The difference lies in the goals and objectives. The conventional layout planning focuses on productivity, safety, project cost and completion schedule (Kalafallah and El-Rayes, 2005; Sadeghpour and Andayesh, 2015) while security layout planning focuses on overall site protection issues. Poor or non-planning of sites can create problems that can seriously affect operational effectiveness. These problems include wrong location of plant and equipment, material stack, reduced work spaces and blocking of access to stores and warehouses (Elbeltagi, 2014). Construction site layout planning enhances site optimisation, work productivity, health and safety and security. Every project is unique and therefore should have a unique layout tailored to the constraints and planning variables of the site.

The aim of security site layout planning is to arrange the objects on site optimally to meet security operational efficiency. Research into construction site layout planning for security is still very limited. The ultimate goal of site planning to counter crime and other security threats, including terrorism, is to protect lives, property and operations (Federal Emergency Management Authority, 2012). Security site layout planning is to create an environment that makes it difficult for criminals to operate. But at the same time the environment should support legitimate site activities that lead to work productivity. In site planning for security two types of spaces should be considered. These are, used space for permanent structures and the unused space for temporary facilities, plant and equipment, materials, stores, workshops, work spaces, access roads and on-site paths. These spaces must be properly evaluated. When evaluating the site space one needs to ask how security can be compromised and what a criminal can get away with. Four issues need to be considered: (1) Defining facilities and operation that can affect security on site; (2) zoning of facilities on site in line with security and other site planning objectives; (3) location and placement of temporary facilities on the available site space, and (4) relating the location and placement of permanent and temporary facilities to security considerations.

The location of facilities on site is a critical element of site planning (Russ, 2009). Facility layout planning and material layout planning should be carried out concurrently. Site space as a construction resource is limited and restricts the construction activities that can take place. It determines the layout pattern. Therefore, a good layout plan must efficiently use the site space to accommodate all objects. Sadeghpour and Andayesh (2015) and Small and Baqer (2016) identify pre-determined space, grid system and continuous space as the three main approaches to site space utilisation. Sadeghpour and Andayesh (2015) in an overview of the constructs of site layout modelling indicate that three main approaches to assigning positions to objects on site have also been identified as rule-of-thumb, ad-hoc and first come-first serve basis. Objects are assigned in the space model as dimensionless representation, approximate dimensions and actual dimensions.

Site layout planning can also be grouped into two categories. These are formal and informal planning. Formal site layout planning is an articulated method of planning with

laid down objectives which allow little room for confusion. It is a well-structured document which allows for proper co-ordination, control and unity of actions of site activities. It involves the production of a comprehensive site layout plan or marking the proposed location of facilities using the rule-of-thumb method on the project site plan). Formal planning, like a standing plan, is a reference material for future site layout planning. Informal planning is undocumented, unstructured and ad hoc in nature. It involves location of facilities on an ad hoc basis as the project progresses and the guessed location of facilities on first come-first served basis. It addresses a specific set of challenges and is abandoned once the objective is accomplished. It is a single use plan suitable for small sites and projects. This type of plan depends on the experience and knowledge of the construction/site manager.

For comprehensive plans, the use of a rule-based design checking system allows real-time design of a construction site layout using pre-defined rules to minimise site conflicts (Zolfagharian and Irizarry, 2014). This is software that assesses a design based on how objects are configured into the design using a system of rules and constraints with a "pass" or "fail" result (Eastman et al, 2009). Eastman et al. (2009) identifies four stages in the rule-based design checking system as follows: (1) Rule interpretation, (2) Building model preparation, (3) Rule execution, and (4) Rule reporting. This software is best interfaced as a plug-in with other BIM models. The use of rule-based design checking system assists human judgement on decision making by designers and construction managers.

2.2. Adapting crime prevention design concepts to site layout planning

The main aim of construction site security layout planning is to achieve the following 7Ds of crime prevention: (1) Define the site security problem and carry out security evaluations as the basis for site layout planning. (2) Deter site crime by using design elements and physical security measures such as fencing, lighting, natural and mechanical surveillance. (3) Detect criminal activities by using natural and mechanical surveillance measures and installing intrusion detection systems (IDS) on fences to detect any security breach. (4) Delay the assailant by making it difficult for him to access the target through fencing, target hardening and hierarchy of spaces so that more time is spent to allow response by on-site security or law enforcement. (5) Deny access to target by applying target hardening measures to thwart the assailant's plan so that criminal action is aborted. (6) Defeat criminal tools, tactics and techniques by an integrated site design that applies security counter-measures and deterrence in different combination (7) Detain offender after containing the situation due to delay and detection and hand over the offender to law enforcement.

The planning and design of the site should address emerging security threats and changing space needs. Concepts from different crime prevention approaches such as physical security, crime prevention through environmental design, defensible space and situational crime prevention can help to guide construction site security layout planning. The major aim of these approaches is to reduce criminal opportunities, reduce crime and fear of it (Crowe and Fennelly, 2013). The concepts include management practices, territoriality, access control, surveillance and lighting. This is expected to address the 7Ds of crime prevention – Define, Deter, Detect, Delay, Deny, Defeat and Detain.

Management practices: An important aspect of site management practice for site security layout planning is security evaluation of the site. A major element of crime prevention is to recognise and acknowledge the existence of a threat, the vulnerability of a

site and users and the risk posed to the site, workers and visitors. These should be properly evaluated in order to know the acceptable level of risk and the proper protection and mitigation measures to apply. A threat could be defined as a situation, activity, action or event that can lead to or cause death, injuries, loss, damage and/or destruction of an asset or group of assets.

Management should also determine the target hardening measures to be used on site. Target hardening systems are physical protective actions aimed at protecting the workers, checking unauthorised access to the site and project documents, and safeguarding disruption of operations, vandalism and theft. It is aimed at preventing forced entry through the use of tools such as iron and steel cutter, blow torches and explosives aimed at creating man-passable access points to compromise the security of the site. Target hardening emphasises the use of architectural hardware such as locks, burglary proof fixed in openings, reinforced doors and windows. The use of these measures is necessary in different combination in stores, gates, and to protect completed facilities not yet handed over. Design features such as gates, fencing, technological systems such as CCTV, alarm, key control systems and other security technologies also reduce the risk of theft and vandalism on site. The level of the target hardening depends on the assessed threat, vulnerability and risk levels and the level of protection required.

Territorial reinforcement strategies are intended to create and/or extend areas or spheres of influence that help users to cultivate a sense of ownership and territorial control. Criminals can become aware of this as strangers are easily noticed. This becomes a criminal deterrence because offenders are discouraged from carrying out criminal activities. Defined property lines and clearly distinguished hierarchy of spaces promote this strategy. Materials and equipment left in the open could be removed or vandalised. One way of applying the principle of territoriality is to create fenced compounds on site with lockable gates. Fencing a construction site helps to create a general protectable area of security influence.

Access control strategies are intended to increase the effort and deny criminal access to targets by generating an awareness of risks to the intruder. Three levels of access control are required for site layout design and planning for security. These are (i) access into the site, (ii) access to material compounds and sensitive areas, and (iii) access to work areas by visitors and unauthorised personnel.

Surveillance strategies are aimed at making intruders easily observable and maximising visibility of people, building entrances, parking areas, and street zone. Crimes are rarely committed in places in which a criminal knows that can easily be recognised or observed (Bahti and Pearce, 2016). In site layout planning for security clear lines-of-sight for surveillance by security personnel is required. The layout of site facilities significantly affects natural surveillance and security targets (Said, 2010).

Activity support strategy clearly defines site activity areas and designates the purpose of defined spaces and structure. This can help to discourage illegitimate and problem activities. Lighting strategies when used in combination with other security strategies can lead to a reduction in crime. Even though lighting does not stop crime it acts as a deterrent helping to reduce the associated fear and also aid the protection of people and property. Good security lighting helps in enhancing surveillance. Glare that handicaps guards and CCTV should be avoided. Lighting should be designed to avoid deep shadows and dark corners which may give cover to criminals. A good lighting plan should take into consideration lighting arrangements and illumination targets.

3. RESEARCH METHODOLOGY

Copies of questionnaires were administered on 40 construction/site managers involved in various sizes of construction projects in Akwa Ibom state, Nigeria between 2010 and 2016. 31 respondents (77.50%) returned the questionnaire. The respondents indicated that they were involved in the management of projects of different types and sizes within the stipulated period. This indicates at least a seven-year experience in site and construction management which is an advantage to the study. The questionnaire was evaluated using descriptive statistics and the relative importance index (RII) to determine what the respondents considered important variables in construction site planning for security. Likert scale was used as the scale of measurement. The points were assigned as follows: Very important = 5, Important = 3, Unimportant = 1. The formula used is shown below:

$$RII = \frac{\sum_{j=1}^{5} \mathrm{L}_j \mathrm{n}}{5\mathrm{N}} \quad \text{(Carmichael et al., 2007)}$$

Where $L_j n$ is the product of Likert scale integer j and the number of respondents (n) selecting the integer; 5 is the number of integers on the Likert scale used; and N is the number of the respondent sample size. According to the authors, this formula will always return the same RII for a given proportion of respondents (n) scoring Likert integer (j) for any sample N. The analysis also involved the ranking of the different variables according to the relative importance indices. The range of the values (highest to lowest) for each variable provided a measure of how important the variables were to overall preference. The variables with greater importance ranges played a more significant role than those with smaller values. This revealed the variables that contribute most to construction layout planning for security in the study area. The group index value was used to determine the level of importance. This is the average value of the RII for the group of variables (Badu, et al., 2013; Somiah, Osei-Poku and Aidoo, 2015).

4. SURVEY RESPONSES

4.1. Training in security

The study investigated the respondents' training in security and crime prevention (threat, risk and vulnerability assessment, security planning and physical security) as this was considered important since specialised knowledge is required for effective site planning. 12 respondents representing 38.71% had received training in security while 19 respondents representing 61 29% had no training. The results showed that majority of the respondents were not trained in security affairs and therefore are likely to lack the knowledge of how to plan the site for security. Knowledge is an important resource in planning. Without knowledge aids sound decisions and comprises of data and information needed to conceive, develop, produce and implement an optimal construction site security plan. Relevant knowledge leads to informed site planning. Drukker (2012) posits that

planning is the continuous process of making present entrepreneurial decisions systematically and with best possible knowledge. The implication of the above result is that the construction/project managers will be hampered in effectively planning the construction site for security. Many industry operators claim to be project/construction manager without requisite training. Drawing on specialised knowledge from security experts is an option that can effectively help construction managers to plan the site layout for security.

4.2. The nature of construction site planning

Table 1 shows the results of the assessment of the nature of construction site planning. The objective was to find out how the respondents carry out site planning. Two categories of planning were used as follows: formal (comprehensive site planning as part of construction management and marking of proposed location of facilities on project site plan) and informal planning (location of facilities on ad hoc basis as the project progresses and guessed location of facilities on first come-first served basis). The respondents were also asked to indicate the type of planning in relation to project cost. The results indicated that 22.58% of the respondents on projects with cost above N500 million carry out comprehensive formal planning of the site as part of the construction management programme of the contractor while 77.42% did not. It showed that 29.03% of the respondents used formal methods of marking of proposed location of facilities on project site plan while 70.93% did not. It also revealed that 12.90% used the informal planning method of guessed location of materials on first come – first served basis. This results in a disorganised site as observed by Sadeghpour, Moselhi, and Alkass (2006). Informal planning based on guesswork often lead to materials wrongly placed on site (Zolfagharin and Irizarry, 2014). This could lead to blocked sight lines, hiding places for criminals and to the materials being re-located to more suitable position at additional cost, labour and time. On the other hand, Small and Baqer (2016) affirm that the ad-hoc and first-come approaches are useful in overcoming immediate task-related problems. The result also reveals that the bigger the project the better the planning method.

Table 1: Assessment of the nature of construction site planning

S/N	VARIABLE	YES	NO	PROJECT COST (Million Naira)			
				≤ 100	100 - 500	500 - 1 Billion	>1 Billion
1	Comprehensive site planning as part of project and construction management (Formal planning)	22.58%	77.42%			●	●
2	Use of project site plan to mark proposed location of facilities (Formal planning)	29.03%	70.97%		●	●	●
3	Location of facilities on ad hoc basis as the project progresses (Informal planning)	35.48%	64.52%	●	●		
4	Guessed location of facilities on first come – first served basis (Informal planning)	12.91%	87.09%	●			

4.3. Variables influencing construction site layout planning for security

Table 2 shows the result of the assessment of the level of importance of a group of 15 variables in construction site security layout planning for security. This table provided a degree of the relative importance of each variable known as an importance score or significance in descending order. The group index value was 1.47. The result showed 11 most significant variables. These are: (1) grouped location of facilities, (2) security evaluation, (3) perimeter control measures, (4) access control, (5) positioning of objects for clear lines of sight, (6) strategic site lighting, (7) size of site (8) management security and safety practices, (9) natural and CCTV surveillance, (10) site conditions and constraints, and (11) location of site. Group locations of facilities allow better security control and observation. To achieve clear lines-of-sight it important to create surveillance corridors in the layout design. Harris (2013) and Ebong (2017) affirm that strategic lighting plays an important role in security by creating deterrence and aiding surveillance at night. without sufficient lighting a building and its surroundings can attract criminal activities and become unsafe for legitimate users. This agrees with Zolfagharian and Irizarry (2014) that the size of the site and location (ranked 7 and 10 respectively) are important variables of site layout planning. They drive site logistics decision. The size and location of a project are prime considerations in security evaluation (threat, risks and vulnerability assessments) which is a critical aspect of security planning.

Table 2: Assessment of variables influencing construction layout planning for security

S/N	VARIABLES	RESPONDENTS' RANKING			RANK SUM	RII	RANK ORDER
		5	3	1			
1	Grouped location of temporary facilities, storage areas, materials laydown and work spaces	30	1	0	153	1.65	1
2	Security evaluation (identify security problem, assess threat and site vulnerability, analyse risks)	29	29	0	151	1.62	2
3	Perimeter control measures (fence at site boundary and around materials and storage facilities)	28	3	0	149	1.61	3
4	Access control	27	4	0	147	1.58	4
5	Positioning of objects for clear lines-of-sight	28	2	0	146	1.57	5
6	Strategic site security lighting	28	1	2	145	1.56	6
7	Size of site	26	4	1	143	1.54	7
8	Management security and safety practices	26	3	2	141	1.52	8
9	Natural and CCTV surveillance	24	5	2	140	1.51	9
10	Site conditions and constraints	24	6	1	139	1.49	10
11	Location of site	25	4	2	139	1.49	10
12	Dispersed location of temporary facilities, storage areas, materials laydown and work spaces	20	7	4	124	1.33	11
13	Location of permanent facilities	15	13	3	117	1.26	12
14	Location of parking spaces	20	2	9	115	1.24	13
15	Nature of Project	10	15	6	101	1.09	14

4.3. Considerations for construction site layout planning for security

Based on the study, the following should be taken into consideration when planning a construction site for security: (1) Determine security goals and objectives for the site. (2) Identify potential site security problems. (3) Carry out security evaluations: threat assessment, vulnerability assessment and risk analysis. (4) Determine optimal location of site objects: grouped or dispersed. (5) Determine best method to control access into and exit from site. (6) Determine best method to control the site perimeter. (7) Determine object boundaries and level of control. (8) Determine parking types and their locations. (9) Determine appropriate surveillance measures with clear line-of-sights. (10) Control site circulation: roads and on-site paths. (11) Determine type and best location of security lights. (12) Determine location of security posts.

5. CONCLUSION

Security site layout planning is a very important but neglected aspect of construction projects. As discussed in the paper, construction sites have security and site protection problems that affect the successful outcome of a project. The paper identified the variables that could significantly affect construction site security layout planning. Grouped location of objects on site for ease of security control and observation, security evaluation, perimeter control measures, access control, clear lines-of-sight and lighting ranked higher than others and therefore more important. These and the other variables when properly applied in layout design could help achieve the 7Ds of crime prevention. Insecure site layout design exposes the site and assets to successful criminal operations. Security and the efficiency and effectiveness of labour and materials management for optimum productivity could be compromise by wrong location and placement of materials laydown, plant and equipment, offices and storage facilities and poor access to materials and work areas. Site planning for productivity cannot be completely divorced from that for security. In order to avoid conflict a dynamic, multi-objective site layout plan should relate the location and placement of permanent and temporary facilities to integrate security and productivity considerations into an all-inclusive layout plan.

6. RECOMMENDATIONS

Because of the importance of security and site protection to successfully meeting project objectives the paper recommends the integration of simulation and rule-based design checking models into site layout planning for site security. The use of simulation models allows a clear and overall view of the location of site facilities, road network, utilities, infrastructure, work spaces, plant and equipment and materials laydown areas. Several models have been developed. Chau, Anson and Zhang (2004) developed a 3D model for site space utilisation. This model also incorporates work breakdown structure. Ma, Shen and Zhang (2005) developed a 4D simulation model to address site layout and location for facilities placement. This system takes into consideration work breakdown structure, scheduling, site resources and spaces. The use of artificial intelligence (AI) in site layout planning has been introduced by Elbeltagi and Hegazy (2001).

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