

## Applying Lean six sigma DMAIC methodology to identify the significant factors causing delay in Construction Projects in the Electricity sector -Libya

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*Abstract*— The construction industry is one of the main sectors of the Libyan economy, and it is an important industrial sector in terms of economic and social impact and also employment facilities. Currently, the Construction Industry (CI) in Libya contributes 5.2 per cent of the Libyan Gross Domestic Product (GDP), and it employs around 3.2 per cent of the total manpower[2]. This paper will be presented how to use lean six sigma "Define, Measure, Analysis, Improve, and Control (DMAIC)" Methodology to determine and evaluate the most important and frequent factors causing delay in construction projects in the electricity sector (GECOL). Through literature review, a comprehensive list of causing factors delay was determined, such as: slow Decision Making, Lack of experience in construction, improper project feasibility research, Inadequate contractor experience, Inappropriate construction methods, Inaccurate cost estimating, and inadequate fund allocation.

A survey based on a questionnaire carried out among randomly selected personal such as project managers, project engineers and top managers in the General department of Projects in the Company, also the main contractors and consultants are involved in this survey, to get their perception as to the significance of these factors in delay of Electricity projects. The data gathered was analyzed using Lean six sigma DMAIC methodology to identify and rank the significant factors causing delay in Construction Projects in the Electricity sector –Libya.

**Keywords:** Lean Six Sigma, DMAIC, Construction Project, Significant Factors, GECOL.

### I. PROBLEM DEFINITION

GECOL is the largest public company in Libya and it's responsibility to operate and maintain the electricity network in all regions. It's comprises of the three zones, these zones are west area, east and south area.

There is many project implemented to cover the demand of increasing Energy in these zones, but these project faced many issues that it contribute to delay these projects to complete them within the planning schedule [1].

The two main aims of the research were:

- to study the Project's delaying time in the GECOL, with a view to identify the factors that affect delaying time and recommend ways of minimizing the delay.
- to use the six sigma technique to identify the delay and improve management capabilities.

### II. RESEARCH SCOPE

Six sigma researches were done at the GECOL's Project. The research methods chosen were to interview the Project owner (Project Engineer, Project Mangers) directly and the other people involved in executing the work process of project such as main Contractor, Subcontractor and Consultant.

### III. LITERATURE RESEARCH

#### A. Delaying time

The construction delay is a universal evident reality not only in Libya however all the countries faced this global fact. Construction delay can be defined as execute later than intended planned, or particular period, or letter than specific time that all the concerned parties agreed for construction project. Delay in project is counted as a common problem in construction projects [3].

On large level there is no suspicion that the development of country depends upon its achievement of its advance plain with elevated construction contents. There is a French dictum "when the construction industry prospers everything prospers". Escalation of construction industry is of imperative for all regions of national and international economy, as well as everyone involved in the industry like contractors, workers, financiers, architects, engineers etc[4].

The project's success depends on meeting objectives within time and budget limits. Tools and techniques play important role in project management. The major factor of construction problems is project's delay. Delay means loss of income according to and for the owner or client. In case of contractor, delay refers to the higher costs due to longer work time, labor

cost increase and higher fabrication costs. On time completion of project is an indicator of efficiency[5 and 6].

But there are many unpredictable factors and variables resulting from various sources affecting construction projects. Some main sources are the involvement and performance of parties ( Owner, Contractors, or consultants), contractual relations, environmental and site conditions, resources availability etc. It is very rare to see that a construction project is completed on time [7]. In this research, discussed most critical factors causing delay in large construction projects in General Electricity company of Libya (GECOL)[1].

**B. Six Sigma**

First introduced by Motorola in 1986, Six Sigma is a method to measure the quality of a process to fulfill customer’s needs which approaches perfection up to 3.4 defects per million opportunities. Data and statistical analysis were used to identify defects in processes and reduce variation. With Six Sigma, defects in a process can be measured by identifying the best method to eliminate defects and approach ‘zero defect’. Customers’ satisfaction is the main factor. A new and more effective method has to be adopted to ensure customers’ satisfaction.

Six Sigma specifies a very high standard of quality achievement. This is identified through levels of failure and involves very low costs. In the following table, the different of sigma value according to level of failure and costs could be seen[2]:

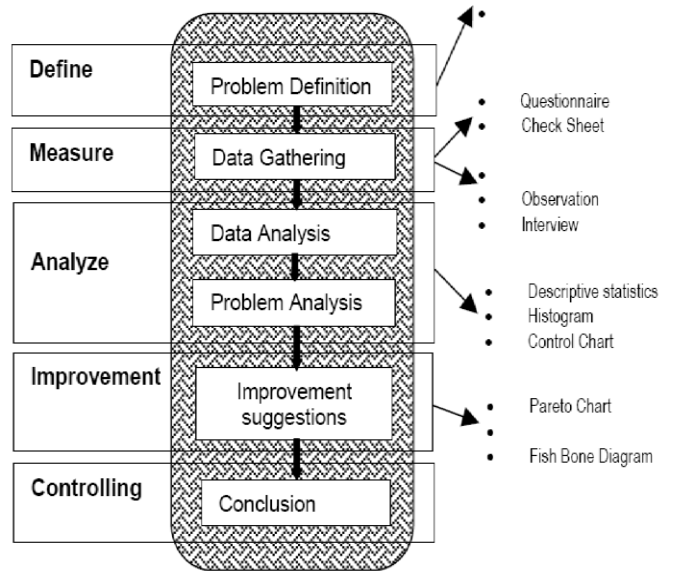
**Table 1: DPMD level and CDPG sigma value**

Sigma Level	DPMD	CDPQ
1- Sigma	691,462 (Low competitive)	Incalculable
2- Sigma	309,538	Incalculable
3- Sigma	66,807	25.40% of sales
4- Sigma	6,210 (USA industries)	15.25% of sales
5- Sigma	233	5.15% of sales
6- Sigma	3.4 (World industries)	< 1% of sales

Source: Pande and Holpp, 2002, 'What is Six Sigma?'

Note:  
DPMD = Defects per Million Opportunities  
CDPQ = Costs of Poor Quality

The Six Sigma method which consists of the five steps of “Define – Measure – Analysis - Improve -Control (DMAIC)” is the roadmap to achieve the objectives of this research. Each of the steps of this research is shown in Figure(1) [8].



Source: Thomas Pyzdek, 2001, 'The Six Sigma Handbook'.

**Figure 1: DMAIC Steps**

Six Sigma utilizes a variety of existing project management, statistical and analytical tools. Several toolkits of the Six Sigma were applied during this research such as :

- Descriptive statistics:  
Statistical image shows characteristics of collected data. At this level, data will be presented using the best presentation tools such as histogram, pie chart or others.
- Pareto Chart  
Chart shows level of influence from a variable to the research problem.
- Cause and Effect Diagram (Fishbone Diagram)  
Diagram shows the relationship of a cause that gives rise to a certain problem.

**IV. DATA GATHERING**

**A. Sample size**

This research, conducted at the GECOL's Projects , was an exploratory and evaluation research for the cause of delaying projects. Respondents of this research were selected Project Engineer, Engineer on Site and Accounts Contract at the General Projects department and the other parties such as main contractors and consultant . Table 2 shows the total number of respondents in this research.

Table 2: Type of respondents

Respondents		Frequency	Percentage %	Accum
Owner	Project Manager	9	23%	23%
	Project Engineer	15	38%	61%
	Site Engineer	5	13%	74%
	Contract Accountant	4	10%	85%
Contractor	Main Contractor	4	10%	95%
Consultant	Consultant	2	5%	100%
Total		39	100%	

**B. Type of data and collection methods**

Several variables used in this research for data collected about Project's delaying . Three major collection methods were used: The first method is an observation. Data were collected through direct observation on the site and monthly reports . The second method is through interviews, in carrying out this research, some of the project staff and Project managers have interviewed to obtain information about the main issues causing the delaying. Also Accounts Contract at the contract department has interviewed to find out their comments and remarks concerning the subject. The third method involves collecting data from respondents through questionnaires.

**V. DATA ANALYSIS**

**A) Descriptive statistics**

Out of the 20 projects which were selected for the research, only 2 projects have finished within 6 Months . On average, delaying time for a project to complete is more than 9 months. This long delaying time gives a negative perception on the strategic planning in the GECOL's Projects (see Table 3).

Table 3: Distribution of Projects delaying time

Delaying Time	Total	Percentage
Less than 6 Months	2	1.8%
6-less than 9 Months	5	22.3%
9-12 Months	3	49.1%
More than 12 Months	10	26.8%

**B. Causes of delaying Project**

According to data gathered from monthly progress for running Projects, and the interviews with the some of project managers , project engineer , and accountant of contractor at contractor. The researchers have identified a list many parties that contribute the causes of delay projects. There were many major elements that influence the delaying Project, these are : Client -Related , Equipment -Related , Manpower- Related, Project Finance –related, Consultant – Related, Material – Related, External Factor –Related, Government Regulation ,Contractor – Related, and Project Management- Related. The Fishbone in figure (2) shows and summarized these result which conclude from survey.

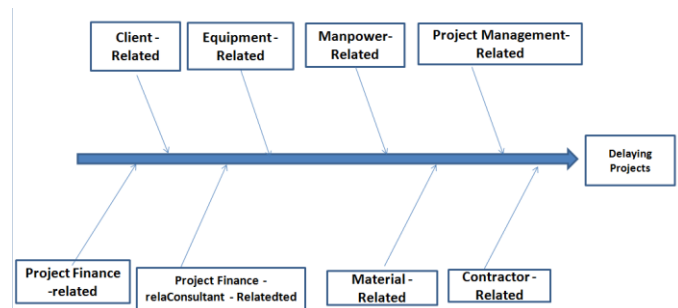


Figure 2 : Cause of Delaying Projects

The parties that contribute to causes of delay projects are listed in questionnaire form and submitted to many respondents to select the top 5 parties according to contribute for delaying of the project . Table (4) show the summary result of the Respondents for ranking of parties to contribute for delaying of the project.

Table 4: summary result of the Respondents for ranking of parties

Casuse relate	Code	Frequency	Percentage	Cumulative
Client -Related	A	30	33%	33%
Contractor - Related	B	24	26%	59%
Project Finance – related	C	21	23%	82%
Project Management-Related	D	6	7%	88%
Equipment -Related	E	4	4%	93%
Consultant - Related	F	2	2%	95%
Material - Related	G	1	1%	96%
Manpower- Related	H	2	2%	98%
External Factor – Related	I	1	1%	99%
Government Regulation	J	1	1%	100%
Total		92	100%	

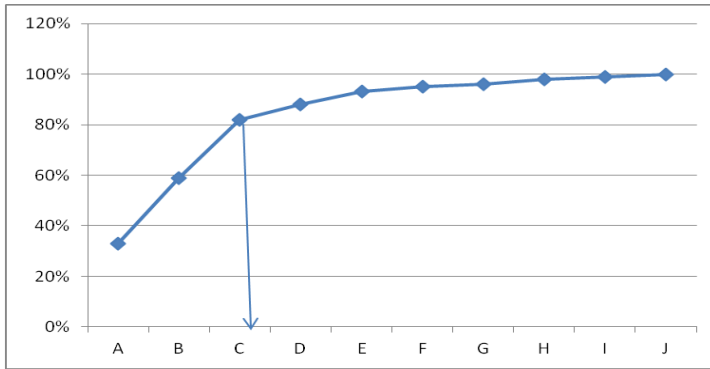


Figure 3: Problems of Delay projects - Pareto chart

Based the result of ranking of the parties cause and effect in delay project as shown table (4), the Client - Related is ranked the first, where it has got the highest frequency .then Contractor - Related is ranked the second ,and Project Finance - Related is ranked the third. These parties are composed 80 % of problem that causing delay projects. From Pareto chart diagram (3) above, three main problems which accounted for 80% of delaying projects are:

- Client- Related.
- Contractor –Related
- Project Finance -related

#### 1)Cause and effect of Client - Related

Based on the Brainstorming, and interviewing with the some of project managers , project engineer , and main contractors. The researchers have concluded, identified, and summarized many root causes that contribute to delay of projects due to client part.

The Fishbone in figure (4) shows and illustrate these cause, and the most important cause are slow Decision Making, Lack of experience in construction, delay of the settlement of contractor's claims, changes orders, delay of progress payment, lack of communication/coordination, improper project feasibility study

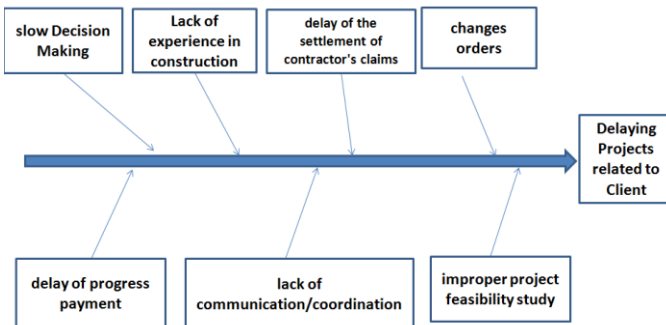


Figure 4 : Cause and of Client –related Factors

#### 2. Cause and effect of Contractor - Related

Based on the Brainstorming, and interviewing with the some of project managers , project engineer , and main contractors. The researchers have concluded, identified, and summarized many cause factors that contribute to delay of projects due to Contractor part. The Fishbone in figure (5) shows and illustrate these cause, and the most important cause are: Inaccurate time estimating, Inadequate contractor experience, Inappropriate construction methods, Inaccurate cost estimating, Poor site management& supervision, Improper project planning & scheduling, Incompetent project team, Unreliable subcontractors, and Obsolete technology

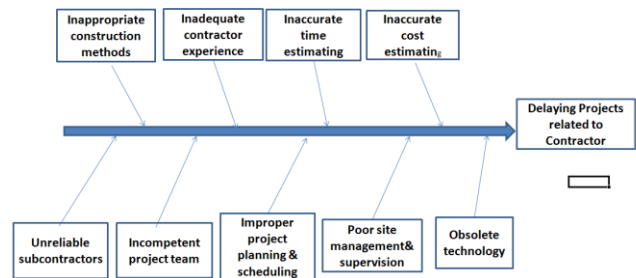


Figure 5 : Cause and of Contractor –related Factors

#### 3. Cause and effect of Project Finance –related

Based on the Brainstorming, and interviewing with the some of project managers , project engineer , and accountant of contractor at contractor department. The researchers have concluded, identified, and summarized many cause factors that contribute to delay of projects due to Project Finance –related. The Fishbone in figure (6)shows and illustrate these cause, and the most important cause are: Difficulties in financing the project by the contractor, cash flow problems faced by the contractor, inadequate fund allocation, client's financial difficulties, problem between the contractor and his subcontractors with regard to payments, Inaccurate Cost Estimating.

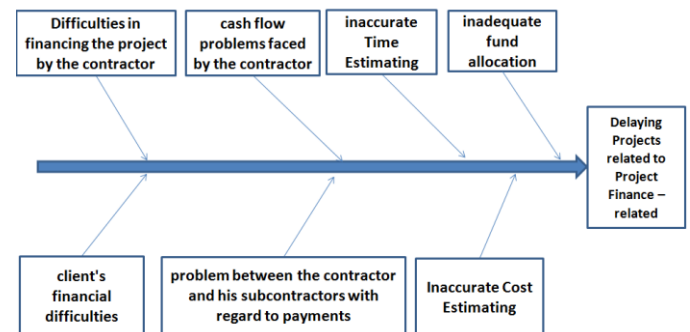


Figure 6 : Cause and of Project Finance –related Factors

## VI. IMPROVEMENT, SUGGESTIONS AND CONTROL

Improvement and suggestions to avoid delays of Projects

1) There are many steps to be considered from GECOL to avoid the delays in construction projects such as: making risk management, followed by proper planning as the second factor which need to be considered to avoid delays. The researchers recommend to follow these steps to avoid and minimize the delay:

- Making Risk Management Proper Planning
- Proper Payment from Client Prepare Insurance Claims
- Good Scheduling Program
- Client Representative for Project Selecting Expert
- Understand Their Assignment Clear Contract and BQ
- Compute the Amount of Financial Damages

2) For decreasing delay in project diminish the change in drawing during the construction.

3) It is necessary for contractor that by increasing number of labors productivity in construction increased.

For reducing delay in project, contractor must have knowledge about his resources strength and obtain up-to-date Machinery, and try to obtain new equipment for construction.

4) It is contractor liability that he must manage the capital resources throughout the project and use it appropriately because he doesn't countenance economic and cash flow problems.

5) For reducing delay managerial and technical staff should be acquired for site management and supervision. It is necessary to include skilled and experienced workers in staff because of them the performance of work is improved

6) From interviewing, the GECOL Projects mostly delay occur in large construction projects is change of government law due to which construction is stopped and delay of government Compensation for land.

7) For controlling to minimizing the delaying of projects, the GECOL should be a closed monitoring, supervision and establish a good communications links with main contractors, sub contractors, and consultants. And it should be used the project management tools such as project scheduling tool and quality control charts for managing these project.

## Conclusion

Data were analyzed using the six sigma approach. A questionnaire was used to gauge the GECOL's responses on identify the significant parties involved in Project which causing delay in Construction Projects as well as to measure the level of significant with the GECOL's Project services rendered. Conclusion: Three main significant parties causes have been identified as the contributing factors towards excessive delay in Construction Projects, namely: Contractor – related, Client Related and Finance difficult. Attempts should therefore be made to reduce the delaying time as well as to improve and enhance the Project performance.

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