Supply Chain Management of Infrastructure Projects in Iraq

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Abstract-Infrastructure projects take a long time, are complex, multidisciplinary, use different materials and products, and have high risk. These characteristics affect the process of supplying materials. The current paper studies the ability to improve the supply chain process and decrease its cost by identifying the factors that affect it. These factors are used as variables in the mathematical model, which is working under uncertain conditions when the consumption rate of materials is not constant. The information used in this model is obtained from Building Information Modeling (BIM) and Geographical Information System (GIS) techniques and the genetic algorithm is utilized to determine the optimal supplier and the quantities of supplies for different materials. The case study used in this research is a concrete bridge. The obtained results show that the cost can decrease by about 28.2% by changing the supplier and the quantity of supplies.

Keywords-infrastructure projects; supply chain; BIM; GIS

I. INTRODUCTION

Supply chain is crucial for the successful completion of a construction project. Construction supply chains are complex networks with various relationships of resources and product/service logistics, information, and money flows. Furthermore, construction project planning and execution involve numerous participants from various organizations, necessitating intensive communication efforts to complete the project efficiently. A lack of adequate supply management in any construction project leads to cost and time overruns, claims, disputes, and low productivity, all of which can lead to project failure [1-4]. Infrastructure is the backbone of the economy and a necessary input to every economic output. It is critical to a nation's prosperity and the public's health and welfare. Infrastructure's condition has a cascading impact on a nation's economy, impacting business productivity, Gross Domestic Product (GDP), employment, personal income, and international competitiveness [5]. Governments invest huge amounts of capital in infrastructure projects, and programs. Due to their complexity, large-scale, long duration, high investment, and longitudinal site conditions, infrastructure projects are exposed to higher risks than traditional construction projects [6, 7].

In infrastructure, poor coordination and supply chain management directly impact productivity and performance. Due to the amount of information generated during the life cycle of projects and participants, they need precise regulations. New technologies are transforming the infrastructure design and construction industry. BIM technology provides for the continuous sharing of a digital model that can manage the whole life cycle of a building project. Recent research defines BIM in many ways. BIM is a product or an intelligent digital representation of a collection of structured data which defines a building project. It is a collaborative approach that improves project quality and efficiency by using open standards for information interchange. Another definition of BIM is that it is a facility management tool that provides a trustworthy, verifiable, transparent, and long-lasting knowledge base that can be used to run the facility throughout its life cycle. BIM provides several benefits in the construction industry, such as increased productivity and efficiency, faster production and detailing, better support for automating operations, and less internal coordination errors. The use of BIM effectively integrates the design and construction processes, resulting in better work quality, lower costs and faster project completion [8-12].

The I-BIM (Infrastructure Building Information Modeling), [13-17] is an essential management information system for digital infrastructure processes. It is one of the most modern techniques used in the Architecture, Construction, and Engineering (ACE) sector [18, 19]. It monitors construction activities and manages construction supply chains [20, 21]. In addition to the I-BIM technique, GIS is considered one of the most important techniques in the supply chain. GIS is a framework designed to collect, store, manage, and analyze geographic or spatial data. GIS allows the representation of geospatial data for efficient collection, storage, sharing, and management. The general-purpose geodetic information system can work on the regular PCs, PDAs, and on portable PCs and PDAs, and even the versatile handhelds [22]. The integration of these techniques, will improve the performance of infrastructure [23-32].

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II. METHODOLOGY

This paper aims to optimize the use of BIM and GIS in supply chain management for infrastructure projects.

A. Determining the Factors that Affect Infrastructure Project Supply Chain Management

The identified factors emerged from interviews with engineers working in infrastructure projects. The questions and answers are listed in Table I.

TABLE I. INTERVIEWS QUESTIONS AND ANSWERS

Question	Answer
Are the engineers responsible for the purchase process?	No, the contractor is responsible.
Is there a planning process for managing the supply chain before starting the projects?	No, the suppliers are identified according to the price and distance.
Are there some techniques or methods used in management?	No
When the supply process occurs, are there connections between the design and supply process?	Yes, it depends on the design element to supply the materials.
Are there criteria for selecting suppliers except from price?	Price and distance.
How are the import deals conducted?	Before the start of the project.
Are there any material tracking processes?	Yes, the quantity of materials is checked when the storage level becomes zero.
What is the way of the movement of the material on the site? What factors affect the level of inventory on-site?	Not uniform, depends on the work performance.
How do the circumstances surrounding the projects affect the supply process?	They lead to delay the process and stop the projects
Are all quantities of materials supplied at one time?	Depending on the quantity of materials. If the quantity is huge, it will be divided.
Does the time of activity affect the supply process?	Yes, but it did not take in the process.

From Table I, the emerging factors that have important effects are:

- The number of supplies describes the timing of the materials.
- Nature of materials: various types of materials characterize the infrastructure projects. Structural, mechanical, and electrical materials are used. The traditional methods deal with different types of materials in the same way, so we will show how the nature of materials can affect the process of supply chain management while focusing on structural materials.
- Performance in the site of projects: The performance of projects is a factor that cannot be easily calculated and is affected by many other factors. The supply chain affects it directly because the consumption rate of materials will change depending on the performance percentage.
- Deficiency in tracking the projects and incomplete information: infrastructure projects are big, generating huge information. Tracking this information is complicated and leads to incomplete information transfer to the other participants.
- Design changes and absence of coordination.
- Collaboration and obligation between suppliers and the entity responsible for the project.
- Time of activity.

B. Selecting Proper Techniques

The technique most used in supply chain management is GIS, but with the development in the construction industry, BIM has also become popular due to its ability to model and generate information. Both techniques have particular use in the supply chain (Figure 1), but using these techniques individually will not return a benefit, so integration between them is required.

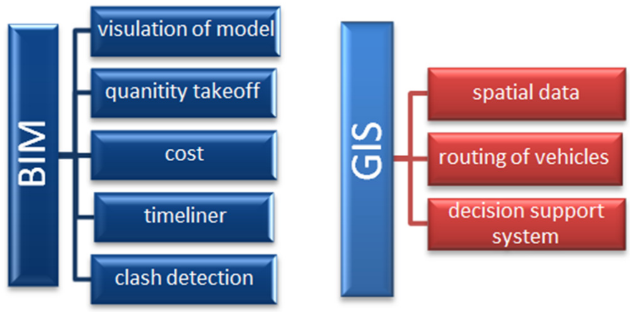

Fig. 1. BIM and GIS benefits in supply chain management.

C. Identifying Control Parameters on the Supply Chain

The most critical control parameter on the supply chain process is cost. The supply chain process includes the following types of cost:

- The cost of ordering, which is connected to the preparation of a supplier's order, including the cost of placing the order and other associated expenses.
- The delivery cost of transporting the materials from the manufacturer to the retailer supplier to the warehouse and then to the project site or from the retailer supplier to the warehouse and then to the project site.
- Purchase cost and holding cost, which are the costs of keeping the materials in the warehouse, the level of inventory of materials in the site, the time of activity, the delivery capacity and performance, and the consumption rate. These main factors generate the mathematical model.

D. Generating the Mathematical Model

The mathematical model improves the supply chain management of infrastructure projects by decreasing the supply cost. The model in [20] is used in the manufacturing industry, and modified in construction projects. It is subject to the following assumptions:

- The total material quantity is known.
- The planning horizon is long.
- There is no lead time or the lead time is constant.

- Consumption rate is not constant, but varies with performance. The performance can be low, medium, or high. Accordingly, the relationship between consumption rate and performance, can be also low, medium, or high. This relationship between performance and consumption will directly affect the inventory level in the site and warehouse, as shown in Figure 2.

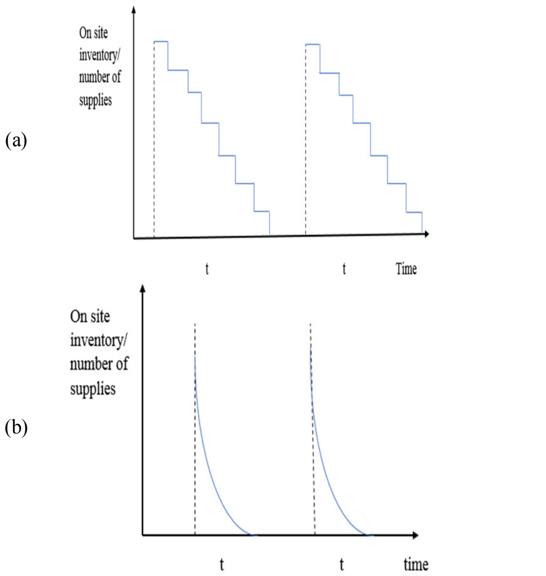

Fig. 2. Material movement when the consumption rate (a) is constant and (b) varies.

The mathematical model is described in (1)-(4):

$$Co = R * N \quad (1)$$

where C_o is the ordering cost, R the ordering cost rate, and N is the optimal number of deliveries and orders.

$$CD = N * DD * Df \quad (2)$$

where C_D represents the delivery cost, DD is the delivery distance form supplier to the site of project, and D_f is the delivery fee per km for each material.

$$CM = Q * P \quad (3)$$

where C_M is the material cost, Q the quantity of the material, and P the unit price for the material.

$$Ch = \int_0^t Q/Ne^t \, dt * CI \quad (4)$$

where C_h is the holding cost, t the duration of activity (time), and C_I is the inventory cost rate, which is proportional to the inventory level.

The final mathematical model will be:

$$\text{Minimize } Z = Co + CD + CM + Ch \quad (5)$$

subject to:

$$Q/N \leq I \qquad Q/N \leq C \qquad I \geq CR$$

where C is the capacity of deliveries of each supplier, I is the level of material on site inventory, and CR is the consumption rate of the materials in site. The first condition means that the quantity of the supply divided by the number of suppliers must be less than the level of product in the site, while the second condition means that the quantity of the supply divided by the number of supplies must be less than the capacity of the supplier in order to avoid supply shortage. The third condition means that the level of the product in the site must be less than the consumption rate in order to avoid work halt.

III. CASE STUDY

Al-Mufraq Bridge is a concrete key infrastructure project in Diyala region. Any change in plans, project halt, difference in cost, change of orders, etc. will not affect only this project, but will cause problems to the people that live in this region. Information regarding this project can be seen in Table II. The project modeling in Revit software can be seen in Figure 3.

TABLE II. AL MUFRAQ BRIDGE INFORMATION

Name	Al-Mufraq Bridge
Location	West of Diyala
Coordinates	33.74222, 44.61383
Project start	2011
Project end	22/4/2014
Project cost	$17032145 million
Description	The main bridge body length is 450m long and 31m wide, with 4 lobes 150m long and 7m wide. Main and right roads are approximately 2km. The number of piles is 304.
Obstacles	The biggest problem was that the bridge roads were located within private property, so one of the road works was stopped. The works also stopped for days due to the delayed delivery of supply materials.

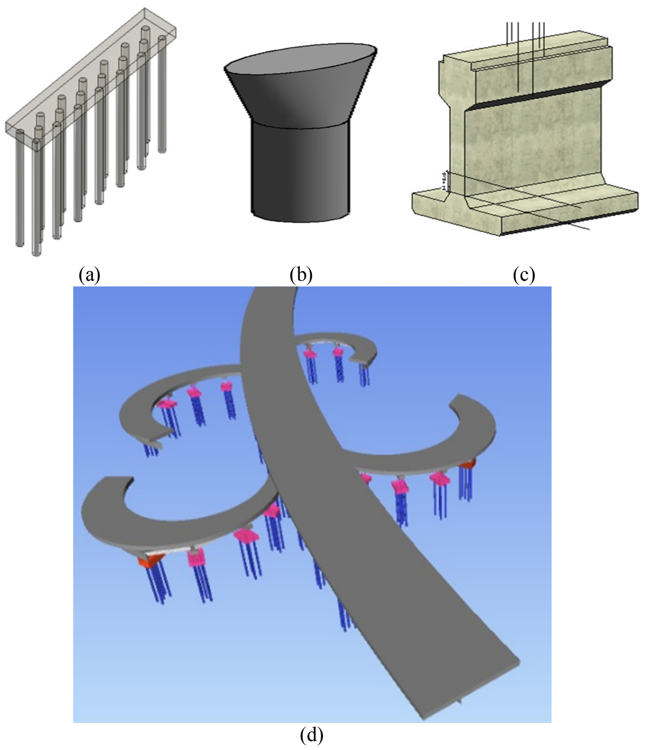

Fig. 3. (a) Piles, (b) girder, (c) column, (d) the bridge.

TABLE III. INFORMATION ABOUT PILE ELEMENTS FROM BIM-GIS

BIM information				GIS information			User information		
Q (number)	**P ($)**	**t (months)**	**I (number)**	**S (supplier)**	**D_f ($/Km)**	**DD (Km)**	**R ($)**	**CI ($)**	**C (number)**
304	2500	152	50	S1	1.2	577	30	0.3	2000
	2333			S2	2.5	67	35		750
	2667			S3	2.3	72	30		750
	2667			S4	3.7	182	32		1000
	2333			S5	3.1	215	30		2000
CR	15 piles per month								

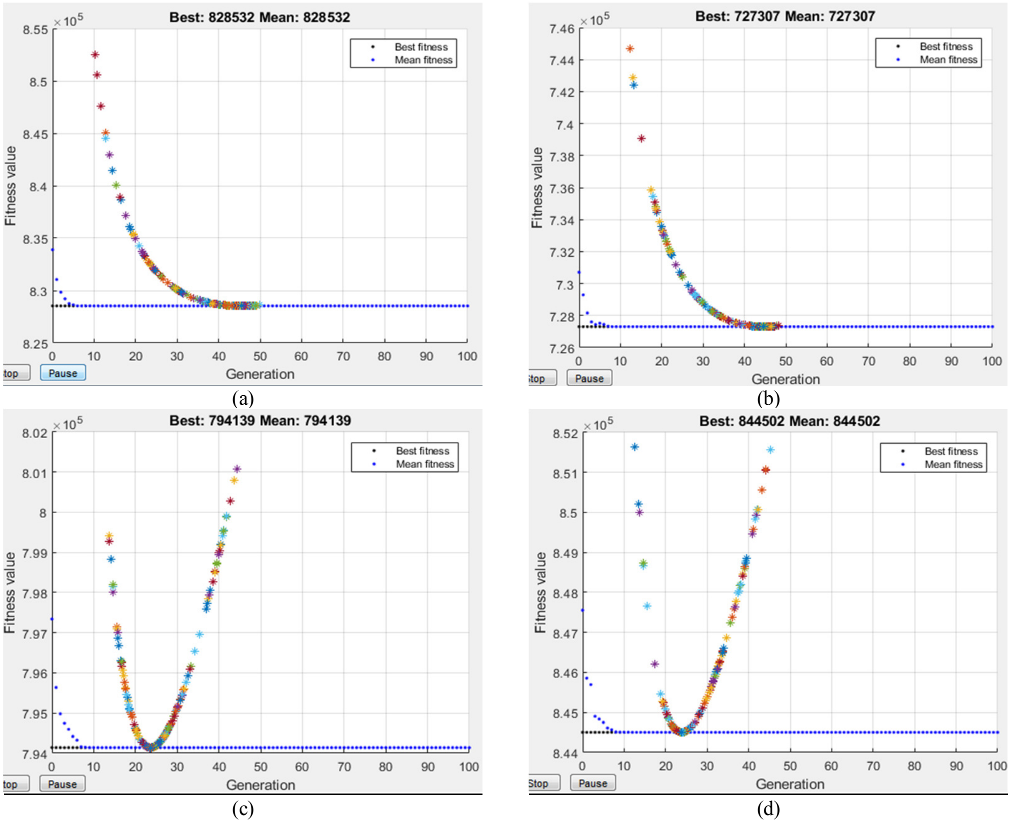

Fig. 4. Relationship between Z and N for different pile suppliers by using GA.

TABLE IV. COST OF PILES FOR VARIOUS SUPPLIERS

S	**N**	**Z ($)**
S1	23	794140
S2	44	727310
S3	45	828530
S4	23	844500
S5	24	742750

IV. RESULTS AND DISCUSSION

The piles are some of the most important elements in the bridge. The piles are responsible for a large part of the cost of the project, so they are used to test the final mathematical model. The information about the bridge is taken from BIM. The information about the location of the project and the suppliers is taken from GIS, as illustrated in Table III. The mathematical model was solved by using the GA in Matlab. The results are illustrated in Table IV and Figure 4. The results show that supplier S2 has the least Z value with N equal to 44 deliveries. This means that the piles should be supplied 44 times to the site to decrease the entire cost and then compare it with the real cost of piles in projects which is 1013333$. The saving in cost will be 286023$. The second material considered is the girder (Table V). Its information will be the input for the final mathematical model, which was solved by using the GA in Matlab. The results are illustrated in Table VI and Figure 5.

TABLE V. INFORMATION ABOUT GIRDERS FROM BIM-GIS

Q (M.L)	6616.222				
P ($)	400	450	450	420	435
S	S1	S2	S3	S4	S5
t (months)	2				
I (M.L)	900				
D_f ($/Km)	1.2	2.5	2.3	3.7	3.1
DD (Km)	577	67	72	182	215
R ($)	30	35	30	32	30
CI ($)	0.42				
C	36000	30600	34200	36000	28800
CR	800 M.L per Month				

TABLE VI. COST OF GIRDERS FOR VARIOUS SUPPLIERS

S	N	Z ($)
S1	8	2654500
S2	9	2981100
S3	9	2981000
S4	9	2787100
S5	8	2885800

The results show that the supplier S1 has the least cost with N=8, which means that the process of supply girders will be conducted 8 times during the construction in order to decrease the whole cost of supply. When it is compared with the real cost (2940000$), the savings in cost will be 285500$.

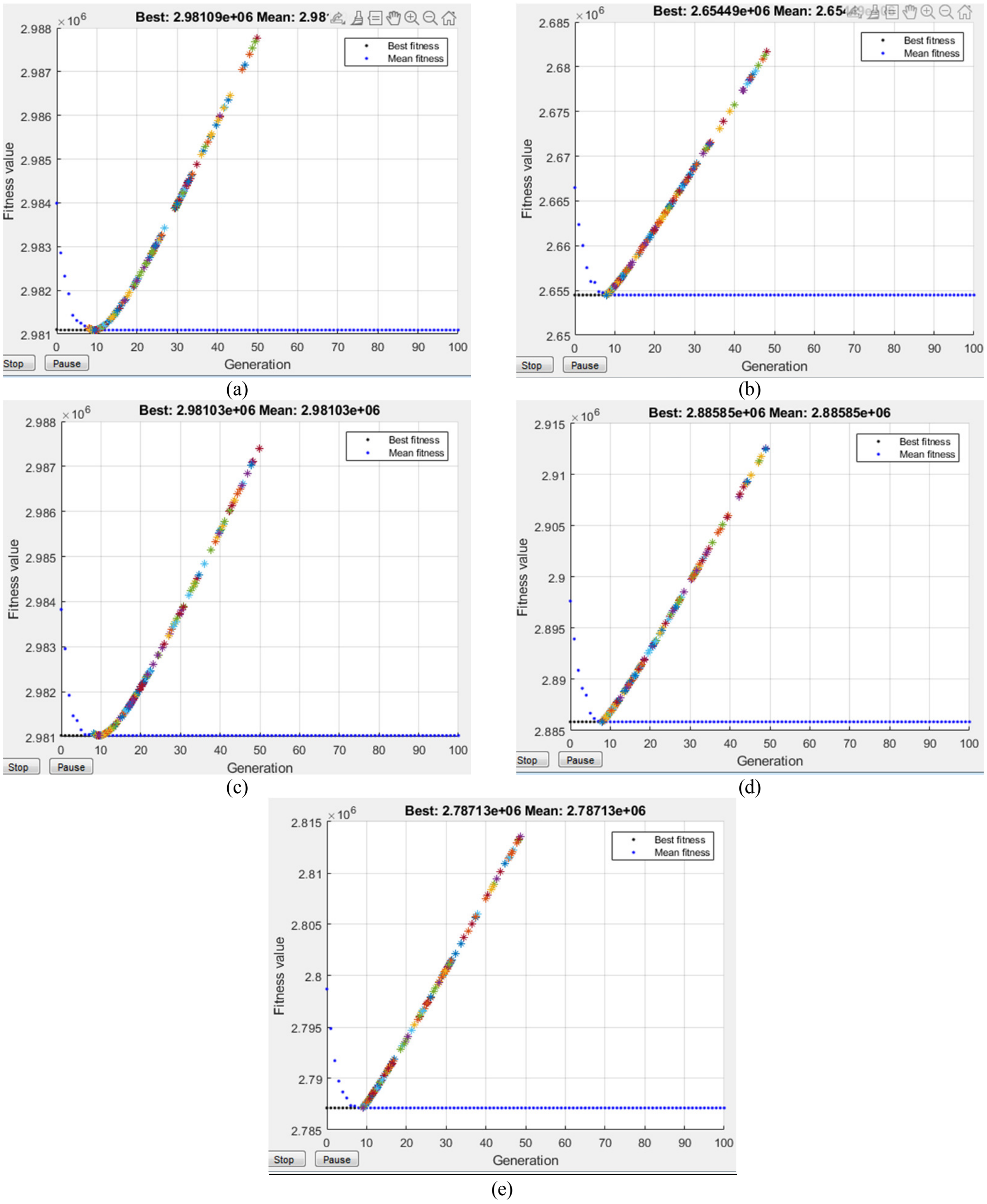

Fig. 5. Relationship between Z and N for different girder suppliers by using GA.

V. CONCLUSION

This study sought the ability to improve the material supply process for infrastructure projects by decreasing the supply cost through selecting the optimal supplier and the optimal number of deliveries. The factors that have effect on the process were identified and were the considered variables of the mathematical model. BIM and GIS were used to obtain needed information such as quantity, timeline, costs (BIM), and the locations of the project and possible suppliers along with the distance between the suppliers and the projects site (GIS). The mathematical model was solved with the GA. It was found that the supply process is not connected just with the cost of materials or with the distance, but there are other factors that should be taken into consideration, such as the time of activity, consumption rate, type of materials, design details, and correct information about the project. The traditional methods can't cover the supply process in infrastructure projects and the need to use more modern techniques, such as BIM, GIS, and artificial intelligent is evident.

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