A COMPARATIVE ANALYSIS OF APPLICATION OF SIX SIGMA PROJECT MANAGEMENT TECHNIQUE IN SMALL AND MEDIUM SCALE CONSTRUCTION COMPANIES IN NIGERIA

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ABSTRACT

The critical objectives of construction industries nowadays is to complete a project within a stipulated time, scope and budget through process standardization and efficient use of resources, provided by project management techniques such as Programme Evaluation and Review Techniques, Critical Path Method, Cost Benefit Analysis etc. But still most of the construction companies face poor client satisfaction due to non-completion of the work as per the required standard and specification. Since the development of the Six Sigma in 1980s in manufacturing industry, its popularity as a process improvement method has significantly grown. However, the adoption of this concept is quite new in some construction industry. The aim of this project is to compare Six Sigma method with other Project Management Techniques and investigate the acceptability of its implementation within small and medium scale construction companies. The research in this project made efforts to establish complete analysis of 59 retrieved well developed instruments with data from major professionals in the construction industry. The research concluded that there is no doubt about the positive effects of the implementation of Six Sigma in the construction industry. Particularly, Six Sigma can provide a broader quality concept, detailed performance measurement, coordinated and repeatable process/performance improvement.

Keywords: Six Sigma, Construction industry, project management.

INTRODUCTION

In the construction industry, the aim of project control is to ensure the projects are completed within the time frame, budget and scope in terms of quality. This involves constantly measuring progress; evaluating plans; and taking corrective actions when required. During the last few decades, numerous project control tools and techniques, such as Graphical Evaluation and Review Techniques (GERT), Gantt and Bar Chart, Program Evaluation and Review Technique (PERT), Benefit-Cost ratio and Critical Path Method (CPM), have been developed. Despite the wide use of these methods, some building construction projects still suffer time and cost overruns.

The construction industry is often criticized for its poor performance, low safety, poor work quality, wasteful, inefficient, and low productivity. In 1999 over one billion sterling pounds were spent on projects due to errors and rework (Nicholson 1999). According to Lahndt (1999), project mismanagement, insufficient planning, and poor craftsmanship contribute to poor quality performance. Many studies have urged mangers in the sector to understand the relationship between quality management and performance. This calls for a need in the construction industry for quality management strategies and quality improvement programmes to improve work quality and to enhance performance.

Notwithstanding the existence of several project management techniques, there are incessant increase in delay, high cost of operation and cases of substandard construction of projects (Research area: Port Harcourt city). Thus, there exist need to investigate the cause of these abnormities, to see if the problem is with the efficacy of the techniques or its applicability and acceptance. This work tries to analyze Six Sigma within construction of projects context, comparing it against different construction management techniques like PERT, CPM, GERT and CBA, and evaluate its (six sigma) features that could meet these needs of construction industry from process improvement perspectives.

The Construction Project Management

Construction project management according to Opara, (1986) is the overall planning, co-ordination and control of a project from inception to completion aimed at meeting a client's requirements in order to produce a functionally and financially viable project that will be completely feasible. The most common responsibilities of a Construction Manager according to The Construction Management Association of America (CMAA) fall under the following seven (7) categories: Project Management Planning, Cost Management, Time Management, Quality Management, Contract Administration, Safety Management and CM Professional Practice which includes specific activities like defining the responsibilities and management structure of the project management team, organizing and leading by implementing project controls, defining roles and responsibilities and developing communication protocols and identifying elements of project design and construction likely to give rise to disputes and claims(Arnaboldi et.al, 2004).

A project manager is a professional in the field of project management having the responsibility of planning, execution and closing of any project, typically relating to construction industry, architecture e.t.c (Muller and Turner, 2007). Project Management according to PMBOK is application of knowledge, skills, tools and techniques to project activities to achieve project requirements. (Wysocki, 2009).

Construction Management Techniques

Different techniques and tools are used in managing projects for a desirable outcome. Some of these techniques are Work Breakdown Structure, Gantt Charts, Prince 2, Critical path method and Programme Evaluation and Review Techniques, Project Sensitivity Analysis, Cost Benefit Analysis, Graphical Evaluation and Review Technique (GERT) and Construction Project Software. But in this work, the following were considered; Critical Path Method, Programme Evaluation and Review Techniques, Cost Benefit Analysis, and Graphical Evaluation and Review Techniques.

Arnabodi, Azzone, & Savoldelhi (2004), observed that the critical path method is the most widely used scheduling technique in Construction Project Management. But this is limited to complex but fairly routine projects with minimal uncertainty in the project completion times. For less routine projects there is more uncertainty in the completion times, and this uncertainty limits the usefulness of the deterministic CPM model. Programmne Evaluation and Review Technique (P.E.R.T) an event-and-probability based network analysis system; often used in large programme where the project involves numerous organizations at widely different locations became a close alternative to CPM. This allows a range of durations to be specified for each activity whose parameter are usually stochastic. However, the activity time estimates are somewhat subjective and depend on judgments, which introduce some level of

biasness in the estimate. Also its assumption of beta distribution for these time estimates is sometimes different from the actual distribution.

Graphical Evaluation and Review Technique (G.E.R.T) is a network model developed to handle the most complex project planning challenges of complicated project activities sequence that is non-deterministic. Originally GERT required activity attributes to be known and set deterministically, what was necessary condition to allow calculations of the probabilistic network. Also GERT has some limitation in its application to project management. These include: Non repeatability of any activity, thus cases of rework are handled as a change request and requires re-planning the network. Also the definition of critical path, considered to be the longest path, even though variances allow the likelihood of other paths being longer.

Six Sigma has two key methods: DMAIC process (Define, measure, analyze, improve, control) and DFSS methodology (Design for Six Sigma). Forbes and Ahmed (2009) noted that **DMAIC** is for existing processes which requires significant improvement due to its low or poor performance below expected quality specification. DFSS serves as a systematic methodology for designing new products and/or process at Six Sigma quality levels. (Kwak and Anbari, 2006). Sleeper (2005) sees DFSS as a successful method applicable on new products/process developments to meet customer expectations for performance, quality, reliability and cost. Reasons for implementing Six Sigma can vary from one construction project to another, depending on their objectives and peculiarities with respect to the operating parameters. (Samman and Graham 2007) stated the following as the most common reasons for industries to implement Six Sigma to resolve issues facing the construction industries:

- Cost reduction
- Cycle time reduction
- Error and waste reduction
- Increase competitive advantage
- Improve customer satisfaction
- Change company culture
- Improve quality.

RESEARCH METHODOLOGY

The Study Population

The project population for this study comprises the top construction professionals who are in active practices in the case study area. The professionals include Project Managers/Engineers, Senior Geotechnical Engineer, Group IT Managers, Quality Assurance Managers, and Planning Engineer etc. Information about the professionals were obtained from the list of professional bodies to find out the cadre of personnel who are registered and have the basic knowledge about project management techniques. For this research, a sample was drawn from my research population and adequate measure was taken to ensure that the characteristics of my sample are the same as its population as a whole.

Instruments for Data Collection

As a result of the nature of this research, the instrument for data collection used for the research was questionnaire. The Questionnaires used contains both Close/Structured and Open/Unstructured ended questions.

Table 1: Types of questions used in the questionnaires

Open-ended Questions	Questions which require respondents to construct answers using their own words. Respondents can offer any information or express any opinion they wish, although the amount of space provided for an answer will generally limit the response.
Closed-ended Questions	Questions which require respondents to choose from a range of predetermined responses and are generally easy to code and to statistically analyse.

In this research, two sets of questionnaire data were administered. Questionnaire data 1, deals with the effectiveness of project management techniques in the construction company (55 were administered and 46 were retrieved).While Questionnaire data 2, deals with the effectiveness of Six Sigma implementation (15 were administered and 13 were retrieved).The retrieved questionnaires were used for analysis in the research.

A field work (primary data collection) and problem solving approaches were adopted for this research, with respect to the implementation of Six Sigma in the construction industry. This research was based on participation and observation in companies that granted such permission for the study of construction projects, that makes use of the investigated project management techniques. An evaluation of their previous method of project execution was compared with a more recent method; as they hope evolve to the application of the management system in recent time. Interviews and brainstorming with professionals from within and outside the construction industry were very useful. The study was developed in line with office and field participation from initial planning and scheduling to implementation and delivery of the project.

RESULTS AND DISCUSSION OF RESULT

Results Presentation

The descriptive method of data analysis is employed for this research. The method of analysis will follow the structure set out in the questionnaire in order to achieve the objectives of the research**.**

QUESTIONNAIRE DATA 1: Comparing the effectiveness of project management techniques in the construction industry.

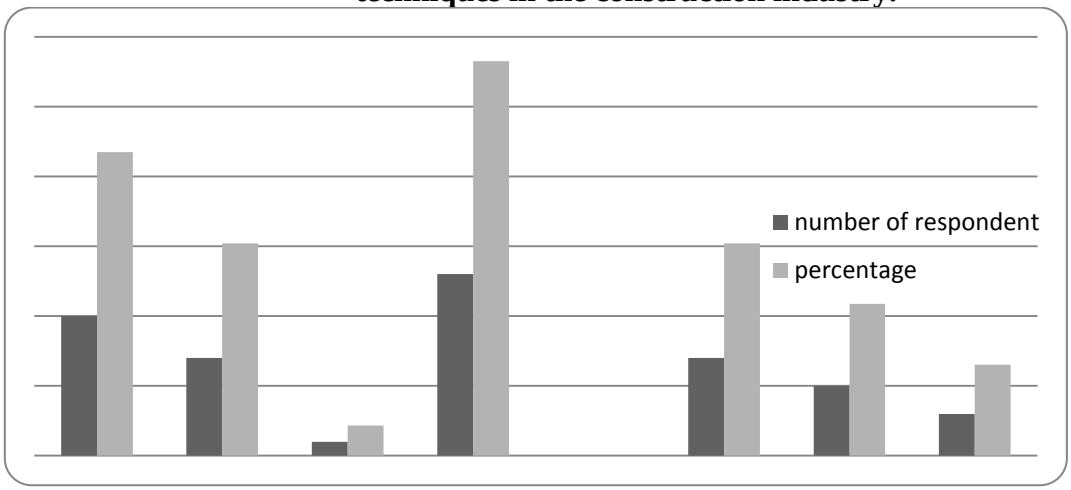

Figure 1: Chart for type of projects
SOURCE: FIELD SURVEY 2014

From the figure 1 above the largest percentage of the respondent 28% had actually handled the construction of infrastructure like multi-storey building and conference centers and corporate building etc, followed closely by the percentage (22%) of those that are into the construction of residential building. The number of respondent that are in the construction industry for consultancy purposes shared the same percentage with those that are into highway projects (15%). The least percentage showing from the respondent where for those that are doing rehabilitation of structures at 2%, while there was no showing for those that have actually done projects on bridges and mast.

Table 2: The importance of some strategic objective for the construction company

Company's Strategic Objectives	RANKING				
	5	4	3	2	1
Profitability	25	11	9	1	0
Client's satisfaction	30	9	7	0	0
Quality of project	28	12	6	0	0
Higher competitive power	11	9	20	4	2
Effective use of resources	21	18	2	4	1
Employee's satisfaction	8	13	21	1	3
Credibility	9	16	17	3	1
Research and Development	1	14	22	3	6
Creativity/Innovation/Aesthetics	3	18	15	9	1
Social responsibility	0	30	15	1	0

SOURCE: FIELD SURVEY 2014

Table 2 involved the importance of some strategic objectives to the company. The rating is to show how construction companies in Port Harcourt city value the set out objectives in the company when on any construction project. From the respondents, the highest number for Profitability is 25 being "very high" and its least 2 being "low" in the ranking scale. At the client's satisfaction objective, the respondents rated it highest with 30 respondents saying their company chooses it very high and lowest at medium with 7 respondents. Quality of project comes in with the highest rating with 28 respondents at "very high" and lowest at 6 for medium. 20 respondents said that their company's higher competitive power was moderate, being the highest registered for that objection. This is followed by the effective use of resources where respondents recorded its highest rating at very high with 21 respondents and the lowest rating at very low with 1 respondent.

Table 3: Percentages of employed engineers in the construction company trained on project management techniques.

% of Trained Engineers	Frequency	Percentages %
➢ 0 _ 25	21	50
➢ 26 _ 50	18	42.857
➢ 51 _ 75	3	7.143
➢ 76 _ 100	0	0
Total	42	100

SOURCE: FIELD SURVEY 2014

Table 3 above shows the respondents' answers to the number of engineers employed in their company who have actually been trained on the project management techniques. In the course of the research, four (4) respondents said that they do not have engineers trained in the techniques. From those that have engineers that are actually trained in the project management techniques, 0-25% recorded the highest number at a percentile of 50% followed closely by 26-50% at 43%. 76-100% recorded no data from the respondents. This shows that more than half of the companies used in the project research have engineers who do actually project management techniques and so the data that follows were reliable.

Table 4: Construction Management Techniques used by the company

Construction Management Techniques	**frequency of usage**	**Percentage**	**RANKING**				
			5	**4**	**3**	**2**	**1**
Programme Evaluation & Review Techniques	29	69.048	4	15	9	1	0
GANTT CHART	5	11.905	1	3	1	0	0
Critical Path Method	34	80.952	11	18	4	1	0
SIX SIGMA method	2	4.7619	0	1	1	0	0
Graphical Evaluation & Review Techniques	1	2.381	0	0	1	0	0
Cost Benefit Analysis	30	71.429	9	15	4	1	1
VERT	0	0	0	0	0	0	0
OTHERS: Prince2, CCPM, Agile project management	16	38.095	2	9	3	1	1

SOURCE: FIELD SURVEY 2014

Table 4 above shows the rate of usage of project management techniques that is being investigated and also their effectiveness in the construction company through rating. CPM recorded the highest percentile frequency usage by the respondents at 81% and ranked highest by 18 respondents at 18 being "high" and its least recording at 1 for "low". This is followed closely by CBA and PERT at 71% and 69% respectively. Where the former recorded its highest ranking as 15 respondents chose "high" and 1 respondent said "very low", while the latter recorded the high value with CBA but its least recording was as 1 respondent said "low". Only a respondent claimed knowledge of GERT, from this it was deduced that it does not have any effect on the construction industry especially in Port Harcourt city. For six sigma method, only 5% claimed awareness of the technique, but from

their rating of the method being at "high" and "medium" rank we can say that it would be a wise experiment to implement it further.

Table 5: The number of construction company that measure, check and control variation in the listed areas

Area of concentration	Number of respondents	Percentage (%)
Cost	36	78.261
Time	28	60.87
Quality	40	86.957
Process Flow	31	67.391
Company's Performance	41	89.13
Client's Satisfaction	38	82.609
Wastage	29	63.043
Employee's Complaints	13	28.261

SOURCE: FIELD SURVEY 2014

Table 5 above shows the analysis of the company's variation in the areas of cost, time, quality, process flow, company's performance, client's satisfaction, wastage and employee's complaints. The highest percentile recorded by the respondents was client's satisfaction, which further states that the sole aim of the companies are to achieve high quality project delivery. And these are areas were Sig Sigma method can enhance. Furthermore, employee's complaints ranked lowest at 29%. All the variables investigated recorded high awareness by the respondents, and as was earlier stated, these are areas where the implementation of Six Sigma will possibly enhance.

Table 6: Construction industry performance increase factors

Enhancing Factors	Number Of Respondent	Percentages (%)
Communication	30	65.21739
Process documentation	6	13.04348
Education and training	39	84.78261
Strategic vision	0	0
Regular audits	18	39.13043
Change of project management	28	60.86957

SOURCE: FIELD SURVEY 2014

Table 6 analyzes the data collected from the respondents concerning the factors that they believe can increase the construction industry performance. This question was included in the questionnaire with the view of bringing in the qualities that Six Sigma hopefully will bring with its implementation in the industry. The highest data of response was for education and training at 85%. This suggests that for an improved performance level in the industry. Other factors that will bring in improved performance level in the construction industry which recorded high percentage from the respondents were communication and change of project management at 65% and 60% respectively.

Table 7: Possibility of benefit of implementing the new construction management technique to the construction industry

	Number Of Respondent	**Percentage (%)**
YES	25	54.34783
NO	8	17.3913
NOT SURE	13	28.26087
TOTAL	46	100

SOURCE: FIELD SURVEY 2014

Table 7 analyzes the question asked in the research to respondents as to whether the implementation of a construction management technique that will correct some of the deficiency in time spent on project, cost and quality be beneficial to the construction industry. 54% of the respondents said yes, 28% said not sure while a meager percentage of 17 said no. This will further strengthen my case for the implementation of six sigma in the industry.

QUESTIONNAIRE DATA 2: The effectiveness of six sigma implementation.
Table 8: The operational division that has implemented Six Sigma.

Operational Division	**Number Of Respondent**	**Percentage (%)**
Business & administrative services	11	84.61538
Building maintenance and construction	4	30.76923
Engineering services (mechanical and electrical)	6	46.15385

SOURCE: FIELD SURVEY 2014

Table 8 further analyses the operational areas in which Six Sigma has been implemented in the company. The respondent percentage recorded the highest at business and administrative services with 85% followed by engineering services at 46%. The least is Building maintenance and construction at 31%. This further lay claim to the fact that the only place where sigma six has been perfectly implemented is in the corporate business world.

Table 9 Six Sigma projects which started and that were completed or not completed.

Percentage Rating	Completed	Completed %	Not Completed	Not Completed %
Below 25%	0	0	4	30.76923
26 _ 50%	1	7.692308	3	23.07692
51 _ 75%	3	23.07692	1	7.692308
76 _ 100%	9	69.23077	1	7.692308

SOURCE: FIELD SURVEY 2014

Table 9 above show the number of project has started and completed with those that were started and not completed since the implementation of six sigma. 31% of the respondents said that they have the entire project started and completed, and so it didn't tick any in the not completed section. The retrieved data analysis shows that the ratio of projects been completed with the implementation of Six Sigma is good enough for it to be implemented elsewhere.

Table 10: comparing the strategic objectives that seen changes since the implementation of Six Sigma in the establishment.

Percentage Rating	Resource Utilization Respondent	Resource %	Time Spent On Project Respondent	Duration %	Savings Achieved Respondent	Resource Utilization Respondent
0 _ 30%	0	0	0	0	1	7.692308
31 _ 60%	1	7.692308	1	7.692308	1	7.692308
61 -80%	1	7.692308	8	61.53846	6	46.15385
81 _100%	11	84.61538	4	30.76923	5	38.46154
Total	13	100	13	100	13	100

SOURCE: FIELD SURVEY 2014

Table 10 above shows the data collected from establishments who has implemented the Six Sigma method, and have compared the strategic objectives changes in the areas of resource utilization, time spent on project and savings achieved during the period that Six sigma has been implemented to when it has not been implemented. All the investigated objectives came back from the respondents and checked out to yield a significant positive change in these areas. This further highlights that six sigma methods brings with it an improved business orientation.

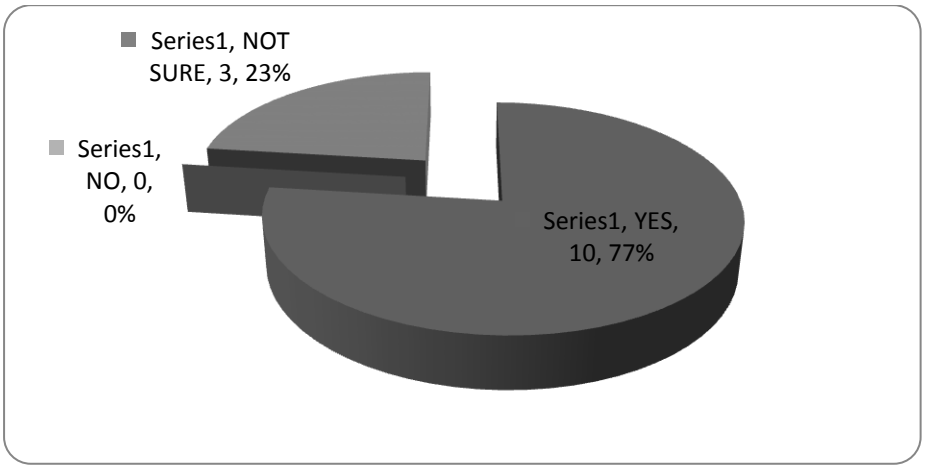

Figure 2 data showing how Six Sigma is better than other construction management techniques as suggested by the respondents.

SOURCE: FIELD SURVEY 2014

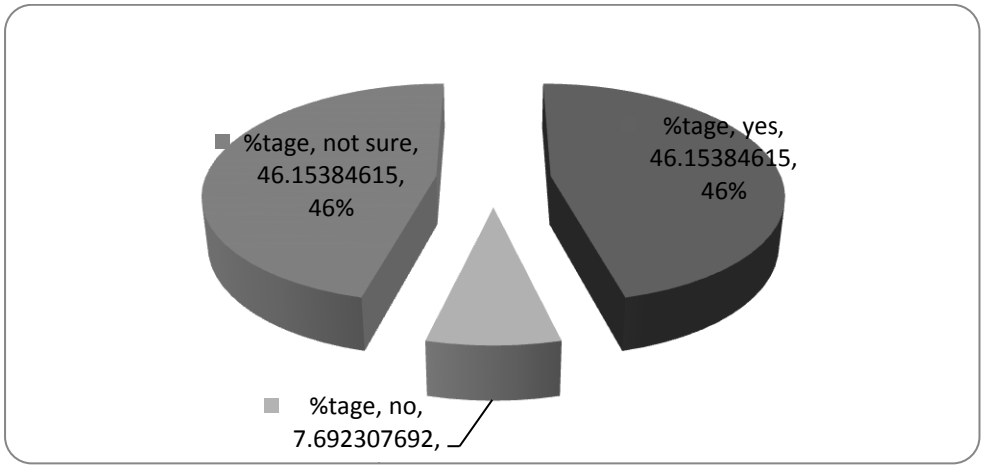

Figure 3: A Pie chart representing opinion of respondent s on the ISO implementation of six sigma in the construction industry

SOURCE: FIELD SURVEY 2014

Table 7 and figure 2 simply show from the data collected from the field survey that Six Sigma has truly been beneficial to the establishment and so could be implemented in the construction industry. Figure 3 shows the Opinion of respondents on the ISO implementation of six sigma in the construction industry. Yes and Not sure recorded a tie in percentage in their opinion. With the respondents that said No at 8% with reason best known to them. Thus it will be right to suggest that the technique be implemented first of all experimentally in the construction industry to enhance the efficiency.

CONCLUSION

This paper compared Six Sigma with other project management techniques and the idea of applying Six Sigma principle in the construction industry theoretically, and its potential to enhance the quality level and efficiency of construction projects. This study introduced Six Sigma as a continual improvement method which offers a systematic strategy to control and coordinate all involved processes in any construction project, effectively. Obviously, according to this research it could be concluded that there is no doubt about the positive effects of the implementation of Six Sigma in the construction industry.

RECOMMENDATION

This study covered a medium and small sized construction companies and projects in Port Harcourt city of Rivers state. Further research to evaluate the impact of Six Sigma for large sized companies and mega construction projects is recommended. Construction process design with Six Sigma tools and the implementation of Six Sigma on non-routine jobs seem questionable and further studies about these issues might be useful for the adoption of Six Sigma in the construction context. Subcontractor aspects of process improvement also are not discussed in this research. Considering the subcontractor roles on construction industry, it can be another interesting research question.

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APPENDIX 1
QUESTIONNAIRE DATA 1
THE EFFECTIVENESS OF PROJECT MANAGEMENT TECHNIQUES IN THE CONSTRUCTION INDUSTRY.

1. **Construction Company's location:**
   ……
2. **What is your current position in your company?**
   ……

3. **What type of projects does your company undertake? [Tick the applicable 1]**

• Residential Buildings		• Bridges and Masts	
• Highway Projects		• Consultancy	
• Rehabilitation		• Water projects	
• Infrastructures		Others specify:	

4. **How important is the following strategic objective for your company? Please rate from 1- 5.**

• Profitability		• Employee Satisfaction	
• Client's satisfaction		• Credibility	
• Quality of project		• Research and Development	
• Higher competitive power		• Creativity/Innovation/Aesthetics	
• Effective use of resources		• Social responsibility	

5. **For how many years has your company been operating in the construction sector? [Tick the applicable 1]**

• 1-5 years	• 16-25 years
• 6-15 years	• Over 25 years

6. **How many Engineers are currently employed in your company? ……**

Are they trained on Project Management? ……. If YES are, what percentages are: [Tick the applicable 1]

• 0-25%		• 51-75%	
• 26-50%		• 76-100%	

7. **Does your company measure, check and control the variations and failures in the following concepts? [Tick the applicable 1s]**

• PERT		• CPM	
• GANTT CHART		• SIX SIGMA	
• GERT		• VERT	
• C.B.A		Others specify:	

8. **In your opinion, how important and effective was the use of the Project Management Technique(s) to your company. Rate from1-5**

• PERT		• CPM	
• GANTT CHART		• SIX SIGMA	
• GERT		• VERT	
• C.B.A		Others specify and rate:	

9. **How often does the top management provide essential training opportunities in Project Management Techniques so as to match their competence in the construction company? [Tick the applicable 1]**

• Days		• Monthly	
• Weekly		• Yearly	

10. Does your company measure, check and control the variations and failures in the following areas? [Tick the applicable 1s]

• Cost		• Company performance	
• Time		• Client's satisfaction	
• Quality		• Wastage	
• Process flow		• Employee's Complaints	

11. What are the most applicable factors that hinder the construction of a project in your company? [Tick the applicable 1s]

• Availability of resources		Inadequate process control techniques	
• Lack of training		• Changing business focus	
• Internal resistance		Lack of top management commitment	

12. What factors can increase your company's performance and capacity in the construction of projects? [Tick the applicable 1s]

• Communication		• Strategic vision	
• Process documentation		• Regular audits	
• Education and training		• Change of project management	

13. In your opinion, can an/the implementation of a new Project Management Technique be beneficial to your company or the construction company at large? [Tick the applicable 1]

• Yes		• No		• Not sure	

APPENDIX 2
QUESTIONNAIRE DATA 2
THE EFFECTIVENESS OF SIX SIGMA IMPLEMENTATION.

14. Company's location: ……

15. What is your current position in your company?
……

16. What type of projects does your company undertake? [Tick the applicable 1]

• Residential Buildings		• Bridges and Masts	
• Highway Projects		• Consultancy	
• Rehabilitation		• Water projects	

17. **Identify the operational division(s) that has used Six Sigma in your company**:
- Business and Administrative Services
- Building Maintenance and Construction
- Engineering services (Mechanical and Electrical)

18. When was Six Sigma implemented in your company? ……..

19. Number of Master black belt holders in your company?
……

20. Percentage of Six Sigma projects started and completed: [Tick the applicable 1]

• Below -25%		• 51-75%	
• 26-50%		• 76-100%	

21. **Percentage of Six Sigma projects started and not completed: [Tick the applicable 1]**

• Below -25%		• 51-75%	
• 26-50%		• 76-100%	

22. **What is the resources utilization in the years that Six Sigma has been implemented when compared to the previous years without Six Sigma in percentages? [Tick the applicable 1]**

• 0% - 30% increase		• 61%-80% increase	
• 31%-60% increase		• 81%-100% increase	

23. **What is the average duration of projects in the years that Six Sigma has been implemented when compared to the previous years without Six Sigma in percentage? [Tick the applicable 1]**

• 0% - 30% increase		• 61%-80% increase	
• 31%-60% increase		• 81%-100% increase	

24. **What is the savings achieved through Six sigma in the years that it has been implemented when compared to the previous years without Six Sigma in percentage? [Tick the applicable 1]**

• 0% - 30% increase		• 61%-80% increase	
• 31%-60% increase		• 81%-100% increase	

25. **In your opinion, has the Six sigma better than other Project Management Techniques in the construction industry? [Tick the applicable 1]**

• Yes		• No		• Not sure	

26. **In your opinion, can the use of ISO certification on Six Sigma implementation in construction industry be beneficial to your company?**

• Yes		• No		• Not sure	