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EVALUATION & IMPROVEMENT OF CONSTRUCTION MATERIALS PROCUREMENT IN DEVELOPING COUNTRIES

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Abstract: Construction materials management is an important and a complex aspect of project planning and control. The supply of materials has a direct impact on the success of the project. This paper presents a study to identify and analyse the common procurement problems facing the Egyptian construction industry and proposing a framework for a model in an attempt to standardize the process. The procurement problems and suggested solutions were collected via semi-structured direct interviews with industry professionals. By analysing and ranking the data, the common procurement problems and their suggested solutions were identified. A framework for a model was developed using an expert system process chart to model the procurement processes based on the logic obtained from expert recommendations. The framework also incorporates a supplier selection module which uses the Analytical Hierarchical Process (AHP) method in the supplier selection which was validated with a hypothetical case study. Results show that the procurement process is systematic and developing a framework for a system could be a head start for companies to develop their own software to improve the overall efficiency of the process. This paper attempts to create a road map for a contractor to follow to standardize and create an overall integrated system with assigned responsibilities for the procurement process. Procurement plans are not enough for monitoring and controlling the process, firms should work on employing material information systems that integrate all aspects related to material management.

1 INTRODUCTION

Material management is a process by which an organization is supplied with goods and services that it needs to achieve its objectives of buying, storage and movement of materials. According to Bell and Stukhat (1986), functions of material management include planning and material take-off, vendor evaluation and selection, procurement, expenditure, shipping, receiving and inspection, warehousing and inventory, and distribution. Thus, a successful implementation of the material management system needs to consider the decisions made on each phase to assure the completion of the supply chain cycle in an efficient way.

The purchasing department, the entity responsible for material procurement, performs some important tasks including: (1) how much material to buy: assuring that the required quantities will be available and there will be no shortages, (2) when to buy the material: assuring that the required items will be available when needed, involves the preparation of a material requisition schedule which specifies types, quantities, dates, etc. (3) which supplier to choose: generally suppliers with lower prices are chosen; however, some contractors consider supplier with high prices as they offer more services and they provide the purchase in a timely manner, and (4) where to deliver the material: involves preparing site layout for storage and pre-fabrication areas, while providing the space needed for equipment maneuvering. The procurement process starts when the current inventory is checked for the required material, if the material is unavailable or more quantities are needed to proceed with the work, the purchasing department initiates the material procurement process as shown in Figure 1. Once the material is delivered to site, it is inspected in accordance with the specifications and the Purchase Order (PO) requirements. If in the event the received material is rejected or partially rejected, it is returned to the supplier and reorder is issued; else, the material received is stored in the inventory or used on the related task.

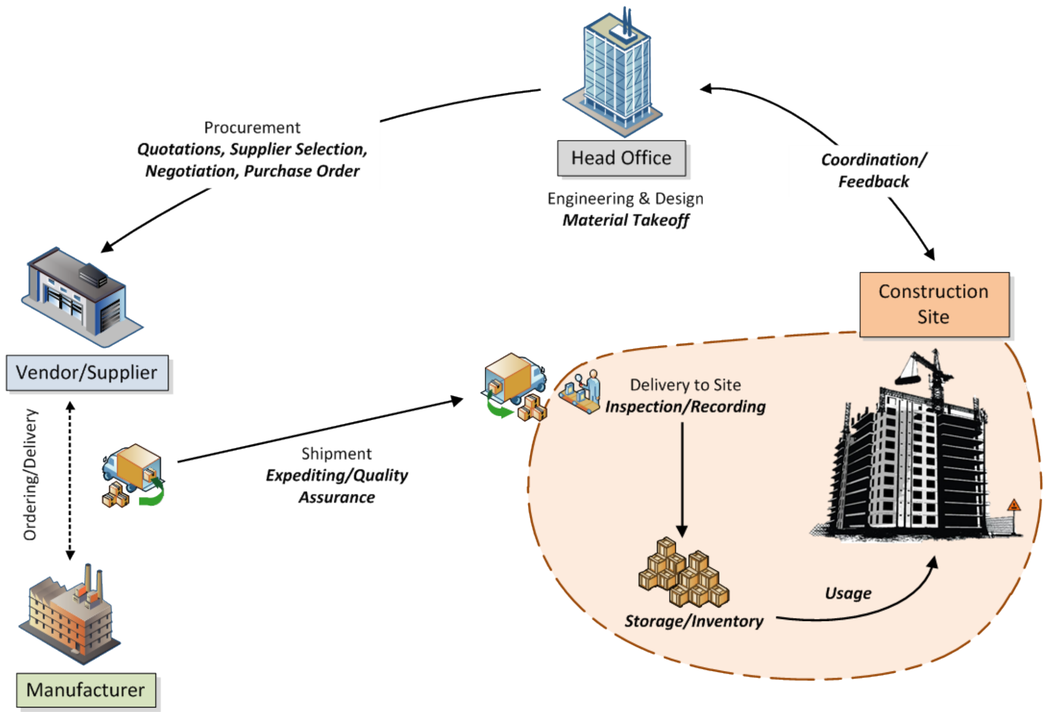

Figure 1: Typical Material Management (adopted from Permodo, 2004)

Material procurement problems can greatly affect the construction stage which could result in delays and disruption of the works such as wrong deliveries, late deliveries, storage problems, backordered materials, etc. Effective planning and communication between involved parties is required to assure the high performance of the process. There are many challenges encountered during the procurement process and can be categorized under four main categories:

1. Bid Pressures: the contractor may be forced to cut costs to satisfy the owner's budget while still being committed to the current scope of work. This puts pressure on the contractor and affects his procurement program
2. Supplier Selection: selection of a reputable supplier which will provide a good quality and deliver the quantities needed at the required dates.
3. Purchase Challenges: the contractor has to follow up the status of the material order and to assure the materials required arrive to the job site in the needed quantities and at the required dates.
4. Storage Challenges: tracking of material ins and outs, selecting proper inventory procedures according to the type of material delivered material distribution and usage procedures.

Thus, effective planning and communication between involved parties is required to assure the high performance of the process. Better management practices and decision making models could be adopted to increase the process efficiency and minimize overall costs. Implementation of information and knowledge based systems in materials management could enhance monitoring and control on the process. For this to happen, contractors and suppliers need to change their procedures and systems from conventional to more sophisticated or innovated tools and techniques.

2 OBJECTIVE

This study aims to identify and propose solutions for the common procurement problems that face the Egyptian construction industry by creating a framework for a model that can act as a road map for the development of an automated procurement management system.

3 REVIEW OF LITERATURE

There have been previous studies and attempts to automate the material management process in general. Researchers are trying to find ways to implement technology in the construction industry in order to improve the efficiency of the operations.

Bell (1986) studied the application of computer systems for materials management. His studies were focused on systems that were used to track and control equipment, prefabricated items and materials. Bell concluded from his studies that implementing a computerized material management system does not promise overall system efficiency; some benefits from the system cannot be achieved directly through a computer program. Tuffour (1987) developed a model to be used as guidance for a contractor in a developing country. He divided the materials management into four main categories; material management organization, procurement procedure, relations with suppliers and material utilization. The objective of the model was to present the roles and responsibility matrix of the people from different departments as they contribute to the materials management organization. Elzarka and Bell (1995) developed an object-oriented computer prototype model for piping systems. Their object was to examine the potential of expert system in the field of materials management. According to Elzarka, their model was integrated with the schedules and the design; it was capable of making automatic quantity take-offs and generate purchase orders accordingly. They also integrated changes to automatically update for the take-off the purchase orders. They concluded that expert systems could be a method used for improving materials management systems. Said and El-Rayes (2011), developed a model for optimizing the construction logistics planning while integrating it with decisions from the material procurement process and the material storage on construction sites. The model utilizes the concept of genetic algorithms to minimize the construction logistics costs including ordering costs, stock-out and layout costs.

Similarly, supplier and vendor selection are complicated decisions by fact since various criteria must be considered during the decision making process when selecting a supplier to purchase from. Analysis of selection criteria for suppliers has been the focus of research since the 1960's. However, literature is very rich with supplier selection decision models in the manufacturing industry. In the construction industry, few researches were conducted to providing a selection criterion for a material supplier.

Kumar et al. (2006) developed and formulated a fuzzy multi objective integer programming vendor selection that incorporates three main objectives: minimum cost, maximum quality and maximum delivery time while using realistic constrains such as vendor capacity and buyer's demand. Kokangul et al (2009) developed an integrated AHP and non-linear integer multi-objective programming to determine the best suppliers and to place the optimal order. Kubat et al (2010) integrated AHP, Fuzzy AHP and Genetic Algorithms to determine the best suppliers; AHP was used to organize all weighting factors and genetic algorithm was used to solve the selection problem.

Unfortunately, the construction industry in general is highly resistant to changes. Compared to the manufacturing industry, changes and new technologies are extensively applied to improve the overall manufacturing and products performance. In construction, every company has its own cultures; therefore, there is no guarantee that a standardize system or approach can fit all companies. Similar issue can be found in the Egyptian construction industry. Introducing new technologies to firms can face much resistance. New technologies require training sessions for employees, moreover software packages or systems are considered expensive to adopt and integrate with the overall company's system. A framework for a simple system could be a head start to develop in-house software that could enhance the overall efficiency of the company.

4 METHODOLOGY

Work on this research was divided onto three stages:

1. First Stage: Data collection and identification of the common procurement problems through conducting semi-structured direct interviews with experts in the material management field.

2. Second Stage: developing a framework for the material procurement process including a supplier selection module using the compiled results from the direct interviews

3. Third Stage: testing the applicability of a supplier selection module via Analytic Hierarchical Process (AHP) method and testing its validity with a case study.

4.1 Data Collection

Semi-structured direct interviews with a total of 26 experts from different construction companies were conducted. The interviewees were asked general questions about the problems with the procurement process and what are the suggestions based on their experience could improve the procurement process in Egypt. The results generated a large list of problems. Some of the major problems were listed and categorized in the following Tables 1 to 4. Also, problems were ranked based on their frequency of being mentioned by a 3-point scale (High, Medium and Low).

The interviews were not only limited to identification of the problems; but also, to identification of the possible solutions required. According to experts, each problem may have a dozen of solutions but all depends on a company's feasibility to implement or test the solution. Moreover, proposed solutions may require assigning of certain budgets, time to test its implementation and training of employees.

Table 1: Engineering Problems

Problem	Description	Freq.
Vague specifications	Current specifications used do not represent the nature or the requirements of the project, they could have been adopted from the specifications of previous projects and were not revised to suite the current project circumstances	High
Drawing do not provide enough detail	Design drawings are not detailed enough for the quantity take-off to estimate the required quantities	Medium
Contradictions between drawings and specifications	Lack of coordination consumes time in issuing clarifications to the designer which in return generates delays	Medium
Procurement schedule not Integrated in the master schedule	Lack of coordination between delivery times and actual activity times in the master schedules which generates either delays if materials arrive too late or storage problems if materials arrive too early	High
Change orders	Constitutes a major problem if the contractor already made deals with a specific supplier and a changer order was issued	High
Inadequate market study	Failure to make applicable procurement plans due to the dynamic nature of the materials market	High
Lack of Communication	In adequate communication between parties involved	High
Too much paper work	Too much paper work and forms to fill which the process more difficult to handle and manage, required a quality management system to keep track of documentations	High

Table 2: Supplier Selection

Problem	Description	Freq.
Long process of quotation methods	Issuing RFQs to suppliers takes time in preparation, issuing and receiving	Medium
Suppliers are unqualified	Too much unqualified suppliers that do not provide the required qualities	High
Supplier evaluation process	No method or system to evaluate suppliers because of the different selection criteria that are not standard for each purchase	High
Suppliers do not complete the bid form	Creates problems in comparing between suppliers	Low
Lots of suppliers with no QA programs	Lots of suppliers do not provide quality assurance programs which makes their selection risky in terms of delivery time with the quality and quantity required	Medium

Table 3: Purchasing and Logistics

Problem	Description	Freq.
Unavailability of products	Due to complex designs, some product are unavailable at local suppliers and requires dealing with international suppliers	High
Required quantities are unavailable	The supplier's capacity in supplying material is not enough comparing to what the project requires or the sum of the required quantities cannot be purchased in bulk	High
Unrealistic delivery dates	Suppliers do not provide realistic dates which affects the start of activities	High
Late deliveries due to traffic	Traffic jams are a main source of delays in Egypt	High
Transportation issues	Some site is located in remote areas, shipments to site face lots of difficulties due to such problems	High

Table 4: Arrival and Inspection

Problem	Description	Freq.
Storage	Lack of site storage is the main problem on delivery, early site layout planning should consider purchases storage locations	High
Managing warehouse	managing ins and outs constitutes the main problem in warehouse management, order points are determined from this area, needs a tracking system like using barcoded items for example	High
Inadequate inspection	some materials required specific personnel, some inspections could be skipped which result in installing nonconforming material	Medium
Materials arrive damaged on site	Materials are backordered which wastes time as if we are restarting the cycle again	Medium

4.2 Model Framework Development

Based on the highly-ranked problems and recommendations from experts, a procurement process framework was developed. The developed framework is simply a process chart that allows capturing and deploying the procurement processes in a format and language that can be easily understood by all parties involved. As a result, it becomes easier and faster for the right employees to do the right thing at the right time reducing waste, risk, and improving compliance. The developed framework allows for integrating instructions, attachments and can launch external software to do a certain task as shown in Figure 2.

The developed process chart comprises a set of shapes. The rectangles with round edges represent the start and the end points of the whole process. The rectangular shapes (with sharp edges) represent a task or a process. Each task is assigned to a department or a person to assure the right employees do the right jobs. Some tasks may include attachments, comments or launching an external software. Attachment is denoted with a clip, comment is denoted with a note and launch program with an arrow pointing downwards. Diamond shapes are decision nodes in which the user has to make a decision for which path to continue the process in. Some cost control nodes may answer with a rejection; therefore, there should be a meeting held with the project decision maker to discuss recovery plans and action. If in the case the contract documents specify a nominated supplier or the contractor has a yearly blanket with a supplier; therefore, the model's logic skips the supplier bidding part and jumps to supplier selection node.

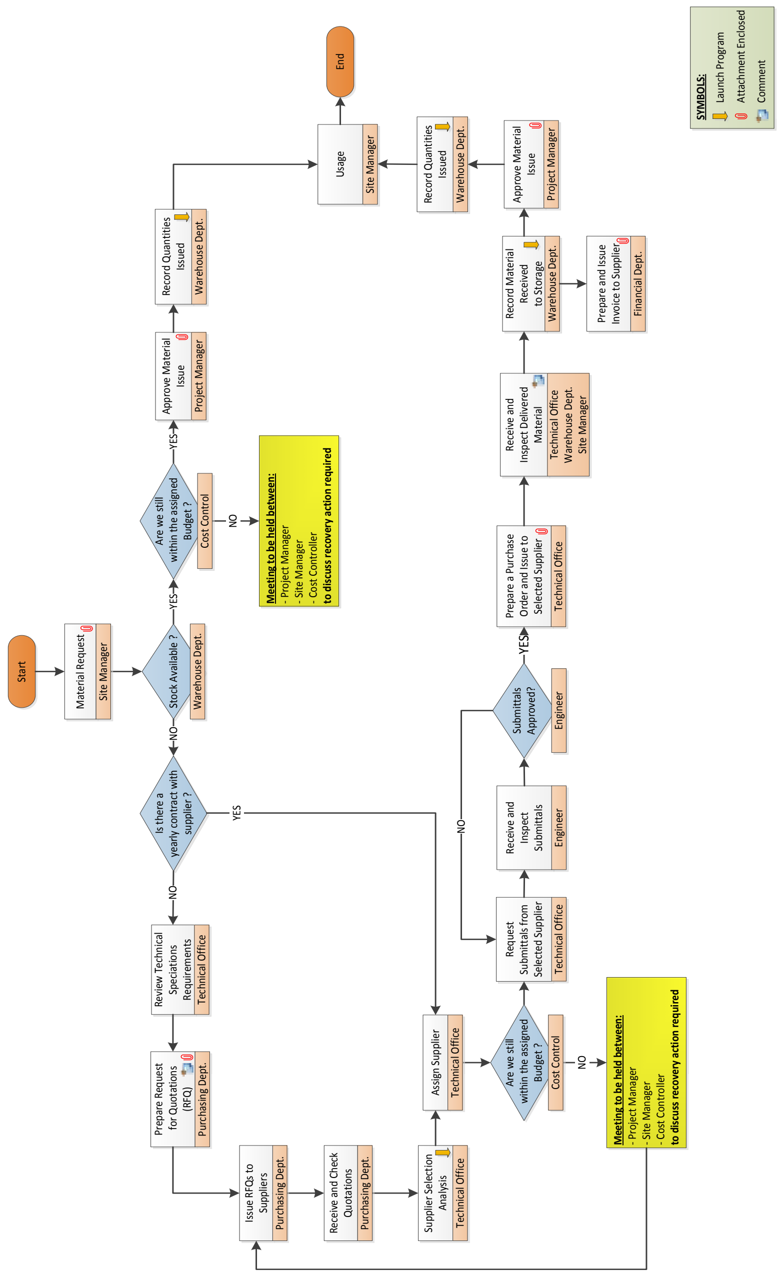

Figure 2: The Proposed Framework

The following Table 5 illustrates the possible comments, attachments or instruction to launch an external program that could be incorporated in the model.

Table 5: Illustration for the model nodes

Task Name	Responsibility	Enclosed Items
Material Request	Site Manager	Attachment: Material Requisition Form
Approval Material Issue	Project Manager	Attachment: Material Issue Form/Letter
Record Quantities Issue	Warehouse Dept.	Launch: Materials log and record quantities issued
Prepare Request for Quotations (RFQ)	Purchasing Dept.	Attachment: Request for Quotation Form Comment: Consider/Revise - Check Specifications requirements - Material Sourcing - Clarifications needed - Product requirements - Packaging procedure - Freight and Handling - Storage requirements
Supplier Selection Analysis	Technical Office	Launch: Supplier Selection Program
Prepare a Purchase Order and Issue to Selected Supplier	Technical Office	Attachment: Purchase Order template Comment: Revise requirements as in RFQ task
Receive and Inspect Material	Technical Office Warehouse Dept. Site Manager	Comment: Inspect the material base on: Required Specifications Issued Purchase Order Material Request Form
Record Material Received to Storage	Warehouse Dept.	Launch: Material Log to record materials received and add its status
Prepare and Issue Invoice to Supplier	Financial Dept.	Attachment: Material Invoice Form
Approve Material Issue	Project Manager	Attachment: Material Issue Form/Letter
Record Quantities Issued	Warehouse Dept.	Launch: Materials log and record quantities issued
Are we still within the assigned Budget	Cost Control	Comment: Compare consumed material vs. budgeted material Ensure items are still within the budget limit Provide answer either approve or reject

4.2.1 Supplier Selection Module (Using AHP)

The supplier selection is a multi-criterion problem which includes both qualitative and quantitative issues. To select the best supplier, there should be a trade-off between the factors that may affect the decision. The commonly used criteria considered when selecting suppliers based on the interview results are: the net quotation (including discounts and transportation, meeting technical specifications in terms of quality, meeting the delivery schedules, financial position of the supplier, production facility and capacity, previous performance on other projects, warranties and claim policies and performance history for similar projects.

The supplier selection module uses the AHP method because it offers a methodology to rank alternatives based on judgments concerning the importance of the criteria and to which extent they comply with each alternative. The target is to select a supplier to provide a certain required material. After issuing RFQs to suppliers, three suppliers' quotations were used for example and the rest were discarded. The objective of this module is to evaluate the best supplier based on a set of criteria. For the purpose of this case, assume four aspects are to be considered that are the basis of the final decision; Price, Quality Assurance, Delivery Time and Capability. The architecture of the supplier selection module is shown in Figure 3.

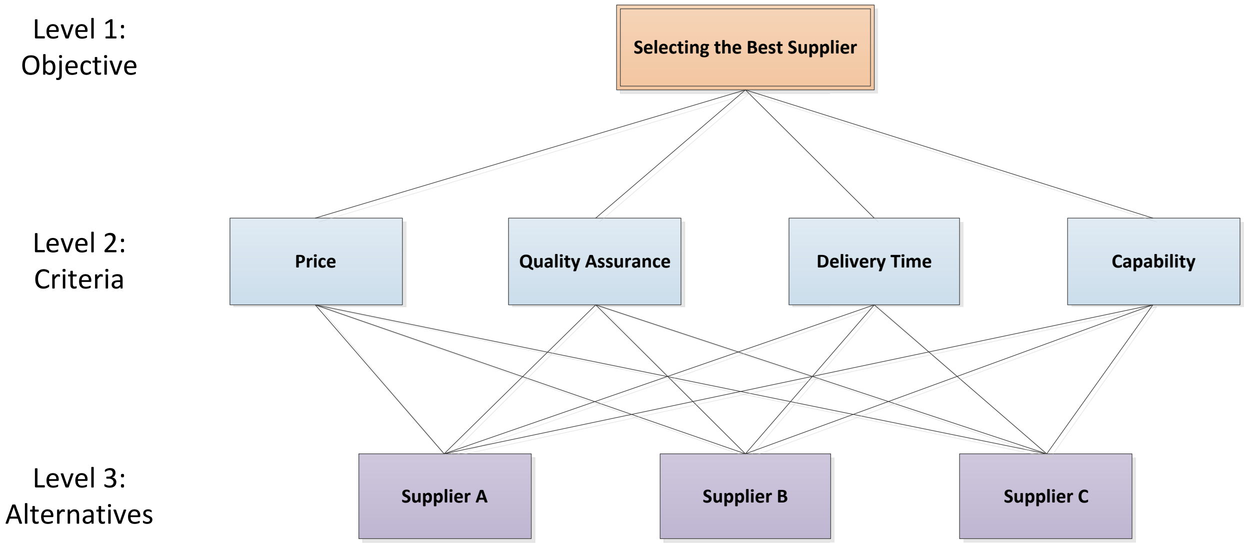

Figure 3: Architecture of the supplier selection module using AHP method

The first step in the AHP method is to identify a measurement scale which can encode the qualitative verbal judgment or preference between the suppliers' selection criteria. The following Table 6 depicts the measuring scale that was used in the AHP model.

Table 6: Measurement Scale

Verbal Judgment or Preference	Numerical Rating
Extremely Preferred	9
Very Strongly Preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate values (when compromise is needed)	2, 4, 6 , 8

The second step is to construct a set of pair-wise comparison matrices sized (n x n) for each of the lower levels, with one matrix for each element in the level immediately above by using the measurement scale of Table 6. The pair-wise comparison is based upon which element dominates the other. Synthesizing the pair-wise comparison matrix, this is done by dividing each element of the matrix by the column total. For example, the entry 0.14 in the synthesized matrix is equal to the inverse of the summation of its corresponding column vector in the pairwise matrix =1 / (1+1+5). The priority vector can be obtained by the average of the row vector. For example, 0.158 = (0.14+0.2+0.13) / 3. A sample proximity matrix along with the synthesized matrix for the price criteria is shown in Figure 4. For the then compiling the results as shown in Figure 5.

Pair-wise Comparison for Price			
	A	B	C
A	1	1	0.2
B	1	1	0.33
C	5	3	1

Synthesized matrix for Price				Priority Vector
	A	B	C	
A	0.14	0.20	0.13	0.158
B	0.14	0.20	0.22	0.186
C	0.71	0.60	0.65	0.656
			Σ	1.000

Figure 4: Pair-wise comparison vs synthesized matrix for Price

The third step is to do a pair-wise comparison for all the criteria together in terms of the importance of each in contributing to the main goal. The pair-wise comparison matrix is shown in Figure 5.

Pair-wise Comparison for Criteria					Priority Vector
	Price	Capability	QA	Delivery	
Price	1	3	1	3	0.4
Capability	0.33	1	0.33	1	0.13
QA	1	1	1	0.5	0.26
Delivery	0.33	3	2	1	0.21
				Σ	1.00

Figure 5: Pair-wise comparison between criteria

The final step is the overall proximity calculation of each supplier. This is a simple weighted average calculation for were each criteria weight is multiplied by its corresponding proximity value as shown in Figure 6. For example, Supplier A: 0.231 = 0.16(0.4) + 0.23(0.13) + 0.16(0.26) + 0.42(0.21).

Proximity Matrix for Supplier Evaluation					Overall
	Price (0.4)	Capability (0.13)	QA (0.26)	Delivery (0.21)	Priority Vector
Supplier A	0.16	0.23	0.16	0.42	0.231
Supplier B	0.19	0.65	0.3	0.12	0.273
Supplier C	0.66	0.54	0.12	0.46	0.483
				Σ	1.000

Figure 6 – Proximity Matrix for supplier evaluation

For Supplier prequalification purposes, the suppliers are ranked according to their proximities as follows C, B and A. therefore, it can be concluded from the table that supplier C has the highest overall priority vector; therefore, it is the best choice according to the selected criteria. After the supplier is selected and approved, the procurement process chart should then be resumed from the “Assign Supplier” node.

5 RESULTS AND CONCLUSIONS

Construction project materials management is an important and complex aspect of project planning and control. The material management process can be represented by a set of interdependent phases. Decision on each phase affects the decision of the following phase. The material procurement process is a critical phase contributing to a successful material management process. Procurement problems could greatly affect the construction stage and result in delays and disruption of the works. Therefore, better management practices need to be implemented to increase the process efficiency and decrease the overall costs.

Literature has illustrated lots problems generated in the procurement process and introduced some of the systems that could be used in order to solve such problems. Creating intelligent programs could be a solution to solve such complex problems of procurement. Unfortunately, the construction industry is highly resistant to change compared to other industries. Moreover, the Egyptian construction industry is also resistant to change as companies tend to challenge each other in terms of knowledge and experience to maintain a good position in the market ranking. Developing a framework for a system could be a head start for companies to develop their own software to improve the overall efficiency. A model for the procurement process was constructed; its logic was obtained from the recommendations of experts in the procurement field. Using this model could be a road map for developing a program for the process. Incorporating attachments and comments could be used to improve communications, assign responsibilities, standardize the working procedure and minimize errors or waste in the process. In addition, applying the AHP method to solve the supplier selection problem could assist decision makers in their evaluation of suppliers. The procurement process is fragmented-basis process. Preparing procurement plans for a project are not enough to efficiently manage and control the process. Contractors should work on implementing information systems to improve the management and control of such complex processes.

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