

Cost and Time Interaction Behavior on Construction Materials Procurement and Execution Processes in Infrastructure Projects

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Abstract

The cost of construction materials forms a large proportion of the total cost of construction projects. Thus, the lack of a sound time and cost management planning for construction materials procurement will lead to deficiencies in the supply and flow of construction materials, not to mention its negative consequences of delays and financial losses which are often cited as major causes of product degradation. This research will present the development of an applicable procurement management system model particularly for UPVC & Ductile pipes used in water and sewage water infrastructure projects in Iraq. Actual data are collected from seven Iraqi infrastructure projects. These data are analyzed by using SBSS v. 23 statistical analysis programs. On the bases of analyses results, four mathematical relationships have been developed by using MATLAB R2015B and CurveExpert Basic software to be used on building a realistic procurement management system with accurate, acceptable, and appropriate results for the construction materials procurement conditions in Iraq, the system was finally tested by using actual data from Al-Latifiya sewer project in Baghdad governorate, where the system showed an accuracy results of 86%.

Keywords: Construction Materials Management; Cost & Time Relationship; Procurement System Model.

1. Introduction

All kinds of construction projects constitute one of the most important civilization aspects and advancement in society, often referred to the civilization of many nations, including the creativity and the facilities creativity and monuments. Construction projects in recent times become the backbone of life and progress, where the construction sector now forms 75% of any country's investment [1].

Efficient Managing of construction materials procurement in construction projects can led to significant improvement in productivity and project profitability [2]. In order to touch on the details of this context, we will define a set of terms related to the content of the research paper as follows:

Inventory: "A variety of raw materials, semi-finished materials, finished materials or spare materials held by the company for the purpose of sale or use in production processes" [3].

Demand: "The demand is one of the directly factors influenced in deterministic the amount of inventory for any material, which is either specific were the demand is known, or probabilistic is subject to a probability distribution" [4].

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Suppliers selection: “The procurers can categorize supplier selection criteria as Mandatory which represents the criteria that a supplier must meet in order to be on the bid list, Preferred refers to criteria that is not necessary to be meeting by suppliers to enter the bid list and leading criteria which really differentiate suppliers and will separate the exceptional suppliers from the ordinary and should have the highest weighting within the supplier selection process” [5].

Project management: “Is the application of knowledge, skills, tools and technical methods to the activities and activities of the project to achieve requirements of the construction project using limited and scarce resources efficiently and effectively, and the construction industry is one of the most important industries, it is a very important indicator of the high rates of the state economy, and infrastructure and strategic projects are an indicator of progress” [6].

Cost Management: “Cost management is defined in projects as the set of processes involved in cost planning, budget planning and cost control and control. These operations are called project cost management, which means managing project costs and the cost of resources required because they are project activities and scheduling taking into account the cost of maintenance and support of the project product, service or results during the life cycle of the project” [7].

Time delay: “The hugest reasons for time delay recognized in this exploration are; absence of materials in business sectors, deficiency of development materials at site, postponement of material conveyance to site, income issues amid development, and poor site administration” [8]. The overall construction process, from programming to design and through to construction, involves many key participants who need to collaborate continuously in order to complete the project on time, on a budget, and to the level of quality and functionality that the owner requires. However, construction projects have a tendency for key participants to work separately and focus on individual goals, rather than project goals. This tendency is a result of standard industry contracts and a legacy of litigation within the industry [9]. In most construction projects, best possible performance is unachievable with poor productivity resulting in time overrun and consequently cost escalation of the projects, because the construction is a risky industry with uncertainties due to many external and internal factors that influence the construction process [10]. The most important factors leading to time delays and cost/budget overruns are poor contract management, finance and payment problems, shortages of materials and changes in site conditions [11].

Supplying chain managing: Refers to "managing process of the chain hierarchy for the procurement of materials and services, including supply chain management to understand and track the products, services, institutions, organizations, logistics, personnel, activities, information and resources that transform raw materials into the final product that is fit for its purpose" [12]. Data and monetary funding, such parties could be companies that produce items, parts, final productions, logistics service’s suppliers, and including the (end) customer itself [13].

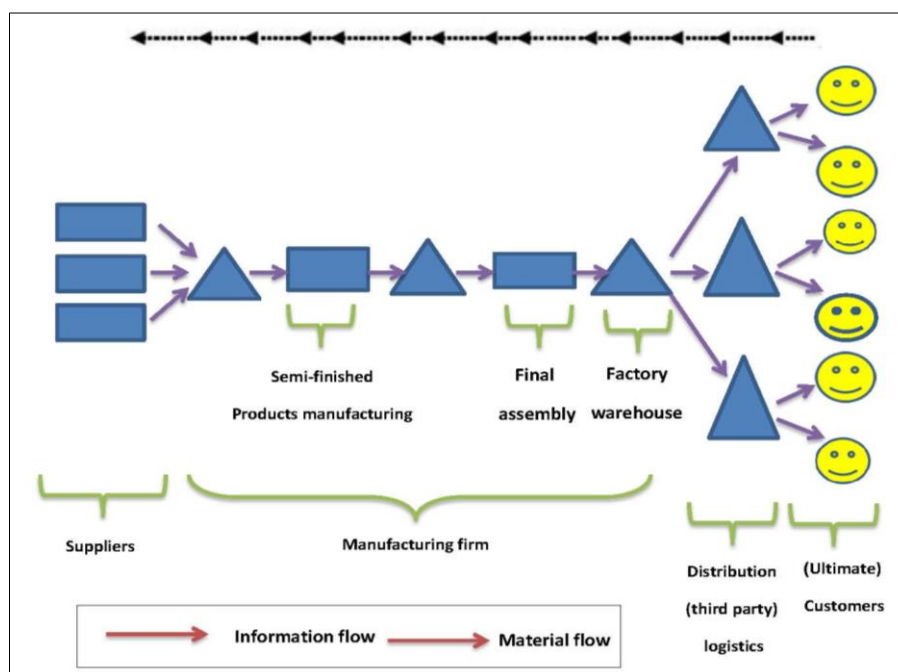


Figure 1. Conventional supply chain example [12]

Project Procuring Managing important: “The private sector and procurement are a strategic function that improves the profitability for any institution, Procuring, which can be observed as assisting smooth operations,

decrease the charges beside expenses of raw materials, also identify superior organs of supplying, There are three major functions that can reveal the importance of procurement in construction” [14].

Infrastructure services: Is the essential facilities that serve the community and necessary for development “availability and quality of infrastructure and services can lead to profound changes in the standard of living of the population by facilitating access to health, education, other social services and the labor market” [15]. Infrastructure could be possessed or run via public or non-public parts, for instance utilizing companies and rail corporations etc.” majority of streets, major airports, water distribution systems plus sewerage networks belong to public sector, while majority of power and telecommunications belong to private sector”. Among the most important types of infrastructure, water wastewater are the most important because of their association in with life, and cannot be dispensed. Government offices, hospitals, restaurants, hotels and other businesses cannot work without such types of infrastructures “many industries - food, chemical and electricity plant, for instance cannot run unless there is good water, which is a part of completed product or utilized in industry processing or refrigeration” [13].

Water and Sewerage water infrastructures: “Among the most important types of infrastructure, drinking water and wastewater are the most important because of their association in with life, and cannot be dispensed. Government offices, hospitals, restaurants, hotels and other businesses cannot work without such types of infrastructures” [15].

2. Research Methodology

The methodology of this research consists the following:

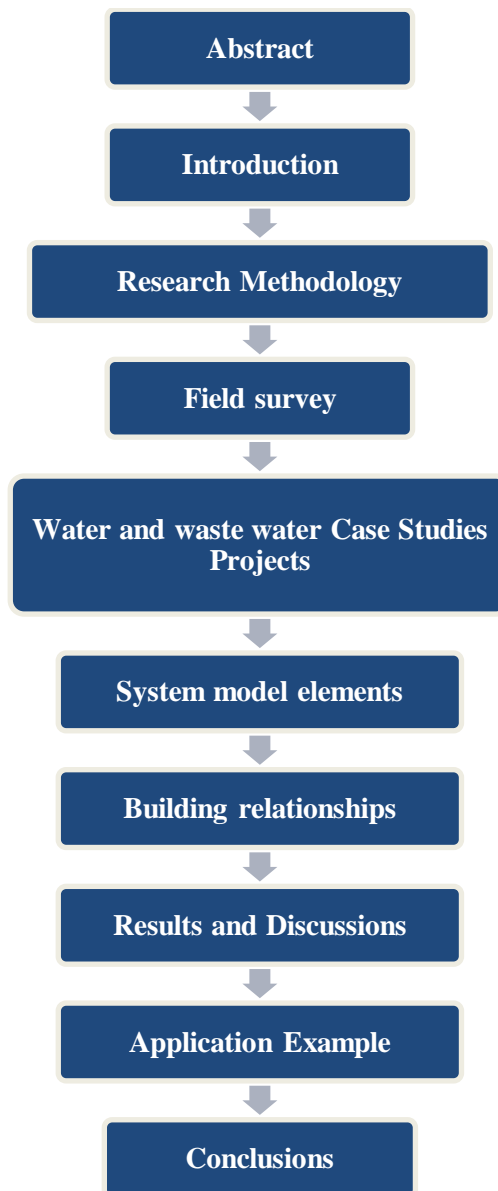


Figure 2. Research Methodology diagram

2.1. Objective

This research presents the development of applicable management system model for Construction Materials Procurement on infrastructure Projects in Iraq, which is capable of simultaneously integrating the critical planning decisions of procurements, to avoid the productivity retraction, financial losses, delays and to reduce the total capital detained in inventory, at the time making sure that production never stops because of lack of construction material.

To reflect the objectives of the study, this research will focus on examining the procurement process of UPVC& Ductile pipes for water and wastewater in infrastructure projects, because of its large cost for the total cost of the execution, the below table (Table 1) illustrated an example of the cost of procuring pipes with respect to the cost of the network and the total cost of the project.

Table 1. Percentage of pipe cost VS Sewer network cost VS project total cost

Project	Total Cost (ID)	Sewer network cost (ID)	Percentage of network cost / total cost	Pipes Cost (ID)	Percentage of pipe cost / net Cost
Nahrawan Sewage Project	224,992,235,000	72,519,070,000	% 32.23	49,389,970,000	% 68.1
Al-Jawadain Sewage Project	208,076,583,939	118,110,926,050	% 56.76	72,746,846,050	% 61.59
Abu Ghraib Sewage Project	303,486,774,000	124,610,000,000	% 41.05	76,323,625,000	%61.25

Therefore, procuring pipes in required quantities when needed is one of the primary goals, and undoubtedly the improvement on this major item management may play a significant role in profitability, otherwise, the many succeeding activities will be delayed and serious budget overruns may occur.

2.2. Field Survey

Field survey is conducted along with statistical analysis of survey data, by using SBSS v. 23 statistical analysis programs, review and discussion of analysis results. To verify the current situation of construction materials procurement management in Iraq, especially in UPVC & Ductile Pipes infrastructure projects, were the following problems are detected:

- Damages caused by undesirable fluctuations flow of construction materials, and their negative impacts on:
 - Decreasing productivity due to construction materials fluctuating availability at execution time.
 - Construction materials shortages or excessive inventory.
 - Increasing materials cost relative to the total construction cost because of materials adding value.
 - Increasing the amount of capital held in inventory.
- Waste, losses and damages especially because of poor planning of construction materials procurement, and the rapidly growing threats on construction materials caused by :
 - The extra-ordinary expiration, deterioration and obsolescence of many construction materials.
 - Careless usage of handling, transportation and storing means.
 - Unauthorized materials acquisition.

Therefore, there is an arising need for effective systems to manage the procuring of construction materials to avoid the mentioned negative consequences and the resulting losses of delays and financial losses.

2.3. Water and Waste Water Case Studies Projects

To demonstrate a functional system, the development of the proposed model was based on consideration of information data of real case studies of the finished and operational water and wastewater infrastructure projects.

- Al-Rasheed sewerage network project.
- Sewerage networks Project of some Sectors of the city of Amarah.
- Al-Rumaiitha District sewer project.
- Najaf sewage project/Stage (3-1).
- Water distribution net of Mahalla 617.
- Water distribution net of Mahalla 506.
- Al-Latifiya sewerage project.

The first six projects will be adopted to build the system, and the results of the system will be compared and analyzed statistically with the last projects data (Al - Latifiya sewer project) for verification purposes.

2.4. System Model Elements

It is so important that cost and time elements are taken into consideration when create a system to manage the procuremnt of construction materials. For further integration, the exceusion process has been integrated with the procuremnet process in this analysis as they are essential and interrelated parts of the construction chain.

2.5. Building Relationships

Four relationships were found, by combining the prvuos four elements variables (cost and time for procurement and execution) the analysis of these relationships produced four mathematical equations by using MATLAB R2015B & CurveExpert Basic softwares to build the mathematical model of the material management system of construction materials.

These relationships are:

- Total procurement cost & Total procurement Duration Relationship.
- Total Execution Cost & Total Execution Duration.
- Total procurement costs & total Execution costs Relationship.
- Total Procurement Duration & Total Execution Duration relationship

The system should be as close as possible to reality, so the behavior of three-dimensional relationships must be determined with the greatest degree of accuracy to reflect the outputs. Each of these three dimension relationships is found by integrating and analyzing two-dimensional relationships by using CurveExpert Basic software to find the real behavior of the relationships built through it, in order to determine the best behavior of each bilateral relationship on its own and on the basis a three-dimensional relationship is formulated.

3. Results and Discussion

3.1. Total Procurement Cost & Total Procurement Duration Relationship

By combining the data of total procurement costs & total procurement durations of the valid project case studies in one three-dimensional relationship by using MATLAB R2015b software for more interaction the following is achieved:

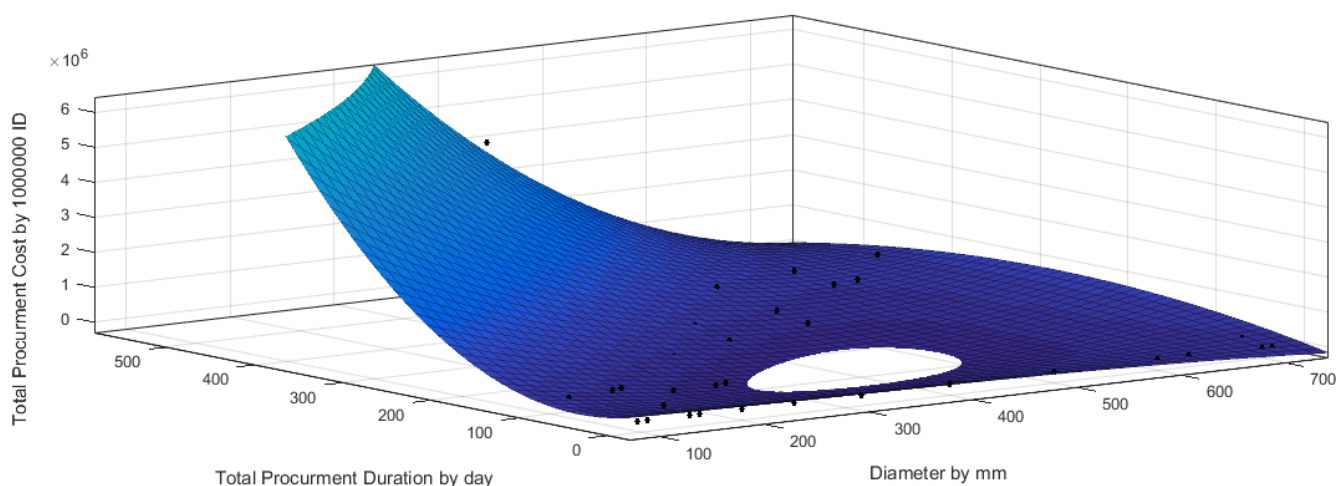


Figure 3. 3D Relationship of total procurement cost & total procurement duration

Linear model Poly32:

$$f(x,y) = 3.181e + 05 - 1724x - 1245y + 3.209x^2 - 37.03xy + 63.37y^2 - 0.00202x^3 + 0.06084x^2y - 0.09678xy^2 \tag{1}$$

3D relationship of total procurement cost & total procurement duration. Coefficients (with 95% confidence bounds).

Table 2. Goodness of fit

SSE	R-square	Adjusted R-square	RMSE
7.998e+12	0.8882	0.8753	3.405e+05

3.2. Total Execution Cost & Total Execution Duration

By combining the data of total execution costs & total execution durations of the valid project case studies in one three – dimensional relationship by using MATLAB R2015b software for more interaction, the following figure is obtained:

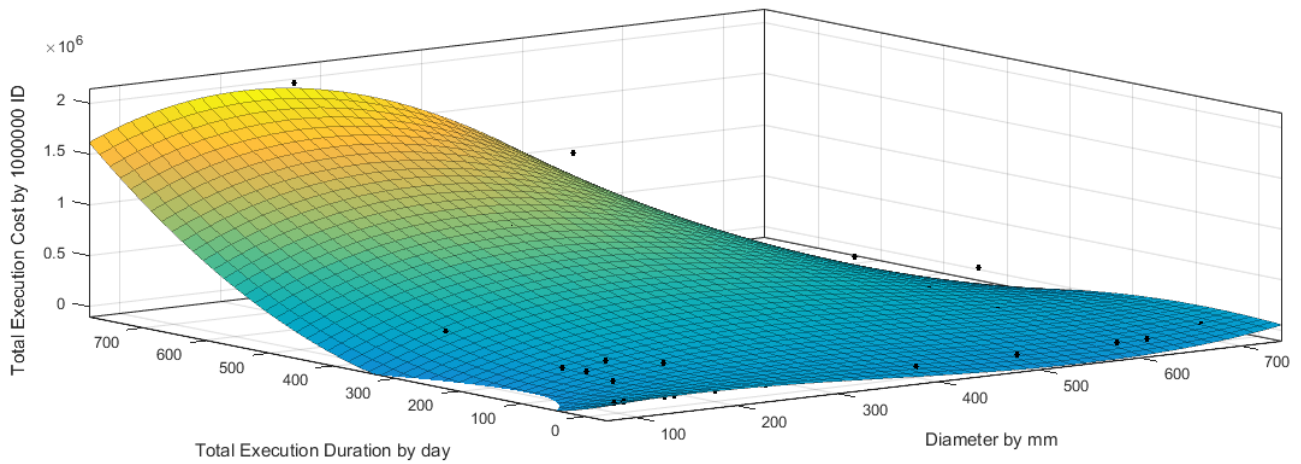


Figure 4. 3D Relationship of total execution cost & total execution duration

Linear model Poly32:

$$f(x, y) = -1.284e + 05 + 1812x - 2848y - 5.797x^2 + 14.55xy + 5.82y^2 + 0.005022x^3 - 0.01388x^2y - 0.01064xy^2 \tag{2}$$

3D relationship of total execution cost & total execution duration. Coefficients (with 95% confidence bounds).

Table 3. Goodness of fit

SSE	R-square	Adjusted R-square	RMSE
1.879e+12	0.7875	0.7629	1.65e+05

3.3. Total Procurement Costs & Total Execution Costs Relationship

By combining the data of total procurement costs & total execution cost in one three - dimensional relationship by using MATLAB R2015b software for more interaction, the following is achieved:

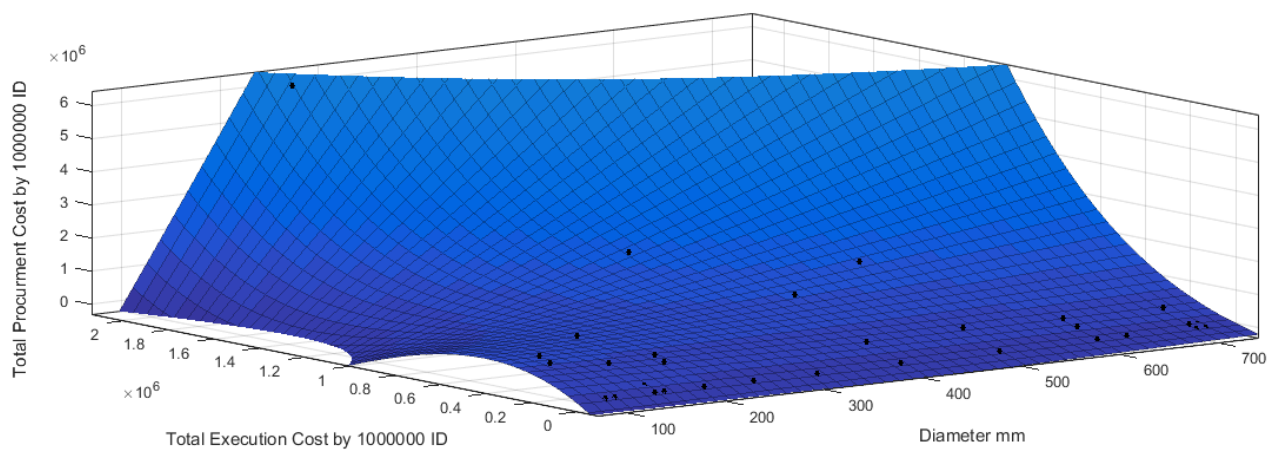


Figure 5. 3D Relationship of total procurement costs & total execution costs relationship

Linear model Poly33:

$$f(x, y) = 8660 - 121.4x + 4.447y + 0.173x^2 - 0.005291xy - 7.093e - 06y^2 - 2.575e - 05x^3 + 2.821e - 06x^2y + 1.275e - 08xy^2 + 1.838e - 12y^3 \tag{3}$$

3D relationship of total procurement costs & total execution costs relationship. Coefficients (with 95% confidence bounds).

Table 4. Goodness of fit

SSE	R-square	Adjusted R-square	RMSE
3.121e+12	0.9564	0.9506	2.142e+05

3.4. Total Procurement Duration & Total Execution Duration Relationship

By combining the data of total procurement durations & total execution durations in one three-dimensional relationship by using MATLAB R2015b software for more interaction, the following is obtained:

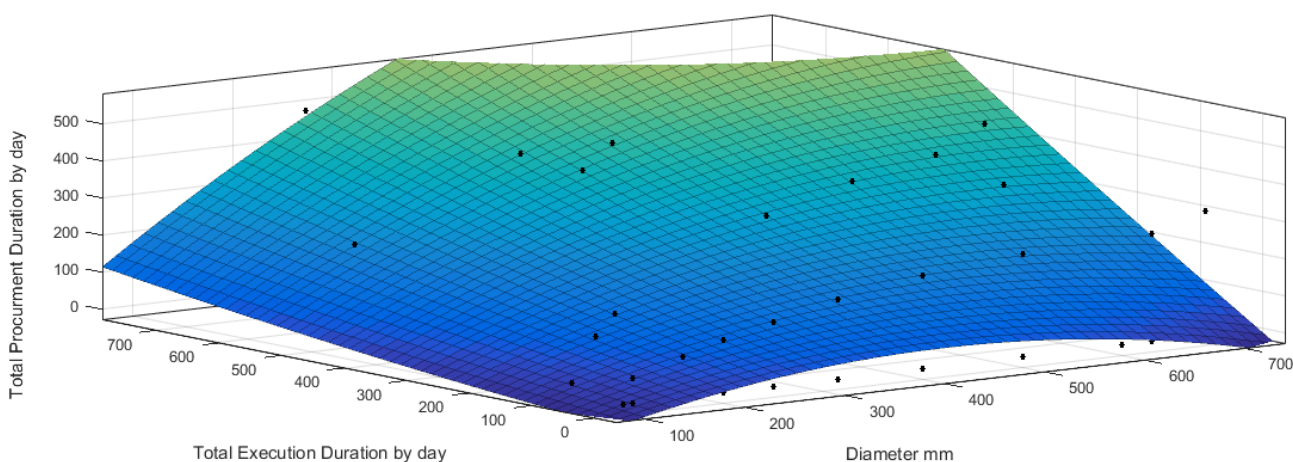


Figure 6. 3D Relationship of total procurement duration & total execution duration

Linear model Poly22:

$$f(x, y) = -88.77 + 0.8643x + 0.0221y - 0.001024x^2 + 0.001476xy + 8.12e - 05y^2 \tag{4}$$

3D relationship of total procurement duration & total execution duration. Coefficients (with 95% confidence bounds).

Table 5. Goodness of fit

SSE	R-square	Adjusted R-square	RMSE
5.01e+05	0.7456	0.7279	83.42

3.5. Application Example

Data of Al-Latifiya sewerage project (Baghdad Governorate – Iraq) was applied to the proposed four relationships of system model software, for the purpose of identifying the percentage of results accuracy as follows:

The diameters and the total procurement duration data of (Al- the Latifiya sewage project) were applied on the system model.

Table 6. Al-Latifyyia project procurement cost data application

Dia.	Procurement duration	Procurement cost-result	Procurement cost-real
110	416	7382670.859	1522500
160	416	6068242.515	200625
200	277	1740430.406	3091463
250	188	181101.2	967275
315	309	1046508.297	3159281.25
400	207	239547.558	1429838
500	328	125058.32	3436043
630	154	8259.2584	359370

By comparing the results of the total procurement cost of the system model result (average 2037025.598 ID) with the actual total procurement cost (average 1770799.406 ID) very close relationship was found and the precision was 86%. While the results of the application of other relationships data were found as follows (details of the data in Appendix C):

Table 7. Data application results of Al-Latifyyia sewage project

Relationship	Real data average	Result data average	Accuracy percentage
Total Execution Cost & Total Execution Duration	4584656.24 ID	590266.5375 ID	87%
Total procurement cost & total Execution cost Relationship	4180757.47 ID	3833755.187 ID	83%
Total procurement Duration & total Execution Duration Relationship	287 day	327 day	86%

4. Conclusions

The conclusions based on the present study for UPVC & Ductile Pipes procurement management in Iraq are:

- The procurement of construction materials in infrastructure projects in Iraq often fluctuates, due to the dependency on availability of payments from the employer, in addition to the geopolitical conditions.
- Factors influencing the management of construction materials procurement in Iraq can be summarized as follows :

I. *Financial factors* such as Type of financing, interest rate, delay penalty, constancy of payments, banking support and services, existence of laws and legislation that protect the rights of suppliers, total cost of construction materials and the number of batches, ways of payment, discounts offered by manufacturer (if any) when ordering large quantities, rate of fluctuation in procurement prices, losses caused by ordering more or less quantities of construction materials than required, damage during transport, storage or miss use during execution, locking- up capital in purchase of additional quantities of construction materials to ensure regularity of implementation compared to the cost of repeated small orders.

II. *Technical factors* related to the accurate procurement planning of construction materials ordering, the identification of quantities, types and originators, and the estimation of time with a logical safety factor, audit in a manner that ensures the absence of errors and conflicts, to determine the time and cost of manufacturing those construction materials transferred work site commensurate with the stages of the project and operational requirements, providing the manufacturer with all specifications, designs and other technical purposes in a timely manner.

III. *Administrative and legal factors* concerning with the administrative procedures and contexts adopted by the employer and their flexibility to suit the updates, laws and regulations regulating the work of sub-contractors and suppliers and the level of legal protection of their rights, the security situation whether in the work sites or transportation pathways, providing basic services for the work site such as water, energy, transportation and others services.

5. Currency

The currency of the pipes costs is Iraqi Dinar (ID), where each American Dollar's equal to 1200 Iraqi Dinar.

6. Conflicts of Interest

The authors declare no conflict of interest.

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