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CONTROL FACILITY LAYOUT PROBLEMS IN CONSTRUCTION PROJECT SITES IN IRAQ

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Abstract: The layout of temporary facilities in a construction site deals with the selection of their most efficient layout in order to operate efficiently and cost effectively. The layout design seek the best arrangement of facilities within the available area. In the design process of the layout, many objectives must be considered to effectively utilize people resources, equipment, space, and energy. The research aims to design practical scheme to locate the temporary facilities in construction sites with less travel distance between them, so it has been to follow the scientific methodology of the research included two phases, the first was the study of theoretical research and previous studies relating to research, and represented the second phase of the study process which has been used in two ways, namely: a survey field for a number of experienced in construction sites management and analysis of answers and compare them with the theoretical study while the second way to use the results of phases theory and practice in the design of a mathematical model to accomplish the aim of the research to reach optimum planning for the sites of temporary facilities in construction sites and using the software matlab to find in the minimum transition between each pair of these facilities and minimum distance between all of the facilities The results showed through a survey of experts need to design places of temporary facilities right before starting the implementation of the project, in addition to the efficiency and effectiveness of the proposed mathematical model in the scheme for temporary facilities design and obtain accurate results.

Keywords: *facility, Construction site management, layout of site facilities, Optimization, travel distance.*

السيطرة على مشاكل نظام تخطيط المرافق المؤقتة في مواقع المشاريع الانشائية في العراق

الخلاصة: ان تخطيط مسقط المرافق المؤقتة في المواقع الانشائية يتعامل مع اختيار التصميم الأكثر كفاءة لمسقط هذه المرافق من أجل العمل بكفاءة وفعالية من حيث الكلفة. ان تصميم المسقط يسعى لتحقيق أفضل ترتيب للمرافق المؤقتة داخل المساحة المتاحة، ويجب الاخذ بنظر الاعتبار خلال عملية تصميم التخطيط هذه العديد من العوامل للاستفادة الفعالة من الموارد ، المعدات،الفضاء،والطاقة. يهدف البحث الى تصميم مخطط عملي لتحديد أماكن المرافق المؤقتة في الموقع الانشائي بأقل مسافة انتقال بينها لذا فقد تم اتباع منهجية علمية للبحث تضمنت مرحلتين، الاولى تمثلت بالدراسة النظرية للبحوث والدراسات السابقة المتعلقة بالبحث، وتمثلت المرحلة الثانية بالدراسة العملية والتي استخدمت فيها وسيلتان هما: اجراء استبيان ميداني لعدد من ذوي الخبرة في ادارة المواقع الانشائية وتحليل الاجابات ومقارنتها مع الدراسة النظرية في حين كانت الوسيلة الثانية استخدام نتائج المرحلتين النظرية والعملية في تصميم نموذج رياضي لانجاز هدف البحث في التوصل الى التخطيط الامثل لمواقع هذه المرافق المؤقتة في الموقع الانشائي وباستخدام البرنامج الحاسوب (MATLAB) لايجاد أقل مسافة انتقال بين كل زوج من هذه المرافق وبين المرافق جميعاً. وقد اظهرت النتائج ومن خلال استطلاع الخبراء ضرورة تصميم اماكن المرافق المؤقتة تصميماً صحيحاً قبل البدء بتنفيذ المشروع، اضافة الى كفاءة وفعالية النموذج الرياضي المقترح في تصميم المخطط للمرافق المؤقتة والحصول على نتائج دقيقة.

الكلمات الرئيسية: *المرفق المؤقت، إدارة المواقع الانشائية، تخطيط مسقط المرافق المؤقتة، الأمثلية، مسافة الانتقال.*

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1. Introduction

Before beginning the actual implementation of the project to take some important measures that would put the implementation processes in its proper context, and in order to ensure that the project goes in sequential steps, interdependent and smoothly without the effecting of the stops for reasons caused by poor planning of the operational process.In order to carry out the necessary equipment for the implementation of the construction projects, it must be managed based on a thorough study of all the variables and circumstances surrounding the project until graduating appropriate set of decisions that ensure the success of the implementation processes when it begins. Facility Layout Problem (FLP) is known as to have a significant impact upon manufacturing costs, work in process, lead time and productivity, [1]. The layout problem is one of the most crucial problems in the planning of service facilities since efficient layout is critical to cost-effective operation of these facilities. Also, site space is a resource that is as important as money, time, material, labor, and equipment. Despite of its importance, site planning is often neglected and the attitude of engineers has been that it will be executed as the project progresses. A layout is traditionally developed using relationships among the various facilities. These relationships are based on the judgment of experts who decide the importance of such relationships between each pair of facilities [2].Construction space is an important part of construction resource, the same as time, labor, material, plants and cost. Unfortunately, construction site can only be arranged with project manager's own experience. Thus incorrect decision or operation will be made when project managers use their experience inappropriately or are lack of enough experience. This traditional layout method is too limited to meet the need of large-scale modern construction site management. Visual and intelligent management of the construction site has become an urgent need. Consequently, the research in this area becomes a hot spot [3].

The layout problem is one of the most crucial problems in the planning of service facilities, since efficient layout is critical to cost effective operation of these facilities. A layout is traditionally developed using relationships among the various facilities. These relationships are based on the judgment of experts who decide the importance of such relationships between each pair of facilities. The decision of experts, however, is vague and is usually based on many quantitative or qualitative considerations pertaining to the closeness relationships among the facilities [4].

Performance measurement models are essential to support various decision making problems that may arise during life cycle of a facilities layout. Available models are only suitable for early stages in the design phase of life cycle. However, measurement models have a great consequence in other phases also such as production planning, control and when modification to be incorporated due to the changes in market demand, which happens very often in today's global competition. In addition, the existing models have considered only material handling cost as the performance measurement factor.

Nevertheless, the empty travel of material handling equipment, layout flexibility and area utilization have a significant contribution towards the layout effectiveness. It is therefore necessary to have a measurement model to determine the facilities layout's effectiveness by considering all significant factors [5].

Proper job layout improves communication and unnecessary movement, increasing efficiency .It is one of the most important and essential job before starting any construction is to prepare a job layout indicating clearly the areas and site available for office ; warehouse, storage of materials, equipment's, excavated earth ; formwork; reinforcing materials, fabrication etc. These are required to be arranged in such a manner that working should be easy and minimum time be consumed in carrying materials from storage areas to project site or construction site [6]. Efficient site layout planning is essential for optimum material handling, which generally results in higher productivity, and helps in minimizing accidents on job-site [7].

Among the important tasks of site management is the site layout planning. Extensive time loss and cost overruns could result in large projects, where the number of manpower, subcontractor, and equipment involved are high, if there is no effect and systematic approach to site planning .A detailed planning of the site layout and location of temporary facilities can enable the management to make considerable improvement by minimizing travel time, waiting time, and increasing worker moral by showing better and safer work environment [8]. In reality, construction practice varies depending on site and projects conditions; i.e. construction facilities, equipment, and material change from one project to another. As well, site planners consider various rules and constraints in locating objects on site according to their knowledge and experience or project conditions.

1. Research Justification

There are many technical problems in construction sites, which affect the project goals of (cost, duration and quality) caused by the lack drop temporary facilities in the appropriate places in the site in addition to the lack of a clear methodology in the design of the layout of these temporary facilities and it often depends on personal interpretations which leads to loss of time in transition and switch between them, so this problem was chosen to be studied and analyzed in order to understand clearly and find the appropriate solution and using the best techniques.

2. Research Objectives

Depending on the justification for conducting research could identify the following main goals of the research:

● Identifying the factors affecting site layout planning.

● Identify effective steps can be followed for the purpose of proper design of the places of temporary facilities in construction sites.

● Using one of the modern computer programs to prepare a mathematical model to determine how to optimize the design of these temporary facilities layout to ensure optimal transmission is less distance between them.

3. Research Methodology

In order to achieve the goals of the research methodology has been divided into three phases:

- The first phase (theoretical study)

  Theoretical study included a review of the research and scientific studies and references on the subject of search.

- The second phase (the study process)

  This phase included a field questionnaire to benefit from the experience of a number of experts in the field of construction site management and analysis of the answers to learn how to determine the optimal distance between the temporary facilities.

- The third phase (development of a mathematical model)

  Depending on what has been reached in the previous two phases will be the development of a mathematical model using a computer program to reach an optimal scheme proposal to temporary facilities layout at construction sites to ensure optimal transmission less distance between them.

4. Factors Affecting Site Layout Planning

The layout of a construction project is governed by the following factors [6,7]

- Type of project and its location

The size of project camp deployment of its resources in the project area is governed by the type of project and its location. For example if the project consists of construction of multi-stored building in a localized area, it would be advantageous to have the project units located in a central area.

- Method of execution of the project

Construction of concrete deck bridge; steel bridge for railway need altogether different layout as their requirement of material and machineries are altogether different.

- Availability of Resources

The project resources consist of plant, equipment, machinery, construction stores and manpower. When all or most of these resources are locally available the task of the project management is considerately simplified.

- Availability of Water supply, Electricity, and Sewage Disposal Works

In case these essential requirements are not locally available, considerable additional efforts for these facilities have to be made and incorporated in the layout.

- Availability of medical facilities

It is not necessary to have a dispensary or hospital within the layout of the project if such facilities are available in the adjoining area. The project layout in such case would include only a field medical aid post.

● Availability of Welfare Facilities

In the project theater the workers are constantly overworked and it is the duty and responsibility of the project management that welfare, recreational and religious facilities are provided if they are not locally available.

5. Site layout planning elements [٨,9,10,11,12,13]

The following points should be considered in good site layout in order to increasing productivity and safety, reducing area(s) needed for temporary construction, and maximizing utilization:

● Safety

- Fire prevention, it is required to supply fire extinguishers on a construction project.
- Medical services.
- Construction safety clothing, like safety shoes, hard hats, gloves and goggles must be used by the workers.

● Site Accessibility

Easy accessibility will keep the morale of the equipment and vehicle drivers high, minimize the chance of accidents, and save time in maneuvering to arrive at and leave the project.

● Information Signs

- Site map, it should locate details of the project.
- Display of labor relation' policy and safety rules.
- Emergency routes and underground services.

● Security

- Entrance, it is important to have guard entrance to the site provided by a booth Points guard .

  These points are held at all ports of entry and exit of the sites for the purpose of control provisions of the commitment of the workers to come and leave as work schedules, and also to ensure that any exit from the precious equipment located within the site.

● Lighting, it is important to have a standby generator to maintain site lighting

● Fencing, the boundary should be fenced

Assesses contractor temporary walls surround the site and in some cases may that be outside the boundaries of the land in the case of actual establish structures on the outer limits of the land in this case the contractor to issue permits required for the emergence of temporary fencing out of the actual border of the land

● Accommodation

On large construction projects, it is necessary to provide camp accommodation for all type of staff involved in the project.

● Offices

The offices should be closed together, close to the site, and in safe area.

● Water supply and sanitation

It is necessary to have water and toilet facilities in convenient location to accommodate work office.

● Material handling

The use of proper equipment for material handling and advanced planning for minimizing multiple handing will result in direct cost and time saving.

● Storage and site cleaning

It is necessary to plan and reserve storage areas for materials so that multiple movements of materials are avoided.

● Craft change-houses

Craft change-houses provide sheltered space for craft personnel to change and store clothes, wash, and rest during waiting periods.

● Batch plant and fabrication shops

Batch plants are provided on projects where it is more economical to produce on site than to buy a ready mix. Shops are used where materials and equipment are fabricated on site.

6. Temporary facilities selection

The important considerations when selecting the required temporary facilities for s specific project are [8]

● Construction type
● The construction of an industrial plant requires more storage and fabrication area for mechanical and electrical work than other projects such as a highway project.
● Type of contract
For turn-key contract, the contractor can consolidate the administrative and construction operations, means that fewer but larger and more efficient temporary facilities can be selected.
● Project size
A relatively small project can be managed from a trailer or portable structure, while a five to ten year project may need temporary facilities of a more permanent nature.
● Project location

● Project located in, for example, uninhabited regions or in place where skilled labor is scarce requiring additional facilities for eating and living.

There is a list of common temporary facilities that can be used in a project [8,12]. While some temporary facilities are to be selected from this list for a specific project, taking into account the factors cited above, as well as other temporary facilities justified by the uniqueness of the project.

7. Model Development

Five of the facilities have been choice on-site in addition to the building to be a model for the completion of this research is as in "Table 1".

Table 1. Suggested Temporary Facilities [8]

Facility number	*Facility name*	*Facility area- m^2*
1	Offices	144
2	Storages	240
3	Mixer with the central	500
4	Maintenance workshops	180
5	Quality control laboratories	40
6	Building to be constructed	3040

where the assumption of the areas is according to reference [8] and as in the suggested site layout shown in "Fig. 1" and the site area assumed to be (110 m * 110 m).

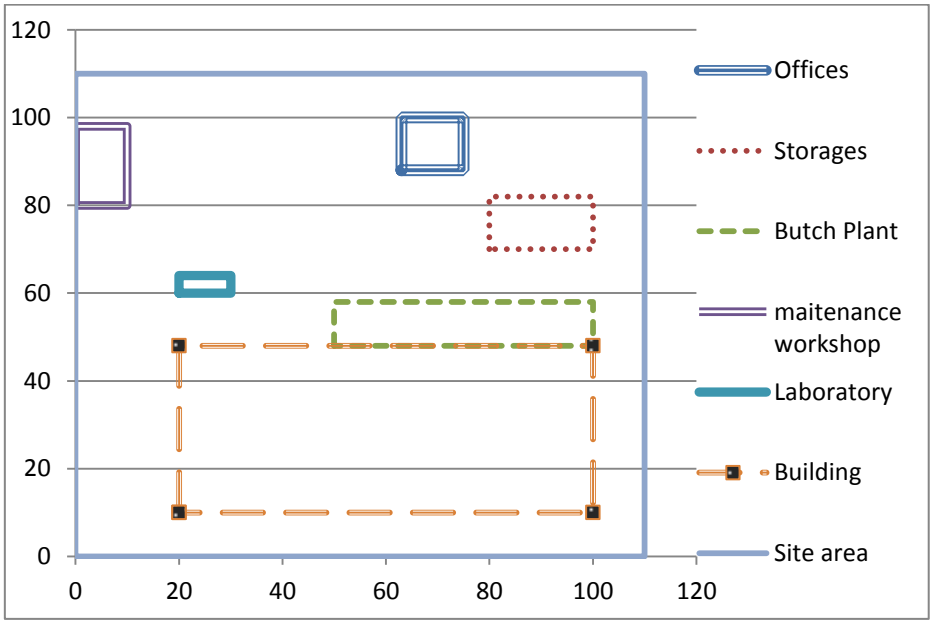

Figure 1. Suggested site layout

The practical part included two activities: the first is a questionnaire where they were (38) expert in the field of implementation of projects on site, (68%) of them were engineer, and other holders of M.Sc. and Ph.D. degrees, and their experience ranged between (5) and more than (30) years, (0.66%) of them were between (5-20) years, (0.42%) of them were between (21-30) years of actual field service.

The first question was about the number of units of materials (Material flow – Mf) transferred per day between each two temporary facilities above mentioned, the second question was about the number of connections (Information flow – If) (oral and reports) transferred per day between each two temporary facilities above mentioned, the third question was about the number of handling equipment's (Equipment flow –Ef) (mixers, trucks -- ext.) used in transfer of materials per day between each two temporary facilities above mentioned, the fourth question was their opinion about the importance of the distance between each of the two facilities. The answers were collected and analyzed statistically to find the percentages.

The second activity was the application of the General Search Method using (MATLAB) program as optimization process to solve the facility layout problem (FLP) by finding the optimal layout of the facilities relative to the building under construction in construction projects.

The total travel distance between the facilities of the construction site can be calculated by calculating the distance between the centroids of each two facilities, considered as the diameter of the triangle and using the Pythagorean theorem and then calculate the total travel distance to site layout for (n) of the facilities as follows [2].

$$\text{Total travel distance} = \sum \text{Dij Rij} \qquad (1)$$

Where:

Dij = Distance between centroids of each two facilities (i and j).

Rij = the desired closeness relationship value between facility i and j.

i , j = number of temporary facility as in " Table ".

To calculate the values of Rij, each of the previous three questions (the number of transferred material (Mf), the number of connections (If), the number of equipment handling (Ef), the percentages was calculated for the expert's answers between each two facilities and divided by weight factor of the importance (Wf) corresponding to each of them and then find the average.

We have assumed that (the number of units of materials and the number of connections and the number of equipment handling) have the same weight factor of importance and equal to (1) according to the following " Table 2". [2]

Table 2. The Definition of Intensity Importance of factor i over factor j [2]

Intensity Importance	*Definition of Importance*
1	Equal importance of i to j
2	Between equal and weak importance of i to j
3	Weak importance of i to j
4	Between weak and strong importance of i to j
5	Strong importance of i over j
6	Between strong and demonstrated importance of i to j
7	Demonstrated importance of i to j
8	Between demonstrated and absolute importance of i to j
9	Absolute importance of i to j

And using the following equation (to find the mathematical mean):

$$Rij = \frac{\left(\frac{Mf}{Wf}\right)+\left(\frac{If}{Wf}\right)+\left(\frac{Ef}{Wf}\right)}{3} \quad (2)$$

Where: Wf = 1
Then the values of R_{ij} will become as in "Table 3"**.**

Table 3. Facilities Relationship (Rij Values)

Facility name	*Facility no.*	٦	٥	٤	٣	٢	١
Offices	1	6.96	2.16	1.67	2.39	6.37	--
Warehouse	2	12.54	1.96	3.68	13	--	
Batch plant	3	11.69	3.33	1.51	--		
Maintenance workshop	4	1.47	1.08	--			
Quality control lab.	5	1.86	--				
Building to be constructed	6	--					

So we can rewrite the equation (1) and according to the suggested site layout as follows:

Total travel distance = $\sum$ Dij Rij = $\sum$ 6.37 √ (x2 - x1)2 + (y1 – y2)2 + 2.39 √ (x3 – x1)2 + (y1 – y3)2 + 1.67√ (x1 – x4)2 + (y1 – y4)2 + 2.16 √ (x1 – x5)2 + (y1 – y5)2 + 6.96 √ (x1 – x6)2 + (y1 – y6)2 + 13 √ (x2 – x3)2 + (y2 – y3)2 + 3.68 √ (x2 – x4)2 + (y4 – y2)2 + 1.96 √ (x2 – x5)2 + (y2 – y5)2 + 12.54 √ (x2 – x6)2 + (y2 – y6)2 + 1.51 √ (x3 – x4)2 + (y4 – y3)2 + 3.33 √ (x3 – x5)2 + (y5 – y3)2 + 11.69 √ (x3 – x6)2 + (y3 – y6)2 +1.08 √ (x5 – x4)2 + (y4 – y5)2 + 1.47 √ (x6 – x4)2 + (y4 – y6)2 +1.86 √ (x6 – x5)2 + (y5 – y6)2 (3)

8. Optimization Process

Optimal design of physical layout is an important issue in the early stage of system design. To achieve this goal, new manufacturing systems must be designed**.**
Optimization is the process of finding an alternative with the most effective distance or highest achievable performance under the given constraints, by minimizing desired factors and minimizing undesired ones (the decision goal).

The function that is to be maximized or minimized is called the objective function. Usually objective functions are defined by the letter (z) and the analysis purpose is the maximization or minimization of the objective function. The following represent the objective function:

$$\text{Objective function} = Z = \sum Rij \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (4)$$

The values of the variables must satisfy constraints. Constraints are the restrictions for the variables that are used when generating an optimal solution, so the minimum travelling distance equals the solution of the following equation:

$$\text{Min. } Z = \sum R_{ij} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (5)$$

This equation has been solved by General Search Method using (MATLAB) program with step of search equal to (20) and the constraints was given so that the distance between the centroids of each two facilities should be within the site area and must not be within the building (to be constructed) space, this solution was conducted for only five main facilities but the program can be developed so the user can use it for any number of facilities or for any change in the areas of these facilities, In this application example, the best layout is shown in " Fig. 2".

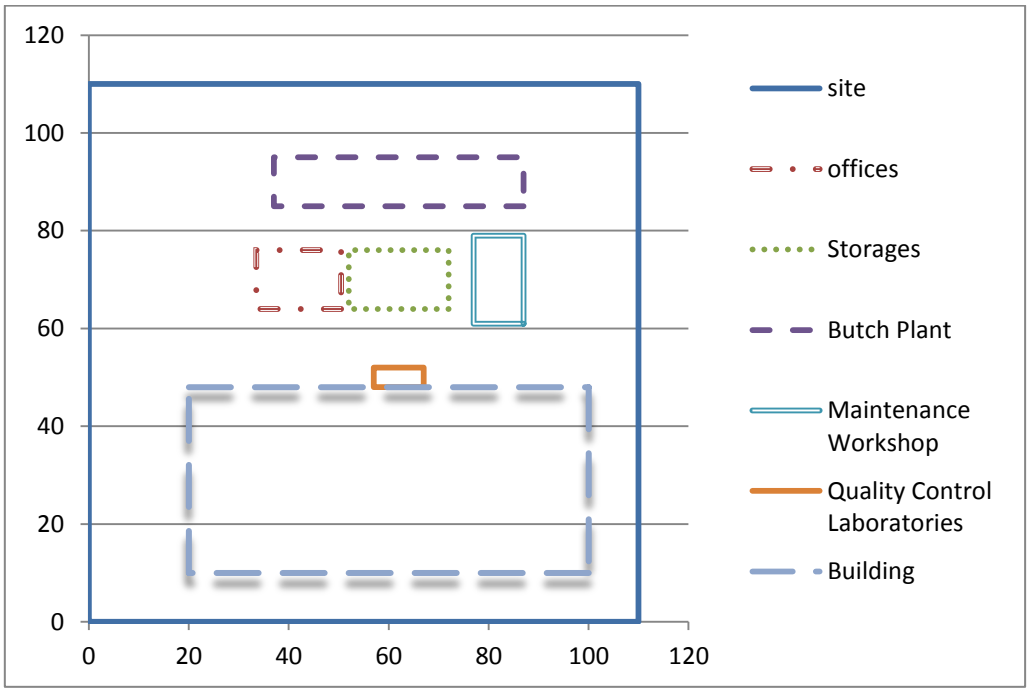

Figure 2. The selected site layout

The shaded area in the figure represents the building to be constructed (facility number 6). As shown in the figure, it is noticed that facility number (1) (the offices) is placed far from the building to be constructed in the site. This is a logical arrangement thus offices remain constant in its place and will not be removed around because of the need to work from time to time to the space occupied by, same thing with the storages and the Maintenance workshops.

On the other hand, the Quality control laboratories (facility number 5) are placed near by the building to be constructed which is also considered to be a logical placement.

Comparing suggested site layout with the answers of the responses about the fourth question in the questionnaire (their opinion on the relationship as distance between each two facilities), it is clear that the suggested site layout match with their answers, except for the offices building, which in their opinion that the relationship is absolutely necessary which means , the offices must be too closed to the building to be constructed in the site, and regarding the quality control laboratories they see that the relationship is not necessary it possible to be anywhere from the building to be constructed in the site, while it turned out to

solve the problem is that the statistical optimization recommends that facilities layout be as suggested in this research.

9. Conclusions

Through research work, a number of conclusions has been reached and can be summarized in the following points:

1- There does not have a prior design of temporary facilities layout at construction sites in Iraq before the implementation of the construction works.
2- Total travel distance between temporary facilities can be calculated through an optimization process by using the objective function mentioned in this research for any number or kind of temporary facilities.
3- Results showed through data need to design the temporary facilities layout before starting the implementation of construction works to reduce the transition were optimized in order to work efficiently and effectively to achieve the project objectives.
4- It was reached through the use of technology or software, including the research program (MATLAB) requirement to develop a mathematical model to achieve optimization of transport distances between temporary facilities on construction sites.
5- The suggested site facilities layout has been tested through a questionnaire and according to the answers of the responses it can be used in the construction sites to solve the facility layout problems.

10. Recommendations

The researcher recommends the need for attention to the design of the temporary facilities layout before starting the implementation of works in the construction projects not through.

As the researcher recommends the adoption and application of the suggested mathematical model to locate the temporary facilities in the construction sites because of its positive features in ease of application and understanding of the results, accuracy and it is comprehensive for any additional facility or any change can happen in the site or building design.

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