DESIGN PRACTICES IN PETROCHEMICAL FIRMS IN SAUDI ARABIA, SABIC AS STUDY CASE

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DEDICATION

I dedicate this report to my parent, wife, Ali and Little Amna

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ABSTRACT

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TITLE OF STUDY : Design Practices in Petrochemical Firms in Saudi Arabia, SABIC as Study Case

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This report identifies and assesses the design practices at Saudi Basic Industries Corporation (SABIC) presented by Design Management Department (DMD). It assesses the degree of fulfilling the DMD design practices its clients' (SABIC Affiliates) requirements for their projects. The data of design practices was obtained from literatures and interviews with DMD key personnel such as senior design engineers and specialist design engineers. The data of affiliate's satisfaction is obtained from interviews with selected project engineers from four different SABIC affiliates. In conclusion, affiliates are satisfied moderately with design practices quality. This report ends up with some recommendations to improve the current design practices at DMD and to fulfilling the affiliates' requirements. The recommendations are: (1) introduce Quality Control System edited by third party, (2) introduce a contractibility plan and (3) prepares a feasibility study for proposed projects.

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1 INTRODUCTION

Petrochemicals are very important in our daily life. The scope of products manufactured from petrochemicals is broad range from, insulators, cable wrap, fertilizers, plastic, and rubber to every day items like home furnishing, cloths and toys. The demand of petrochemical is increasing in the last three decades as per Saudi Arabia General Investment Authority (SAGIA) annual report (SAGIA, 2005).

Saudi Arabia is home of twenty-two petrochemical complexes located in the two industrial cities Juabail and Yanbu. These complexes are owned by the Saudi Government and privet sector. Some complexes are joint venture between local and international investors. Saudi petrochemical production accounts for 8% of the world output and it is planned to reach 15% in 2015 (Al Mady 2004).

Petrochemical industry is one of the most important industries in Saudi Arabia. In 2005 SABIC alone had recorded profits of 19.2 billions Saudi riyals (SABIC, 2005). The average growth of the petrochemical industry in Saudi Arabia over the last five years is 58% (Ramady 2005). This growth comes as a response to global demand of petrochemicals. However, the increases in demand lead to expanding the existing plants and build new ones. For example SABIC has a series expansionary projects and new petrochemical complex like YANSAB and United.

Petrochemical projects associated with the production of petrochemical products such as intermediates, polyester, polyolefin and fertilizer. Those projects are highly technical in nature and frequently built by large, specialized industrial contracting firms that do both design and construction. Beside main process related projects there are many support projects that of less complexity and can be designed and constructed by the petrochemical company itself or by local contractors. In both cases, design services are required. Petrochemical projects just as other projects need to be executed as per the high quality specification, within budget and on time. Moreover, each petrochemical project is unique because for each petrochemical product, there are industrial codes and standards which control the design and construction of related petrochemical product. In addition, petrochemical projects are high technology project and most of the technologies are patented. These patents make the process of design and construction much complicated. This research attempts to identify and assess the design practices in SABIC and attempts to improve the current quality of design services practices provided by design management department (DMD).

1.1 Research objectives

The main objective of this research is to identify and assess the design practices in petrochemical industry in Saudi Arabia in general and in SABIC particular. This assessment attempts to improve current design practices. To achieving this objective, the following questions will be answered:

1. What is the best design practice applied in the international petrochemical firms?
2. What is the common design practice applied in Saudi petrochemical firms?
3. What is SABIC design practice for petrochemical projects?
4. How to measure the performance of design practice?
5. What is the role of local engineering firms in petrochemical projects?
6. How to improve the design services in petrochemical industry in Saudi Arabia.

1.2 Scope of the research

This study is limited to design practices performed in Saudi Basic Industrial Corporation (SABIC) by Design Management Department (DMD).

1.3 Significance of the research

The significance of this study stems from its nature since it is related to the petrochemical industry, which plays a very important role in the Saudi economy. Globally, the demand of petrochemical is increasing and Saudi Arabia is considered one of the top petrochemical suppliers source (RAMADY 2005). For this reason, petrochemical industry is expanding to meet the demand. An essential ingredient in meeting this demand is to expand existing plants and to build new ones. Constructing new petrochemical plants needs to be executed in very efficient manner to maximize the profit of the projects. Obviously, efficient construction depends on efficient design. As such, design plays an instrumental role to this critical industry.

2 LITERATURE REVIEW

2.1 General

Generally, design services for industrial projects are provided either by in-house engineering department or by professional A/E. As a regulation requirement, engineering services must be provided by approved licensed engineering firm. The Ministry of commerce and industry (MOCI) controls the industrial projects in the Saudi industrial cities and The Royal Commission for Jubail and Yanbu (RCJY) which established as an autonomous organization of the Saudi Government controls the industrial projects executed in Jubail and Yanbu industrial cities.

2.2 Characteristics of Petrochemical Project

Petrochemical firms are well organized and one of the most important departments is Engineering Department. Most of petrochemical firms have continuing construction projects either expansion or upgrading the existing facilities. Sometimes in-house design department capability is not enough to handle the projects due workload or due the complexity of the project. In this case, the owner outsources the engineering services. Outsourcing might by in form of manpower supply or as a contract with engineering firm (Clough and Sears, 1994).

The typical contracts types in petrochemical projects are: Engineering, Procurement and Construction (EPC), Engineering, Procurement, Construction and management (EPCM) and lump Sum Turn Key (LSTK). These types can be observed from reviewing the worldwide petrochemical projects profiles (Amison, 2005).

In EPC projects, there is one entity who is responsible to provide the engineering (basic design and detailed design), the materials and equipment, and the construction for the project. The attributes of EPC contract as the following:

- The owner signs a single contract with the CPM contractor like Bechtel or Technip for the delivery of the entire project.
- The design and construction are time overlapped where construction may begin before design is 100% complete.
- Procurement may begin prior to construction.
- Specifications are performance-based rather than prescriptive.
- Minimal owner involvement and decisions are required.
- Design and construction quality are controlled by the EPC Contractor.
- Costs are known once the EPC contract is awarded, and typically are fixed.

- Transfer of responsibility and most risk from the owner to the EPC contractor for the entire design and construction.
- Construction experience is integrated into the design process.

Other type of contract is EPCM where the contract includes the project management within the scope of the contractor. In LSTK there is little or no owner involvement in a project wherein the contractor essentially turns over the keys for the facility to the owner at the end of construction. In all EPC, EPCM and LSTK contracts, commissioning and startup are often included in the contractor's scope of work. (Masucci and Freidheim, 2005).

The history of petrochemical projects shows that, there are many players in petrochemical construction industry including owner, engineering firm, construction contractor, technology owner, licenser, vendor (material supplier) and project manger. Petrochemical projects started with the selected of the technology of producing the desired petrochemical product such as polyethylene or polypropylene for new plant projects. There are many agencies provide the different technologies to produce same product. The owner selects the appropriate technology based on his priorities and his ability. Technology owner may delegate the license to another agent. In this case project owner has to pay the licenser for using the technology. After the technology is selected and licensed, owner can selects the type of contract such as EPC, EPCM or LSTK to complete the project (Loudermilk and Stein, 2002).

2.3 Engineering services

Engineering services cover a wide range of services including design, project analysis and construction support services.

Project analysis services are those services related to the feasibility of the project. Feasibility study addresses the need of the proposed facility, the economic requirement, site accessibility, location suitability, legal requirement, operation manpower to operate the new facility, value engineering, disturbance of ongoing operations and market analysis. Project schedule is a major consideration in the project analysis since it needs to be selected in the right time to minimize shutdown time and disruption of ongoing production.

Project support services include bid evaluation, technical evaluation construction supervision, quantity survey, cost control and construction management.

2.4 Design and planning services

Design and planning services is the main function of engineering services. Developing design for a given project entails the preparation of the required engineering documents to build the project. Generally, the design package of petrochemical projects includes scope of work, drawings, specifications, required calculations, material needed, project cost estimate and hazard identification study. Design packages may include documents used for bidding and official communications (Clough and Sears, 1994).

Design Best Practice can be defined as a process or method that, when correctly executed, leads to enhanced system performance. Each firm has its own practices to develop the design works within the general agreed practice known in each industry. General agreed practices are issued by professional organizations such as the Construction Industrial Institute (CII), National Petrochemical and Refiners Association (NPRA) and American Chemical Society (ACS). However, there are different approaches to develop design services which vary from industry to another and from firm to another. Each industry has its norms and practices.

Generally, petrochemical design packages include project scope of work, specifications, design drawings, material required, cost estimate and process hazards analysis. Each of these items is explained below.

2.4.1 Scope of Work

Scope planning is "the processes of progressively elaborating and documenting the project works that produces the project" (PMBOK 2000, p.55). The scope statement forms the basis for an agreement of the project objectives and its deliverable.

Preparing scope of work is a crucial process because it impacts all later stages. In petrochemical projects the owner must define the scope of work precisely. Because vague scope of work leads to undesired results. For example, a vendor or a contractor may supply or construct something that owner does not need and may cost the owner unnecessarily.

The scope of required engineering services is subject to a considerable variation, depending on the needs and wishes of the owner. Basic to such services, are establishing the needs and desires of the owner, developing the design, preparing the documents required for contractor bidding or negotiation as well as for contract purposes, aiding in the selection of a contractor, and making an estimate of construction cost (Clough and Sears, 1994).

The scope of services provided to the owner by the designer during field construction depends on the needs and preferences of the owner. Responsibility of the designer to the owner may end when the contract documents are finalized and delivered. On the other hand, the owner may require full construction-phase services, including project inspection, the checking of shop drawings, the approval of periodic payments to the contractor, the issuance of a certificate of completion, and the processing of change orders. Although the designer is not a party to the usual construction contract between the owner and contractor, this contract often conveys certain powers to the designer such as the authority to decide contract interpretation questions, judge performance, reject defective work, and stop field operations under certain circumstances (Clough and Sears, 1994).

2.4.2 Design Drawings

Drawings are the most important part of the design package since they contain the major information needed for construction. Drawings show the location of the project site, location of existing utilities and access roads. In addition, drawings show the equipment layout and arrangement. Required quantities are usually shown in detailed drawings in addition to installation details. Contractors refer to the drawing most of the time during all project phases (Clough and Sears, 1994).

Drawings of any petrochemical plant undergo many changes due to the operation and maintenance activities. Typically this changes do not reflected in the existing drawings to form As Built drawings. The archived master drawings remained as it is without change. This action creates problems requiring long time and a lot of extra expanses. To avoid these problems, any petrochemical firm has to apply Engineering Drawings Update Program (EDUP). EDUP is a system to keep all important drawings updated due any change.

However, it is not feasible to update all drawings such as fabrication drawings and shop drawings. The critical and important drawings need to be updated such as Piping and Instrumentation Diagrams (P&ID), Process Flow Diagrams (PFD), design drawings (including location, equipment layout, plot plans and piping plans), electrical drawings (including Single line diagram, cable layout and schematics), underground facilities drawings, Area Classification drawings and equipment data sheets based on inspection records. The new change shall be highlighted by cloud or different pattern to be identified very clearly. Revision number must be shown with written description of the change to keep the record in the drawing itself (Goyal, 2002).

Vendors participate in the design process by supplying products data to the designer. Vendor data are the technical information provided prior to equipment delivery for the purpose of incorporation into design drawings and specifications. In some cases, the incorporation is made in as built drawing after the construction is completed. Vendor data can be a drawing, table, cross section or flow diagrams (Coucha and O'Connor 1996).

The computer production of construction design and drawings is now an important and growing area. Computer-assisted design and drafting (CAD) systems are now being used by engineers, owners, and contractors to design structures and produce finished, dimensioned working drawings for field construction use, a process that makes their operations much more productive and profitable. CAD systems facilitate the rapid development of the design and production of high-quality construction drawings that convey much more information than their manually created counterparts. With CAD the designer can draw, make changes, model, and experiment with speed, efficiency and precision. The most famous two CAD software used in the industry are AutoCad and MicroStation.

Electronic drawing makes the communication much easier especially in petrochemical industry where the designer office is apart from the owner office. Designer can send the design drawings to the owner for review and approval. Owner can review and comments the drawings and resend them back to the designer to issue final drawings.

CAD drawings can be continuously updated relative to changes and modifications made to plans and elevations. Many of these systems also determine the field quantities of work as the design proceeds, which make it possible for the designer to prepare a bill of materials for bidding purposes. Also available is software that generates isometric drawings from plot plan (ISOGEN). Advance CAD software has the capability to enhance all data required for the plant such as equipment data sheet and related calculations hyperlinked to the drawing (smartplant).

2.4.3 Specifications

Specifications describes in worlds of what is to be done and how it is to be installed. The term specifications refer to the description of a product or a method. Sometimes specifications refer to the complete design package that includes drawings and the written description bound in a book to supplement the drawings. The general practice is to refer to drawings as plans and to the book as the specifications (Clough and Sears, 1994).

Specifications are divided into three divisions: bidding documents, conditions and technical division. Bidding documents contains invitation to bid, instructions for bidders and proposal form. Conditions include the general and special conditions of the contract between the owner and construction contractor. Both bidding documents and conditions divisions are used for contracting management. Generally, both divisions are not changed except the special conditions are revised to suite each project. Depending on the owner policy's and rules, those two divisions may take different shapes. For public projects when the government manages the projects and the bidding is open for all qualified contracts to participate with same document format. In the case of petrochemical projects only few qualified contractors whose already familiar with owner's contracting system are bidding for the project. Thus, the bidding document and conditions can be customized.

Normally, big petrochemical organizations procurement department take care of bidding documents and conditions division. Contractors usually submit a prequalification to procurement department and if the contractor satisfies the minimum owner's requirements, the contractor is approved. Once a contractor is approved, he is eligible to be invited for bid. For that reason, approved contractors are aware about owner rules and conditions.

Technical division is purely engineering document. There is no unique method to write the technical specifications. However, there are six basic types of specifications: performance, description, brand name, closed, open and reference specifications. In addition, combination specification containing two or more type may be used in some cases (Clough and Sears, 1994).

Performance specification is one where the performance of the product rather than the product itself is specified. Example of performance specifications is when a pump is required for pumping 10 gallon per minute with 30 pound per square inch (PSI); motor power shall be five horsepower with 220 volts.

Descriptive specification is performance specification plus other criteria such as shape, size or color. In previous pump example, pump skid size or arrangement can be added to the specification to become descriptive specifications. Descriptive and performance specification are called open specifications.

Brand-name specification is where a specific product is specified by manufacturing name and model number. Brand-name specification is closed specifications. Although, in closed specification many brands may be specified as alternatives. In this case, the specification called multi-product specification. Also, this closed specifications can be made open by adding "or approved equal".

Reference specification is where the item desired is referred to by a number corresponding to a number in published specification. This type used when the owner print complete specifications on commonly used products. Usually this type used for specific owner projects only.

Combination of specifications types may be used in some cases. It used where a product is needed with specific mechanical characteristics and comply with certain standards. For example, a pump is needed with particular performance parameters plus compliance with API-610 (American Petroleum Institute, centrifugal pump standards).

In petrochemical projects, performance specifications are used most frequently. However, brand name specification is used too for two reasons: to match existing equipment and to reduce maintenance. Using same brand all over the plant leads to reduced spare parts inventory and maintenance effort. On the other hand using brand-name may cost the owner more since there are cheaper alternatives. Performance specification gives chance to select the best offer satisfying the requirement (Amison,2005).

Petrochemical processes are very advanced technology that innovated by a company or by research institute. The patent is issued for the innovator who may not involve in the marketing or business industry rather than research or producing. Therefore, innovator or patent holder firm may need a third party to market its innovation to the clients. In this case, the license is issued for the tired party who called the licenser. The new technology equipment is manufactured by approved manufacturer. Most of petrochemical process products market is monopoly market where unique product controlled by single firm (Amison,2005).

Consequently, project owner interference is very limited in process related projects and specification type is brand-name specification in this case. Usually owner is involved in utility and support projects where no patent or license available. For those projects, performance specifications can be used.

2.4.4 Cost Estimate

Cost estimate is part of engineering services. The cost estimate is an important document which assists in decision making and cost controlling processes. Cost estimate is defined as the technique that is followed in order to determine the amount in monetary terms necessary to undertake an activity. The determination accounts for materials, labor, equipment, and many other variables that affect conducting that activity. Owner figures out whether the available budget is enough to satisfy the project criteria or not after developing the feasibility estimate (Al-Thunaian, 1996).

A preliminary (Conceptual) estimate is developed as part of the project conceptual plan to set an approximate cost for the project. It is considered more sound than feasibility estimate and cost estimation methods such as range estimate, factor estimate, and parameter estimate are used. Detailed Estimate is developed for bidding purposes. It involves the development of quantity take-off, labor cost, equipment cost, and other cost affecting parameters. The owner may select to develop it in order to be able to compare and analyze bids (Al-Thunaian, 1996).

Detailed cost estimate is prepared after completing the detailed design. All required material is extracted from project drawings. Exact prices of equipment and installation can be taken directly from the vendors. Construction work cost can be estimated by using the previous similar project cost records (Al-Thunaian, 1996).

Economy theory of supply and demand states that, the price is affected by supplied and demanded quantities. For that reason and beside other reasons the prices are not fixed. Normally, each quotation has a validity period. The validity is varying from one month to three months. Price instability is a potential problem in cost control. The typical scenario is when the cost was estimate prepared based on a quotation and the purchasing of an equipment is made during construction at that time the prices has changed (Sturts and Griffis, 2005).

Contingency percentage is used to overcome prices variation problem. Contingency percentage depends on the organization cost policy and the nature of the products. Global economic stability leads to lower contingency percentage and vice versa.

Overhead costs (OH) are those charges that cannot be attributing exclusively to a single product or service or the costs that are not a component of actual construction work but incurred by the contractor to support the work. Overhead constitute very important portion of cost, which varies between 8% to 30% of material, labor, and equipment cost or 12% to 50% of labor cost. Because of this reason some of contractors who underestimate overhead lose their business (Assaf et al, 2001).

The best costing practice is to optimize (OH) level to accomplish its strategic goals at lowest possible general expense. Reasons why it is difficult to measure the effectiveness of OH costs includes:

- Uncertainty of defining the activities that generate OH cost.
- The importance of the indirect activities and its impact in the quality of the performance.
- Ambiguity of the cost of indirect activities.
- Defensive mechanism may occurred because of cutting OH cost.
- Lack of planning and determining the priorities.

In Saudi Arabia, the ratio of company OH cost to project direct cost on the average is about 13%, while the ratio of company OH cost to annual construction volume is 14.3 %. Causes of increased company OH cost include delayed payment, lack of new projects, cost of inflation and government regulations. Factors affecting Company OH costs are: automobile and equipment cost, head office expenses, labor related cost and financing cost (Assaf et al 2001).

In Saudi Arabia, most of engineering firms use budgetary quotations from vendors to complete the cost estimate. Big organizations such as Saudi Aramco and SABIC have their own material management system that provides latest prices of frequently used materials. In some mega projects the work involves repetitious activities such as providing communication towers a long a highway. Work activities are the same but the quantities vary for each location. In such case, designer predefines the work activities and asks contractors (on behalf of the owner) to bid for each activity. Once contractors submit their bids, the engineer evaluates these bids and hires the construction contractor. The contract is based on unit price and many contractors may be hired for same project. In this case the designer will determine the cost estimate after completing the design and preparing the required quantities for both material and labor by using the project cost index.

2.4.5 Process Hazard Analysis (PHA)

Petrochemicals by nature are potential for hazards since they are flammable, explosive and have toxic effects. Moreover, all petrochemicals operations are associated with high risk since all reactions take place in high pressure high temperature. For these reasons petrochemical process needs hazards analysis which formally known as process Hazards Analysis (PHA).

The main purpose of PHA is to identify high-risk hazards associated with a chemical process. Once the high-risk hazards have been identified, corrective action can then be taken either to eliminate them or to minimize their impact (Sutton 2003).

PHA has three goals: the first goal is to identify hazards, where a hazard is defined as the potential conditions that may cause a significant incident. The second goal is to identify the hazards that related to process. The third goal of a PHA analysis is to concentrate on high-risk hazards rather than high consequences (Sutton 2003).

The occupational Safety and Health Association (OSHA) provides an overview of the key PHA methodologies that include the following:

- Hazard and Operability Method (HAZOP)
- What-If
- Checklist
- What-If / Checklist
- Failure Modes and Effects Analysis (FMEA)
- Fault Tree Analysis
- Other Appropriate Methods (such as Monte Carlo Analysis)

None of the above methods is inherently better than any of the others. They all have their place, and are often used in combination with one another (Acutech 2006).

Generally, HAZOP method is the most rigorous and time consuming method. It is the most systematic and thorough type of PHA, the HAZOP technique is sometimes used simply to ensure maximum compliance with regulations, even though it may not be the best technical choice, and even though one of the other methods can be just as effective at finding the hazards in a particular situation. Frequently, company legal advisors recommend the use of HAZOP method because of its completeness and because of its acceptance by regulatory agencies (Acutech 2006).

HAZOP can be defined as "a structured and systematic examination of planned or existing process or operation in order to identify and evaluate problems that may represent risk to personnel or equipment or prevent efficient operation” (Acutech 2006, p 07.). Normally the HAZOP study is carried out when the detailed design has been completed. HAZOP recommendations and comments are incorporated to release the final design revision. The HAZOP is usually carried out as a final check. A HAZOP study may also be conducted on an existing facility to identify modifications that should be implemented to reduce risk and operability problems (Sutton 2003).

2.5 Quality Control Practices

Quality control is very essential issue in design process to deliver design output that meeting the project requirement in safe and economic manners. The quality control practices for petrochemical projects include total quality management and constructability.

2.5.1 Total Quality Management

Quality management system is very essential in the design process. The general practice of design quality management is to use total quality management TQM system. TQM is a structured approach used to improve the design quality. It is a continuous process to identifying owner's requirements and ensures that the owner is satisfied with design services provided. Whereas quality assurance is a systematic action taken to provide confidence that the completed design will satisfy owner's requirements (Bubshait and Al-Atiq, 1999).

ISO 9001(Quality Management Systems Requirements) is implemented by most of design firms to be quality assurance certified. ISO 9001 determine the quality management requirements, responsibilities, resource management, procedures, and monitoring that necessary to establish quality management system (ISO 9001, 2000).

Al-Abdurazzak prepared a study about quality management activates in design and construction (Al-Abdurazzak, 1993). In this study 29 quality management activates during the design phase are identified and ranked as shown in the table below. The ranking is based on a survey conducted for 38 Saudi design firms.

Table 1. Ranking of Quality Management Activities

Factor	Quality Management Activity	Overall Ranking
8	Drawing checks/Review	1
16	Functionality Review	
27	Provision of clear, concise and uniform plans and specifications	
9	Specification checks/Review	2
11	Review of client’s comments	
12	Review / check of standards	
14	Review/check of space allocation	
17	Capacity review	
22	Provision of technically qualified design team members	
23	Provision of cost estimate of the project	
2	Establishment of qualification parameters for persons whose activities affect the quality of work	3
7	Calculation checks of the design	
10	Formal drafting check/Review	
13	Review/check of regulations	
15	Review/check of aesthetics	
19	Frequent contacts between the project parties	

24	Submission of progress reports to the owner	
21	Communication to resolve conflicts	4
25	Standardization of office procedures	
18	Documentation of any documents related to the design team members	5
4	On the job training for employees	6
26	Office library facilities	
1	Definition of the interrelationship and responsibilities of the quality program management and direction	7
20	Communication program	8
3	Establishment of an incentive system to motivate persons to produce quality work	9
29	Arrangements for project peer review	10
5	Short courses for employees	
6	Seminars for employees	11
28	Arrangements for organizational peer review	

Source: Al-Abdurazzak,1993

Another study conducted by Farooq (1997) where he analyzed seventy quality statements measuring fifteen quality management areas. The summary of the importance of the fifteen quality areas and recommendations for their improvement are listed below. Quality areas are ranked as per their importance.

Table 2. Quality Mangaement Area Conclusions

S. No.	Quality Management Areas	Important Conclusions (Summarized)
1	Organizational Quality Policy	Need for more effort in establishing and updating the quality manual.
2	Designer Qualification	Strong need for establishment of a design code for Saudi Arabia.
3	Employee Training and Education	Second least prevalent QMA. High need for more job training and provision of short courses to train local workforce.
4	Design Planning	Need for more emphasis towards identifying design interfaces in preliminary design.
5	Design inputs	Slight need for identifying and defining responsibilities of transmission of design inputs.
6	Design Process	Need for more assignment of project work to a single team. Need for more trust and cooperation with contractor, to increase the prevalency of specifying important construction methods in design documents.
7	Interface Control	Need for greater interface control, and confirmation in writing of informally transmitted information between interfacing entities.
8	Design Review	The most prevalent QMA. A slight increase in the prevalency of aesthetic review is recommended.
9	Design Changes	The second most prevalent QMA.

10	Subcontractor Control	Very slight need for more emphasis in selecting and controlling subcontractor organizations.
11	Document Control	The third most prevalent QMA.
12	Design Maintainability	Slight need for ensuring ease of maintainability while specifying material in design documents.
13	Computer Usage	Need for more frequent use of CAD tools.
14	Working Relationship	Need for encouraging more client interaction. High need for building up more trust and cooperation with the contractor.
15	Performance Quality Audit	High need for end of the project studies for future reference. Urgent rectification of the current low prevalence of evaluation request from the client and the contractor at the end of the project.

Source: Farooq,1997

Generally, independent design offices or consultants at Saudi Arabia are ISO certified because it is one of the contracting requirements. However, in-house engineering departments are not certified or audited by external third party. Even, products of in-house engineering services are checked and certified by internal quality control team but it would it be same quality as the external auditor.

2.5.2 Constructability

Constructability can be considered as one of the quality management activities and can be included within TQM. Not applying constructability principles in design stage may lead to specification problems and unrealistic schedules that create significant difficulties that will face construction contractor. To apply constructability principles, coordinated efforts between owner, designer and construction contractor need to be made to achieve saving in cost and time of projects (Al-Yousef, 2001).

The Construction Industry Institute (CII) defines constructability as ‘‘the optimum use of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall objectives’’ (CII,1986, pp37). CII outlined the fundamentals of constructability as 17 principles that apply to four phases of a project: the conceptual planning, design, procurement, and field operations. These principles are listed below:

Conceptual Planning Phase

1. A formal constructability program is made an integral part of the project execution plans.
2. Early project planning actively involves construction knowledge and experience.
3. Construction personnel are involved in developing the project contracting strategy.
4. Project schedules are sensitive to construction requirements.

5. Basic design approaches consider major construction methods such as modularization or preassembly.
6. Site layouts promote efficient construction (e.g., adequate space for laydown and fabrication yards and efficient site access).
7. Project team participants responsible for constructability are identified early in the project.
8. Advanced information technologies such as 3D computer modeling or field notebook computers are applied.

Design and Procurement Phases

9. Design and procurement schedules are construction sensitive.
10. Designs are configured to enable efficient construction considering issues like simplicity, flexibility, sequencing of installation, and labor skill and availability.
11. Design elements are standardized including maximum use of manufacturers' standards and standardized components.
12. Construction efficiency is considered in specification development including prior review of specs by construction personnel.
13. Modular/preassembly designs are prepared to facilitate fabrication, transportation, and installation.
14. Designs promote construction accessibility of personnel, materials, and equipment.

15. Designs facilitate construction under adverse weather.
16. Design and construction sequencing facilitates system turnover and start-up.

Field Operations Phase

17. Innovative construction methods are used such as innovative sequencing of field tasks, or use of temporary construction systems, or innovative use of construction equipment.

Jergeas and Van der Put prepare a study about the benefits of constructability on construction projects (Jergeas et al, 2001). The study ends up with four recommendations to get the benefit of applying contractibility principles in a project.

1. Involve construction expertise in design process since the initial stages of design. Construction expertise should be the contractor who will be construction contractor otherwise third party will not pay enough attention to participate in a project which may be not responsible for execution of the project.
2. Enhance common objectives, share responsibilities, and trust between project planners, designers, and constructors that can be maintained over the long term by creating shared vision and commitment to the success of the project at the conceptual stage.

3. Change the traditional design-bid-build contracting method in favor of an approach that brings the construction contractor into the project from the very beginning before the design, specifications, and procurement strategy have been established. This requires developing close cooperation between all project participants, with each pooling their knowledge and their resources in a true partnership working as a team to achieve common success.
4. Commitment to try new approaches in the interest of achieving significant gains in project cost, schedule, performance, and safety.

2.6 Design Process Evaluation and Performance Measurement.

Design processes need to be evaluated to measure the performance efficiency. The objective of the evaluation is used to identify the strengths of design process and the weaknesses which need to be treated.

One workshop was hold at Western Michigan University (WMU) in July 2003 to create a performance measurement for the engineering performance process. Fourteen faculty members and administrators representing the major engineering disciplines (mechanical, electrical, civil and chemical) and non-technical disciplines were participated in this workshop. The team identified 10 attributes of a successful design process based on behaviors that should be exhibited by an engineer who is a successful designer. The attributes ranked as per it importance (1 is the most importance) as shown in the below table (Andrew et al., 2003).

Table 3. Performance Attrbutes for Engineering Design Process

Rank	Performance Area	Description
1	**Problem Definition:**	Interviewing client, needs analysis, identifying issues & constraints, developing specifications, define functions/uses, perception check
2	**Communication:**	Informing client/teammates, personal documentation, oral presentations, written reports, visual and graphic elements, professionalism
3	**Prior Knowledge:**	Locating & review available resources, applying existing knowledge/principles/solutions, evaluate external information, depth & breadth of internalized knowledge, identifying learning needs
4	**Divergent thinking:**	Brainstorming, generating alternative solutions, quantity, uniqueness, novelty, problem reformulation
5	**Solution Validation:**	Interpreting & mediating requirements, creating an appropriate test plan, measuring for success, satisfying societal requirements, upholding professional responsibilities, customer acceptance
6	**Decision Making:**	Inclusion of stakeholders, evaluating alternatives against criteria, justifying selection, cost-effectiveness, level of consensus obtained
7	**Create/follow plan:**	Tasks and milestones clearly defined, logical & organized plan/timetable, taking action, documentation of progress
8	**Professional Analysis:**	Appropriate tool selection, tool proficiency, parameter identification, system modeling, sensitivity analysis, estimating, experimenting, optimization
9	**Teamwork:**	Belonging, commitment, ownership, cooperation, performing within roles, managing conflicts, efficiently using/creating resources
10	**Iterating & Assessing:**	Ongoing, captures and applies lessons learned from prior iterations, assess solutions, assess process followed, oriented toward continuous improvement

Source: (Andrew et al., 2003)

The team ended up with two forms of evaluation engineering design process, one is performance chart form (Table-4) and the other one is weighted evaluation form (Table-5). For performance chart the performance descriptions are distributed into five skill level categories: Expert Designer, Senior Designer, Apprentice Designer, Intern and Trainee. Under each category of designer skills level there is an expected action or behavior matching with the level of skills for each task. The evaluator has to select the appropriate description of the designer or design team behavior to identify the skill level in each performance area (Kline et al.,2003).

For weighted evaluation form (Table-5), each task within performance areas has a weight factor based on its importance. The evaluator has to evaluate each task on a scale of 1 to 5 and multiply by weighted factor. The final score is used as indication of skills level of the designer or design team. The score rang is between 200 to 1000 points and each 200 points represent a level of skills (Kline et al.,2003).

Performance Chart form (Tabl-4) is difficult to use due to the complexity of vocabulary used in the description of activities. However, the weighted evaluation form is not accurate because the weighted factors may vary from evaluator to other depends on his priorities.

Table 4. Performance Chart for Design Process

Performer_____________ Assessor_________________ Date___________

Performance Activity:____

Performance Area	Trainee	Intern	Apprentice Designer	Senior Designer	Expert Designer
Problem Definition:					
Identify Needs	Perfunctory	Locked on one	Sees several	Ranked set	Contrasted set
Establish Requirements	Unsure of need	Sees the need	Defines some	Defines most	Paints big picture
Identify Constraints	Disregards	One at a time	Two at a time	Sensitive to all	Places all in system
Define Functions	Open-ended	Primary use	Secondary use	Multiple use	Customized multiple use
Perception Check	Plays role wanted	Does what told	Values the role	Fulfills the role	Facilitates inquiry
Prior Knowledge:					
Locate/review resources	Minimal Effort	Basics	readily available	Extensive in discipline	Extensive all disciplines
Use of Principles	Uses inappropriately	obvious	well-known	subtle & well-developed	essential & complete
Evaluate external info	Seldom evaluates	Often misuses	approved by others	Critically evaluates	Correctly evaluates
Internalized knowledge	Superficial	Partial	Adequate	Extensive	Nationally recognized
Professional Growth	Only when forced	When challenged	reactive	Proactive	Continuous
Divergent Thinking:					
Quantity	Few	Some	Several	Large	Extensive
Distinctively unique	Couple	Few	Some	Several	Large
Out of the norm	Rarely	Seldom	Often	Couple	Several
Causes redefinition	Rarely	Seldom	Occasionally	Often	Couple
Out of the box	Improbably	Rarely	Occasionally	Often	Consistently
Professional Analysis:					
Uses key parameters	Limited/Many Extra	Some/Few Extra	Nearly all/Often Extra	All/Rarely Extra	Right on
Toolbox/usage	Small/Ineffectual	Limited/Basic	Standard/Marginal	Comprehensive/effective	Tool builder/master
Estimating	Way off	Sporadic accuracy	Consistently in ballpark	Consistently close	Intuitively correct
Experimenting	Random trials	Uses given experiments	Adapts experiments	Designs experiments	Creative experiments
System modeling	Simplistic	Bare bones	Nearly complete	Deals with boundaries	Integrates other models
Decision Making:					
Includes stakeholders	Unaware who they are	Incorporates obvious	Knows them all	Accounts for all	Takes every perspective
Consensus	Rarely	Seldom	Occasionally	Often	Consistently
Cost-Effective	Oblivious	Not under control	Reasonable	Consistently controlled	Very efficient
Uses design criteria	Sporadically	Minimally	Periodically	Frequently	Consistently
Justification	Randomly	Occasionally	Dependably	Frequently	Always

Performance Area	Trainee	Intern	Apprentice Designer	Senior Designer	Expert Designer
Create and Follow Plan					
Defines tasks Outlines milestones	Sporadic Unaware	Rudimentary Short Range	Contributes Executes	Thoughtful Modifies	Visionary Originates
Organized & logical	Confusing	Scattered	Mechanical	Solid	Directs
Track & revise plan	Disjointed	Passive	Supports	Implement Change	Assesses
Document Progress	Incoherent	Perfunctory	Methodical	Complete	Comprehensive
Iterate & Assess:					
Frequency	Sporadic	Methodical	Consistent	Continuous	Parallel Processing
Review previous cycles	Seldom	Most Recent	Tries to extend	Captures most	Integrates all
Assess design process	Only moves forward	After big steps	At trouble steps	After all steps	Continuously
Assess design solutions	Only when caught	When things go wrong	When uncomfortable	When substandard	To optimize
Effective iteration	Haphazard	When required	In obvious situations	Purposefully	For significant value
Validate Solutions:					
Interpret Requirements	Oblivious	Knows obvious ones	Knows them all	Meets them all	Exceeds them all
Mediate Requirements	Unaware of conflict	Minimal help	Can be helpful	Fairly effective	Leaves all satisfied
Build Test Plan	Attempts	Sketchy	Plan with holes	Solid	Elegant
Test against criteria	Erratic	Incomplete	Inconclusive	Conclusive	High reliability
Stakeholder acceptance	Unaware of need	Tries to achieve	Helps to achieve	Significantly contributes	Assures
Communication:					
Written reports	Unintelligible	Superficial	Mechanical	Informative	Comprehensive
Oral communication	Often Incoherent	Inconsistent	Transmits	Purposeful	Persuasive
Project documentation	When dictated	Personally useful	Limited audience	Substantive	Thorough
Visuals & graphics	Confusing	Elementary	Supportive	Illustrative	Interpretive
Professionalism	Unaware	Uncomfortable	Attempts	Consistent	Polished
Teamwork:					
Use of resources	Minimal	Responds	Requests	Seeks out	Gets the best
Managing conflicts	Potential troublemaker	Silent observer	Part of solution	Steps in to resolve	Learning experience
Shared Consensus	Not on board	Willing to go along	Sees the vision	Acts on vision	Shapes vision
Belonging/Commitment	Erratic	Compliant	Sees benefits	Enrolled	Committed
Performing Roles	Plays role wanted	Does what told	Values the role	Fulfils the role	Facilitates all roles
Comments					

Source: Andrew et al, 2003

Table 5. Design Process Weighted Evaluation Form

Performer_________________ Evaluator_________________ Date________

Performance Task:____

Performance Area	Raw Score	Weight	Adjusted Score	Performance Area	Raw Score	Weight	Adjusted Score
Problem Definition				**Create and Follow plan**			
Identify needs		**9**		Defines tasks		**3**	
Establish requirements		**7**		Outlines milestones		**3**	
Identify Constraints		**7**		Organized & logical		**3**	
Define Functions/uses		**7**		Track & revise plan		**3**	
Perception Check		**5**		Document progress		**3**	
Applying Prior Knowledge:				**Iterating and Assessing**			
Locate/Review resources		**5**		Frequency		**2**	
Use of principles		**5**		Review previous cycles		**3**	
Evaluate external info		**3**		Assess design process		**3**	
Internalized knowledge		**4**		Assess design solutions		**3**	
Professional growth		**3**		Effective iteration		**4**	
Divergent Thinking:				**Solution Validation:**			
Quantity		**2**		Interpret requirements		**2**	
Distinctively unique		**5**		Mediate requirements		**2**	
Out of the norm		**5**		Build test plan		**2**	
Causes redefinition		**4**		Test against criteria		**2**	
Out of the box		**4**		Stakeholder acceptance		**2**	
Professional Analysis:				**Communication:**			
Uses key parameters		**3**		Written reports		**6**	
Toolbox/usage		**3**		Oral communication		**6**	
Estimating		**5**		Project documentation		**6**	
Experimenting		**5**		Visuals & Graphics		**2**	
System modeling		**4**		Professionalism		**5**	
Decision Making:				**Teamwork:**			
Inclusion of stakeholders		**4**		Use of resources		**3**	
Consensus		**4**		Managing conflicts		**4**	
Cost-effective		**4**		Shared consensus		**5**	
Uses design criteria		**4**		Belonging/commitment		**5**	
Justification		**4**		Performing roles		**3**	

Subscore___________ **Subscore**_____________

Total Score________________

Source: Andrew et al, 2003

2.7 Engineering services cost

Engineering services pricing is not easy job. Expertise, creativity and quality are difficult to quantify. However, there are some methods used to develop prices for engineering services. These methods are percentage of construction cost, multiple of salary cost, multiple of salary cost plus non-salary expense, fixed lump-sum fee, total expense plus professional fee and man-hour charge (Bubshait et al, 1998).

In Saudi Arabia, the common method is man-hour rate. Engineering firms estimate the required total man-hours to complete the job. Total man-hours are categorized into engineers, draftsmen/designers, project support and project management. For each category, there is an agreed rate. Depends on job title and nationality the man-hour rate is determined. Job titles are allocated as per personnel knowledge and experience. Saudi Engineering Council proposed four categories of engineers: engineer, associated engineer, professional engineer and consultant. The total cost of design services is the multiple of number of required man-hour and its rate for each category (Bubshait et al, 1998)..

The other common method used is a lump sum fee where the designer receives a fixed lump sum amount for the complete services. In the case of in-house design service, the cost is determined usually by using man-hour method to control project cost and monitoring the quality.

As per a study conducted by Saudi Council of Engineers, the maximum design fee in Saudi Arabia is 2.5% of total construction cost and accounting for 45 to 48 billions annually. Whereas the design cost reaches to 7% of construction cost in other GCC countries (Faden 2004).

Experience and qualifications of design firm are the most important factors effecting the engineering services cost. Expert engineers with high level of design qualifications produce high quality design services that satisfy the owner requirements. Consequently, high quality design services cost high rate (Bubshait et al, 1998).

2.8 Local Engineering Firms Role in Petrochemical Industry

There are 1400 engineering firms licensed in Saudi Arabia (Faden 2004). Most of these firms work in municipal, commercial and residential industries. Only 5% of engineering firms are handing the industrial projects (Al-Musallami, 1992). This low percentage of participation in industrial project is due the special requirement of industrial projects. Most of the local engineering firms are lacking of the experience and knowledge to handle the industrial project. Some of the local engineering firms establish a joint venture with a foreign engineering to get an access to the industrial projects. Also, local engineering firms as small entities are receiving technical and financial support from both public and private industrial sectors. For example Saudi Aramco and Royal Commission are developing the local engineering firms by direct and indirect educational programs and on job training program for their design contractors to improve their design capability (Ramady,2003). The role of local engineering firms in petrochemical industry is minor due to their limited capability.

2.9 Previous studies

Most of the previous studies in the design services in Saudi Arabia were focused on building projects and none was for industrial projects.

Al-Musallami (1992) made a study titled "Owner satisfaction with consultancy practices in Saudi Arabia". This study discussed the relationship between public owner and local A/E firms in Saudi Arabia. This study attempted to find how local A/E firms are fulfilling the owner's requirements and to what level public owners are satisfied with the provided services. The study proposed four criteria for judging the overall satisfaction: function, aesthetics, cost effectiveness and constructability. This study concluded that the level of public satisfaction is moderate due some problems caused by A/E. The most important problem is faulty design that causes high number of change orders. A/Es are not satisfied with low owner involvement in the design process and with owner under perception for A/E role in the project that consequently reflect the low payment of design services. The author recommended the following actions to overcome problems between public owners and the A/E:

1. The owner should state the needed scope of work very clearly
2. Constructability and design review should be done to avoid faulty design and associated delays and cost over run.
3. Increase communication and owner involvement during the design process.

Al-Basher (1998) in his study titled consultant selection in Saudi Arabia stated in his study, the owner need constant, comprehensive and flexible methodology criteria for the selection of a consultant. Thirteen criteria were identified and ranked in accordance to the views of the owners and the consultants as shown in Table-6. The ranked list of A/E criteria forms a solid tool for selecting the most appropriate A/E firm to perform the required services.

Table 6. A/E Selection Criteria as Ranked by Public Sector and Consultants.

Ranking by Public Sector	The A/E Selection Criteria Description	Ranking by Consultants
1	Staff and Qualifications	4
2	Experience	1
3	Quality Performance	3
4	project Management Capability	8
5	Past Performance	6
6	Quality Control	5
7	References	2
8	Current Work Load	7
9	Firm Organization	10
10	Firm Capacity	12
11	Economical Constraints	9
12	Experience in Geographic Location	11
13	Head Office Location	13

Source: Al-Basher, 1998

3 METHODOLOGY

3.1 Required data

The required data for this research can be summarized as:

1. Characteristics of Petrochemical projects.
2. Best design practices for petrochemical projects applied by international petrochemical firms.
3. SABIC design practices.
4. Local engineering firms role in design services for the petrochemical industry.

3.2 Data collection

The required data will be collected from two main sources: literatures and interviews. Literatures include design procedure and guides prepared by petrochemical organizations. Interviews will be made with key personnel involved in engineering services in SABIC and with Design Management Clients (SABIC Affiliates) project engineers.

3.3 Data analysis

The collected data from both literatures and interviews will be analyzed to measure the efficiency of petrochemical design practices applied in SABIC. Affiliates satisfaction will be taken as a measurement of success of design management at SABIC. Analysis is aimed to make recommendations to improve the design practices in SABIC.

4 SABIC ORGANIZATION AND MANAGEMENT

4.1 General

The Saudi Basic Industries Corporation (SABIC) was established pursuant to Royal Decree No. M 66 dated 13/9/1396H (corresponding to September 6, 1976). The idea behind SABIC was to utilize natural gas associated with crude oil. The principal purposes of Saudi Basic Industries Corporation (SABIC) and its affiliates include, among other things, the setting up, operating and marketing of petrochemicals, fertilizer, iron and steel, aluminum and other hydrocarbon based industries in Saudi Arabia.

SABIC is owned by the Saudi Government (70%) and private investors (30%). SABIC owns more than 22 petrochemical and metal complexes in Saudi Arabia, Europe and Asia. Four complexes are owned wholly by SABIC and the others are joint ventures with local and international investors such as ExxonMobil and Shell.

4.2 SABIC Organization

Since 1976, SABIC was acting as the owner for its affiliates only, management of each affiliate has no direct relation with other SABIC affiliate. In September 2002, SABIC reorganized its affiliates, and got more involved in their management and control. SABIC had been divided into six Strategic Business Units (SBU) as following:

1. Basic Chemicals
2. Intermediates
3. Polyolefins
4. PVC and Polyester
5. Fertilizers
6. Metals

Most of SABIC affiliates in Saudi Arabia are based in the Al-Jubail Industrial City on the Arabian Gulf. Two are located in Yanbu Industrial City on the Red Sea and one in Eastern Province city of Dammam. SABIC affiliates are distributed among the SBUs as per the below table.

Table 7, SABIC's Strategic Business Units and Affiliates

Basic Chemicals	Intermediates	Polyolefins	PVC & Polyester	Fertilizers	Metals
PETROKEMYA IBN SINA AR RAZI UNITED SADAF GPIS	SHARQ GAS	IBN ZAHR YANSAB KEMYA YNBET	IBN HAYYAN IBN RUSHD TAYF	AL BAYROUNI IBN AL BYTAR SAFCO	HADDED JAMCO ALBA

Beside the six SBUs, there are four corporate departments consisting of Corporate Finance; Corporate Human Resources; Corporate Control and Research and Technology (R&T) support the SBUs in their sectors. A new feature is the creation of a Shared Services organization (SSO) which operated in 2003 to provide a range of common services to all Strategic Business Units and Corporations.

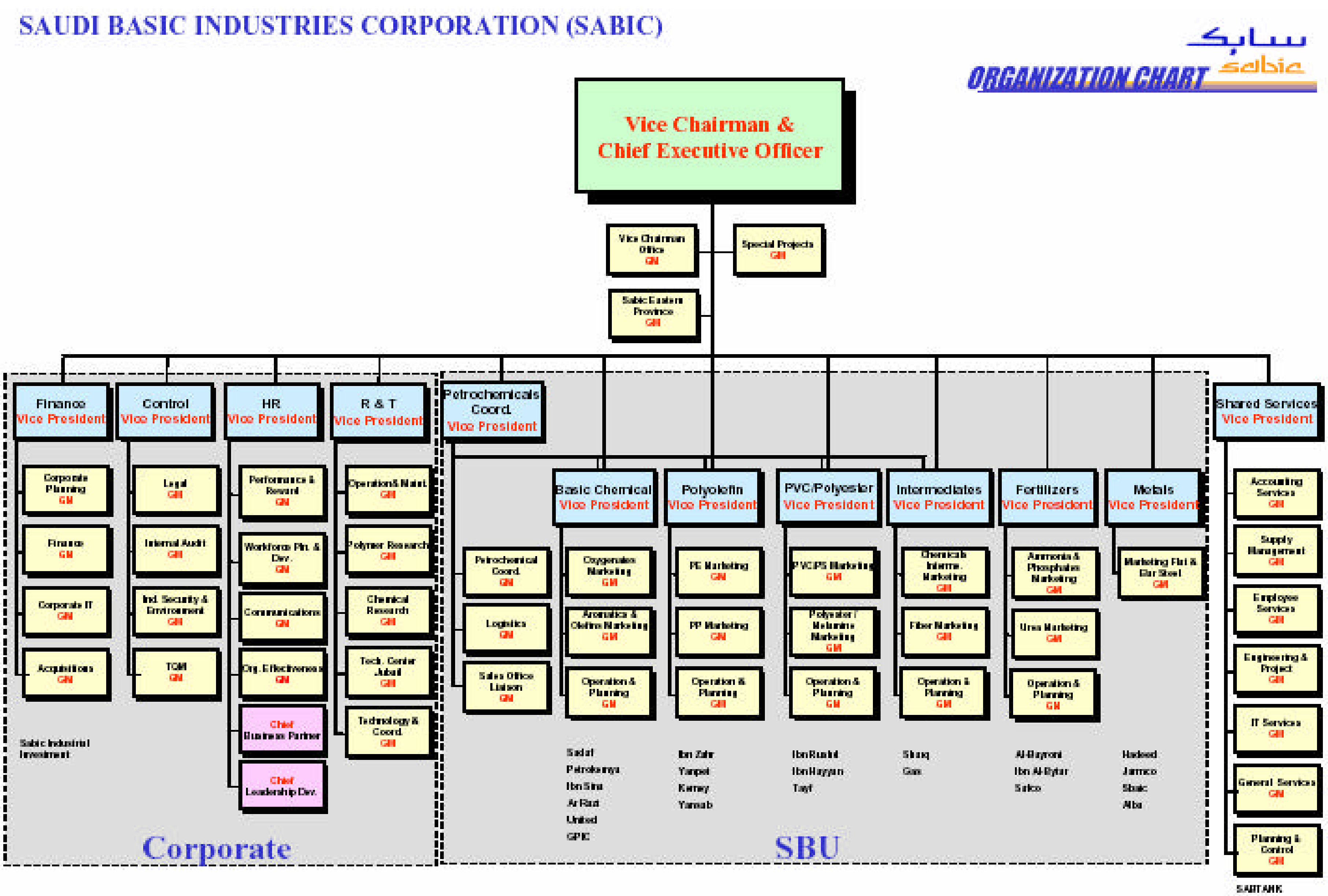

Figure 1. SABIC Organization Chart

4.3 Shared Services Organization (SSO)

In 2003, SABIC formed a Shared Services Organization to provide complementary services between SABIC and its affiliates and to help SABIC achieves its strategic objectives through increased efficiency and efficient utilization of available resources. Shared Services Organization was established in order to provide for best utilization of resources and to centralize the managerial services for all SABIC affiliates. SSO covers seven areas:

1. Information Technology (IT),
2. Accounting.
3. Employment services.
4. General services.
5. Supply management (procurement).
6. Planning and controlling.
7. Engineering and Project Management.

This report is concern about design practices performed by Design management Department which is one division of Engineering and Project Management. For that reason, only Engineering and Project Management is elaborated in next section.

4.4 Engineering and Project Management

Engineering and project management is one of shared services organization (SSO) its function is to provide effective quality project management, effective process engineering, project support and engineering expertise services to all SABIC affiliates. Engineering and Project Management includes four departments: Engineering Department, Project Department, Site Project Management and Design Management Department. The function of each of these departments is described below.

4.4.1 Engineering Department

Engineering Department (ED) function is to prepare and control the required standards and to provide technical support for all affiliates. Standards services include safe working procedures and best quality processes, evaluation services including plant assessment/Technical Benchmarking reviews as well as Quality, Health, Safety and Environment reviews. Specialized technical supports are provided for plants, equipment improvements, troubleshooting services, as well as generalized expert technical support for electrical, mechanical, instrumentation and control systems. ED consists of five sections:

1. Process & process safety engineering section
2. Electrical & process control engineering section
3. Mechanical & civil engineering section
4. Codes & standards section
5. Quality assurance & inspection section

4.4.2 Project Department

Project management (PD) function is to manage the construction of the mega projects (more than SR 50 million). For each mega project there is a project manger assigned by the PD Manager to manage the project. PD provides all project support services from initial stages till the acceptance by the owner and close out the project including review design packages, procurement equipment and material for construction, review the equipment specifications, coordinate between affiliate and contractors, testing and inspection, commissioning and project closeout.

4.4.3 Site Project Department

The main function of Site Project Department (SPD) is to mange affiliate projects (Site Project) where the budget is more than two millions and less than fifty million Saudi Riyals. Project management includes project execution, support services starting from conceptual design to construction supervision and project tracking. Support services during the completion phase of the project including mechanical completion and close-out, pre-commissioning and all relevant documentation.

4.4.4 Design Management Department

Design Management Department (DMD) includes three sections: mechanical and civil section, electrical and instrumentation section and CAD section. Services provided by DMD are varies from conceptual design to detailed design. Conceptual Engineering or advisory support services at the early stages of a project, including cost estimation, conceptual design, site availability, logistics, synergy with other plants, accessibility of raw materials.

DMD service includes also project planning services such as cost estimation, resource and material planning, project execution plan, scheduling, basic design package preparation and invitation to bidding (ITB) documentation.

Another main function of DMD is drafting and drawing services (CAD services) for either projects or separate requests from affiliates. Drafting services are including confirming and indexing AS BUILT drawings and other existing document into Electronic Document Management System (EDMS).

4.5 A Comparison of Old and New Organization

4.5.1 Old Organization

Before establishing the strategic Business Units in 2002, SABIC was acting only as the owner representing the Saudi Government with limited role of handling trading, marketing and legal matters between SABIC affiliates and its customers. Every affiliate was operated and managed by its own management.

For projects and engineering services each affiliate had its own method and policies in project management and design practices due to its products characteristics and Non-SABIC owner interfere in the management of the company. Generally in each affiliate, engineering projects were divided into two categories; modification projects and new projects. New projects such as construction of a new plant, expanding an existing plant or any project exceeding five millions Saudi Riyals. This type of projects is handled by an integrated project management team (within the affiliate) that responsible for preparation the feasibility studies of the projects and invitation to bidding (ITB) package.

Engineering department deals with the modification projects. A modification project starts by an engineering work request raised from the operation department (end user). This request briefly describes the problem supported with existing drawings, related data sheets and sketches for new arrangement. Engineering department receives the request and the manger forms a project team. Depending on the nature of the project and its dominant activities, the project leader will be assigned. For example, in piping projects a piping engineer or a mechanical engineer will be assigned as project leader. Project leader role is to coordinate between all disciplines participated in the project to complete the project.

The design process starts with a kick-off meeting between the engineering team and the operation department (owner of the project). The main purpose of the meeting is to ensure a clear understanding for the project and to finalize the scope of work.

Design starts after ensuring the scope of work from the owner. Design is prepared as per applicable standards for simple and routine projects. After the design is completed by all discipline, the package is reviewed by senior project engineers. Then the package is sent to owner for his comments. In addition a copy of the design package is forwarded to process engineering department to review the package from safety and environment points of views (HSE review). Process engineering department role is to decide either hazard and operability analysis (HAZOP) study is required or process safety review is required to be papered for the project. Moreover, construction department is reviewing the package considering the constructability and capability of in-house construction section to execute the project.

Engineering department incorporate received comment from all departments and issue final package accordingly. General Manager approved the design package after checking that all comments have been incorporated. If the in-house construction section can execute the project, the package will sent to maintenance department to start the construction. Otherwise, the package will be sent to procurement department to invite contractors to bid for the project. Depends on project size, the number of invited contractors is decided. Usually for small job (less than one million) only one contractor is invited to bid. Biddings are evaluated and the lesser one is the winner one.

However, process project that involve highly technical processes usually it require permission from the licenser. In such cases the project is handed over completely to the licenser on a lump sum basis. Lump sum basis or (engineering, procurement and construction (EPC) basis is used also when engineering department overloaded by other projects due either the shortage of engineers or time constrains to meet a certain schedule.

4.5.2 The New Organization

After Engineering and Project Management (E&PM) has been evolved, engineering projects are handled completely by SABIC E&PM. new SABIC projects are classified into three groups:

1. Engineering Notifications where the budget less than two millions Saudi Riyals. This type of project can be handled by affiliate engineer department without referring to E&PM.
2. Site Projects where the budget is more than two million Riyals but less than fifty Million Saudi Riyals. This type is handled by two departments of E&PM, Design Management Department (DMD) and Site Project department (SPD).
3. Mega Projects where the budget is more than fifty million Saudi Riyals. This type of projects is handled by another two departments of E&PM, Engineering Department (ED) and Project Department (PD).

According to E&PM procedures, each project has to pass through six phases or gates as listed below:

1. Gate-1: Concept and pre-feasibility
2. Gate-2: Feasibility and Venture philosophy
3. Gate-3: Project Strategy and execution plan
4. Gate-4: Detailed Design
5. Gate-5: Construction
6. Gate-6: Close up and Re-Appraisal

Gate-1 is initiated by the end user (affiliate) in consultation with the Site Project Department (SPD) where the conceptual design package (CDP) is produced by both affiliate engineer and site project engineer. CDP is forwarded to the Design Management Department (DMD) to prepare a Front End Engineering Package (FEEP) which is Gate-2. After FEEP is made, DMD forwards it to SPM to submit to the affiliate's management in order to study and approve the project strategies and execution plan (Gate-3). Once Gate-3 is approved by the affiliate, detailed design is prepared either by DMD or by Design Office (Gate-4). DMD prepares the construction package along with contracting document to start the construction (Gate-5). After construction is completed SPD and the concerned affiliate inspect the facility. Once the affiliate is satisfied with new facility, the project is closed out by issuing a mechanical completion certificate (MCC) by SPD.

As described above the six projects phases are distributed between SPM and DMD. Since this study focuses on design practices, only the related functions (phases) carried out by DMD is discussed. These phases include Feasibility and Venture Philosophy (Gate-2), Detailed Design (Gate-4) and construction support during the Construction phase (Gate-5). For Gate-2, DMD prepares the Front End Engineering Package (FEEP) and for Gate-4 DMD prepares Detailed Engineering Package (DEP). In some cases DMD provides construction support services like bid evaluation, witnessing tests and inspections. Chapter-5 discusses the DMD role in site project and design practices.

5 DESIGN PRACTICES AT SABIC

Design practices at SABIC includes the engineering process for preparation the basic design and detail design packages. Design package consist of engineering drawings, calculation, technical specification, cost estimate, schedule and list of project materials.

5.1 Front End Engineering Package (FEEP)

Front End Engineering Package (FEEP) or some times called Front End Engineering Design (FEED) consist of a basic design that includes a feasibility study, design alternatives, funds, cost estimate and execution strategies.

5.1.1 General

At SABIC the FEEP is a conceptual design package with feasibility study. It covers and describes the following items:

1. Project Summary
2. Scope of Work
3. Applicable Codes and Standards
4. Responsibilities
5. Safety Requirements
6. Material

7. Execution strategy
8. Cost Estimates
9. Project Planning and Scheduling

5.1.2 Work flow

The initial stage of any project starts with an idea in the owner mind. Site Projects varies in size, type, scope, and other characteristics depending on the idea behind the project. Some projects are replacement of existing obsolete system by new one. Other projects are modifications of an existing system to meet new requirements. Normally, the project initiator is the end user of the facility like the operation department. An affiliate engineer (end user) develops a conceptual design package (CDP) which includes a brief description of the project supported by drawings and sketches.

The CDP, after getting approved by the affiliate, is forward to the Site Project Engineer (SPE) who is located in the affiliate offices for easy communication. Then SPE forwards the CDP to the Lead Project Engineer (LPE). LPE receives the CDP and register it in the Access Software for monitoring and tracking the projects. Then LPE forms the design team comprising of Discipline Design Engineers, Designers /CAD Operators. Depending on major discipline involved, the LPE assigns one of the Engineers of that discipline to co-ordinate design activities and related issues. The LPE reviews the CDP and distributes a copy to the Design Team members for review and comments. LPE forwards all comments and unclear points to SPE requesting to organize a kick off meeting and site visit with the Affiliate Engineers. The design team evaluates the project execution strategy either EPC basis or conventional (FEEP/DE) route, and share the approach with the participants of kick-off meeting. In general, vendor driven or licensor driven projects will be considered as EPC project.

The LPE along with the assigned design team participate in kick- off meeting, clarifying all concerns, fix the project scope and finalize the execution strategy. All issues, requiring further clarification are considered as part of the minutes of meeting with a target closing date. Depending on the nature of un-clarified issues, a joint understanding is made, during course of kick off meeting, whether to commence the FEEP preparation or wait till the un-clarified issues are resolved.

LPE and SPE follow up to close all action items of the minutes of meeting as per agreed date. Immediately after closing of minutes of meeting action items, LPE, with the consultation of the Design Team members estimate the required man-hours to complete the FEEP. LPE forwards the estimated man-hours to the SPE to sign-off. After fixing of the scope, closing of the CDP clarification comments, and receiving SPE consent on FEEP man-hours and its submission date, the LPE advices the Design Team to commence the FEEP preparation.

FEEP includes project summary, scope of work for each discipline, responsibilities for each party, project cost estimate, project plan and schedule, design basis and applicable standards, required material and execution strategy. The design team completes the FEEP to form 90% package, and forwards to the technical Assurance Team (TAT). TAT reviews the 90% FEEP and signs –off after incorporating all the comments of design team. LPE issues the approved 90% FEEP to the SPE to review and forward to the Affiliate for its review and comments. The Affiliate review includes Process Hazardous Analysis (PHA) / Hazard and Operability study (HAZOP) if required. Upon receiving comments from SPE, the Design Team incorporates applicable comments and revises the FEEP to form 100% package. The Technical Assurance Team reviews the 100% FEEP and signs-off. LPE ensures completeness of 100% FEEP and forwards to DMD Section Head for approval. Then LPE issues the approved 100% FEEP to SPE to apply for Gate-3 approval (Project Strategy and Execution Plan).

5.1.3 Scope of Work

In petrochemical projects generally, there are five engineering disciplines involved in the design including process, mechanical, electrical, civil and instrumentation. Though these disciplines are interconnected the scope of work for each discipline is listed separately.

Site project is initiated either to modify the existing system to meet new requirements or to solve a problem facing the plant. For example recently the Royal Commission imposed new environmental requirements that control the plants emissions and waste disposal system. Consequently, all affiliates shall response to this new requirement and initiate projects to meet the new requirement.

For example, in case of high emission boilers, low emission burners need to be replaced the existing ones. So, the scope of work is to replace the existing burner by new burner with low emission. Compatibility of the new burners with the remaining system need to be checked and confirmed by burner supplier. In most cases, suppliers don't recommend to use the existing auxiliary system such as attached piping and electrical cable. The scope of work is usually determined after vendor analysis is conducted to ascertain the compatibility of proposed new system with other existing systems. The design engineer has to verify and finalizes the proposed scope of work.

5.1.4 Codes and Standards

"A standard is a set of specifications for parts, material or processes intended to achieve uniformity, efficiency and a specified quality" (Edward 1997 Page No.10). The main important purpose of a standard is to place a limit on the number of item in the specifications so as to provide a reasonable inventory of tooling, sizes, design shapes and varieties. "A code is a set of specifications for the analysis, design, manufacture and construction of something" (Edward 1997 p.10). The purpose of a code is to achieve a specified degree of safety, efficiency and performance or quality. Standards and codes are completing each other as guidelines for the proper design. (Edward 1997, p.10)

There are many international organizations and societies concerned with and issue standards for different fields. The organizations of interest to petrochemical projects are:

American Society of Mechanical Engineer (ASME)

American Society of Testing and Material (ASTM)

American Petroleum Institute (API)

American Welding Society (AWS)

National Fire Protection Association (NFPA)

Underwriters Laboratories (UL)

Uniform Mechanical Code (UMC)

Uniform Building Code (UBC)

Uniform Plumbing Code (UPC)

Process Industry Practices (PIP)

Institute of Electrical and Electronics Engineers (IEEE)

International Electrotechnical Commission (IEC)

General Telephone and Electronics (GTE)

Electronic Industries Association (EIA)

American Society of Civil Engineers (ASCE)

American Institute of Steel Construction (AISC)

International Maritime Organization Standards (IMOS)

However, international standards and codes need to be slightly modified to meet the local requirements because international standards and codes ware prepared to meet US or Europe requirements. For Saudi Arabia and particularly SABIC, there is some deviation from the original standards. These deviations are related to the geographical location and natural environment such as ambient temperature and wind speed etc.

Each SABIC affiliate had its own standard. E&PM, Engineering Department (ED) create a common standard for all its affiliates. In the same time the old individual standards are still used to keep the uniformity in each plant. New SABIC Standards are applied only for new mega projects. Once conflict between standards occurred, SABIC has to decide which code to be followed.

5.1.5 Safety Requirement

Manufacturing and handling Petrochemicals are of serious health, safety and environment concerns. These concerns drive more safety requirements to avoid accidents and provide more preventive measures. For that reason all safety issues are addressed in this section of FEEP. PHA and HAZOP requirement usually addressed if required.

HAZOP study is made in seek of preventing any hazardous and potential of accidents. HAZOP Study at SABIC is completed in two stages. The first stage is start with preparing of the FEEP during Gate-2 and the other stage is start after completing Gate-4 (Detail Design). PHA and HAZOP are conducted by HAZOP teat that already formed in each affiliate. The typical HAZOP team members are:

1. Team leader (usually from Affiliate Operation)
2. Secretary
3. Project engineer(SPM)
4. Process engineer
5. Control and instrumentation engineer
6. Safety engineer
7. Operation specialist

5.1.6 Materials

Materials are categories into two groups: material take off (MTO) and long lead items. MTO lists the required materials that are generally supplied by the construction contractor. These materials are shelve-material which are available most of the time without special order. The delivery of these items usually takes from four weeks to six weeks.

Long lead items are these materials which need special order. Technical requisitions attached with the FEEP are usually used for purchasing the required long lead items. Delivery time of long lead items plays an important role in project time. Most of the long lead items are manufactured in Europe or America and their delivery time takes from six months to more than one year. Because of this, long lead items are made in a separate list to start ordering and purchasing process as early as possible.

Long lead items need to be specified very clearly. A separate technical requisition is made for each item contains the specification, equipment data sheet, deliverables and attachment.

The specifications used are usually performance type, unless the affiliate recommends a specific brand name to match the existing brand that available in the plant for easy maintenance. The specifications describe the minimum technical and safety requirement as per applicable industrial codes and SABIC requirements. Applicable codes and standards are listed in the specification.

There is a data sheet for each equipment which includes: purchasers reference, services of the equipment, site condition, operation conditions, performance data, construction and material data, inspection and test specifications. Data sheets are filled by three parties: the design engineer, the process engineer (affiliate) and the vendor. Usually design and process parts are filled during the FEEP. Vendor part is filled after the purchase order is issue and equipment selected.

Deliverables is the list of requirements that the Vendor is required to submit along with long lead item. A typical list of deliverables is: vendor data sheet, equipment detail drawings, two years spare parts list, test and inspection certificates, license document and the warrantee.

Sometimes a vendor needs more data and information to supply the proper equipment. In this case, all required document are attached in the technical requisition. The attachment could be piping and instrumentation diagram, process flow diagram, plant plot drawings etc.

5.1.7 Execution Strategy

Execution strategy depends on both nature of the project and SABIC in-house capability. Licensed and patent projects for example are handled with Engineering, Procurement and Construction (EPC) contract where the contractor will be responsible for engineering, procurement and construction. In other cases the detail design is either done in house or outsourced to a design office either because the project is time consuming type or because the work load.

For simple project like replacing an existing equipment, in-house maintenance group can be utilize for construction. For complex project maintenance group do not have the required capability so that the construction contractor is hired. Moreover, for shutdown projects construction contractor is hired since the maintenance group is busy with shutdown activities like overhauling rotary equipments and other scheduled maintenance activities.

Project stakeholders (Affiliate Engineer, Site Project Engineer and Design Engineer) are agree on the execution strategy during the clarification meeting. The major factors typically considered in selection the project execution strategy include nature of the project, capability and current load of DMD, time of execution, and capability of the maintenance group.

Execution strategies for projects other than LSTK projects can be summarized in the below table.

Table 8. Execution Strategies

Project Activity	Possible Strategy
Design	SABIC/DMD Design Office
Project Management	SABIC/SPM
Construction	SABIC Maintenance Group Contractor
Material Procurement	Vendor Construction Contractor SABIC/SPM

5.1.8 Cost Estimate

At SABIC cost estimate is prepared by all design engineers who involved in the project. Each discipline engineer is responsible for his discipline. After the scope of work is finalized, design engineer forward the scope of work and required material to approved contractors and vendors for their budgetary quotation. Normally, three contractors and three vendors are requested for budgetary quotations.

One of the problems facing DMD regarding cost estimate is bad response from contractors and vendors. Contractors and vendors ignore the budgetary quotations inquiries for many reasons. Sometimes vendors or contractors are busy on ongoing projects so they find no time for budgetary quotation. However, providing budgetary quotation does not mean bidding. For this reason, some contractors and vendors don't find budgetary quotation worth the efforts, so they ignore the request.

Another problem is quotation validity period. Usually the validity period is thirty (30) to sixty (60) days. The maximum period can be given be vendor or contractor is three months. Cost estimate is attached with FEEP to get Gate-3 approval (Project Strategy and Execution Plan) when the budget is allocated as per the cost estimate submitted. Contracts and purchase orders are issued on Gate-6 (Detail Design and Construction). The normal time required to reach to Gate-6 is four months from date of the quotation. Once it comes for construction the prices may increase. In this case, budget need to be revised to meet the change in process. Project may be hold due this change because the total approved budgets for project is not cover the new change.

5.1.9 Plan and Schedule

Site projects are classified as shutdown projects and normal projects. Shutdown projects are critical projects since shutdown is required to complete the construction. In some cases, the project is a combination of both shutdown and normal activities.

Since unscheduled shutdown must be avoided to keep production, shutdown projects and shutdown activities must be scheduled in the shutdown period. However, for critical and urgent projects, construction can be performed while the plant is running without disturbing the production. For example, by using hot tapping technique in piping projects, tie-in can be made without disturbing the process. But in this case, cost of construction will increased since advanced technology is used. Generally shutdown takes place during the turn around process. This occurred twice a year, May and November.

Delivery time of long lead items is one of the most important factors effecting the project duration. Duration of the delivery and construction usually provided by vendors and construction contractors. For other activities duration is estimated based on previous experience.

Scheduled prepared is simple Gant Chart without showing the relationship between the activities. WBS is very general and no detailed activities shown. Microsoft Project is used as the scheduling software.

However, this schedule focuses only in the design activities. For construction activities only tentative schedule only. Usually construction contractor provides detailed schedule for construction activities as part of his duties before starting the work.

5.1.10 Drawings

FEEP drawings are conceptual design drawings that show the basic idea of the project only. Normally, drawings attached with the FEEP are piping and instrumentation diagram (P&ID), process flow diagram (PFD), plot plan, equipment layout and sketch of the new proposed arrangement. In some cases even the drawings are not required. For example in case of replacement of an existing equipment with a new one, FEEP is made without any drawing. If the drawings need to be revised to show new equipment, vendor or construction contractor revised the existing drawing and provides the AS BUILT drawings.

Retrieving the existing drawings is time consuming in some plants because a lot of documents are missing or they are not in the right place. Some affiliates have Engineering Drawing Management System (EDMS) where drawings and other documents can be searched very easy.

There is a uniform drafting manual for SABIC. This manual is implemented only for the new mega projects. Currently, it is difficult to use the uniform drafting manual in all affiliates site projects because each affiliate has its own drafting standards. Recently, SABIC started a digitizing project to convert all existing drawings (hard copy) to digital (soft copy) as the first step in applying the new uniform drafting standard. SABIC plans to create global EDMS for all affiliates and make accessible for all concerned personnel. This system will reduce the searching for existing documents.

5.1.11 Responsibilities

This section describes the predefined roles and responsibilities of all project stakeholders: Design Engineer, Site Project Engineer, Affiliate Engineer, safety and Quality Control, Vendor and Contractor. The typical responsibilities are listed below:

- Design Management Department (DMD)
  - Prepare FEEP
  - Prepare Detailed Engineering Package
  - Prepare Technical Requisitions (vendor enquiry packages)
  - Prepare Technical Bid Analysis

- Prepare Construction Scope of Work
- Review and approval of vendor drawings

- Site Project Management Department (SPM)
  - Obtain Gate-3 (project strategy and execution plan) approval
  - Review documents from DMD.
  - Coordinate for review of a affiliate Departments.
  - Initiate Purchase Requisition (PR) and Purchase Order (PO).
  - Coordinate for vendor drawing submittal and approval.
  - Receive material and coordinate for inspection.
  - Supervise construction activities.

- Affiliate Department
  - Review FEEP and approve
  - Review specs/data sheets and other project documents
  - Conduct HAZOP / PHA if required
  - Plan for shutdown required (if any).
  - Coordinate with Site Mgt team for installation / construction.
  - Provide assistance in issuance of permit and safety guidelines
  - Perform the Pre-Start up Safety Review (PSSR)

- Safety and QA/QC
  - Perform QA / QC check

- Perform material inspection

- Vendor
  - Supply required material
  - Provide necessary engineering document for approval
  - Provide performance guarantees
  - Provide the installation requirement
  - Support contractor in installation if required
  - Provide Spare Parts and required maintenance support after installation as required.

- Construction Contractor
  - Execute the project as per detailed design package
  - Supply required material as per material take off(s).
  - Test, inspect all construction work as per SABIC and Industry Codes.
  - Start up and commissioning.

Depends on the nature and characteristics of each project, responsibilities may be revised to meet the special requirement for each project.

5.2 Detail Design Package (DEP)

5.2.1 General

At SABIC only 10% of total projects are detailed designed in-house. The majority of petrochemical process projects are constructed under EPC contract where the contractor is responsible for preparation of the detail design. In the case of EP project, the vendor provides detailed design, fabrication, assembly and delivers the required equipment to the site. A construction contractor is hired to install and execute the project as per the vendor drawings. In both cases the role of DMD is to review and approve vendor detailed design.

For regular projects where vendor's scope is limited, detailed design is either prepared by DMD or by a design office depending on the work loads at DMD. The detailed design package includes all necessary documents required to execute the project. These documents are classified into two types: technical documents and contracting documents. Technical documents are prepared by the DMD and include engineering drawings, construction scope of work, bill of materials and technical specifications. Contracting documents are prepared by Supplied Management Organization (SMO) and include: general conditions, special conditions and contracting formats.

5.2.2 Work Flow

After receiving Gate-3 approval and Site Project Engineer consent to proceed for detailed engineering. Once 90% Detailed Engineering Package (DEP) is completed and checked by the Technical Assurance Team (TAT) and approved by the section head, it is forwarded to the proponent affiliate through SPM. After the affiliate's engineer and the project engineer review the package they send it back to DMD with their comment if any. DMD incorporates all comments and issues the final package for construction. The detailed design package is forwarded for SPM for contracting and construction after bidding process.

5.2.3 Document Index

The detailed design package includes a detailed engineering document index which lists all deliverables, general scope of work and detail design documents for each discipline. It is sorted by discipline and indicates the type of document, size, title, number of sheets and progress status (percentage).Document index is used to control the package and record the status of each document during the design development process.

5.2.4 Scope of work

While FEEP scope of work is written for internal use, detail engineering scope is written for external and contracting purposes. For example in FEEP the statement says "install new centrifugal pump with 30 GPM and 40 ft head" (No matter how will install this pump). The important in the FEEP is what to be installed. But in the detailed design scope of work the statement says "vendor shall supply centrifugal pump" and " contractor shall install the pump". The detail design package focus on "Who will do what".

The scope of work determines the required project tasks for each discipline to complete the project. The scope of work depends on the execution strategy that has been approved in the FEEP and in Gate-3. However, all parties involved in the project shall fully understand their scope of work. For that reason, DEP scope of work is segregated by party. These parties are: construction contractor, vendor, DMD, SPM and affiliate.

5.2.5 Detail Drawings

Drawings for detailed design contain more details that FEEP drawings. Most of the cases, detailed drawings modify existing ones. For new facilities or new equipment that made by vendor, DMD received vendor drawings for review. Then vendor drawings are converted or adapted to match with SABIC drafting standards.

5.2.6 Technical requisition

Technical requisitions which were prepared during FEEP are utilized for DEP. In some cases new requirements or new modifications appear due design development process. As a result, technical requisition is revised accordingly to show the latest requirements.

5.2.7 Material takes off

Bill of materials show in details the required material since it is extracted from the detailed design drawings. For piping material for example, each pipe is illustrated in a separate isometric drawing that determines the required material for that line.

Detailed material lists are leading for accurate cost estimate that reach up to 5% accuracy. Bills of materials are utilized in the project material management.

6 RESULT AND DISCUSSION

The required data as mentioned earlier is collected from two main sources, literatures and interviews with key personnel involved in design processes. Some of the required data such as international petrochemical firms' design practices could not be obtained due the confidentiality and access problem. These practices are not published and it used within the company only. Saudi petrochemical firms (except SABIC) are either under construction or small plants with few projects. However, the general design practices used in petrochemical industry is illustrated in the literature review.

6.1 Design Management Department (DMD) Capabilities

Capability of DMD is measure by the size, experience, design quality and affiliates satisfaction.

6.1.1 Design Management Department Size

The size of DMD is measured by number of the employees. DMD has 158 employees including management, engineers, designers, CAD operator, document control and secretary as shown in Table-9. The total number of employees is 158 includes 68 engineers, 24 designers and 37 cad operators. The engineers are distributed on five areas and each area covers number of SABIC affiliates as shown in the Table-10. Engineers and designers are from four disciplines, civil, mechanical, instrumentation and electrical. Obviously, DMD does not have Process engineer. This because DMD does not handled process project more frequently. If the process engineer is required for any project, a process engineer from the proponent affiliate is assigned for that project.

DMD is serving fifteen affiliates (SABIC has 22 affiliates but DMD is serving only 15 affiliates). These fifteen affiliates are distributed into five areas: Hadeed Area, South Area, East Area, West Area and Fertilizers Area as shown in Table-10. So, the number of engineers and CAD operators is enough to cover the design load. Each affiliate served by approximately one engineer from each discipline and two CAD operators. But the number of designers is not enough because by average each designer covers three affiliates. This over load causes delay and low quality productivity. Also, Technical Assurance Team (TAT) whose check the design packages, is very small number since each TAT engineer covers all the fifteen affiliates.

Table 9. Design Management Deprtment Size

Discipline		Number of Employees
Engineers	Civil	14
	Mechanical	19
	Electrical	12
	Instrument	18
Designer	Civil	6
	Mechanical	8
	Electrical	5
	Instrument	5
Cad Operator		37
Technical Assurance Team		5
Document Control		17
Secretary		5
Supervisors		3
Section Head		3
Manager		1
Total		**158**

Table 10. Affiliates Destrbution

Area	Affiliates Serviced
Hadeed Area	HADEED
South Area	RIYADH Head Quarter, KEMYA, PETROKEMYA, SABTANK
East Area	SADAF, IBN SINA, SHARQ, IBN ZHAR
West Area	GAS, UNITED, AR-RAZI
Fertilizer	SAFCO, IBN ALBYTTAR, ALBAYRONI

6.1.2 DMD Experience

The experience of DMD is measure by design experience of its engineers, designers and CAD operators. Experience is categorized into five categories for each class as shown in the Table-11. 60% of the engineering personnel have 6 to 10 years experience and 20% have more than ten years experience. This level of experience is enough to handle the design services of the most site projects.

Table 11. DMD Employees Experiance

Number of Years	Engineers	Designers	Cad Operators	Total
0-5	12	-	16	28
6-10	35	24	21	80
11-15	16	-	-	16
16- 20	5	-	-	5

6.1.3 Type of Projects Undertaken by DMD

DMD involves in site projects with budget of two million Saudi Riyals and less than SR 50 million. The type of projects undertaken by DMD varies from buildings, process, utility, security, fire fighting to environmental. Building projects include Heat, Ventilation and Air Conditioning (HVAC) system improvement, plumbing project, offices rearrangement, building maintenance and building expansion. Process projects any project related to production process. Example of process projects are catalyst modification, revamp the reactor, install new furnace and vessel replacement. Utility includes water supply, drainage, storm water, compressed air and lighting and power supply to the plants and buildings. Security projects are related to access gates, electronic personal gates, monitoring cameras system, radio network and emergency control center. Fire fighting projects include both buildings and plants firefighting system either new installation or modification the existing system. Environmental projects are those related to release gases, disposal of waste chemicals and waste water treatment.

Table 12. Projects Completed by DMD on 2006

Project Type	Number of Projects	Percentage
Building	49	13%
Process	132	36%
Firefighting	37	10%
Utility	78	21%
Security	17	5%
Environment	50	14%
Total	363	

Project type's percentages are shown in Table-12. Process projects present the maximum percentage (36%) of total projects. The next type is utility projects with 21% then the environmental and building projects with 13%.

All Front End Engineering Packages of site projects are prepared by DMD, but not all Detail Engineering Packages prepared by DMD. Only 10% of the projects are detail designed by DMD whereas the rest of projects either designed by design offices or under Engineering, Procurement and Construction (EPC) contract with professional construction contractor such as Udhe or Technip. EPC contract is frequently used for 90% of process projects and almost all security projects. The overall all percentage of EPC projects is 84% which represents the majority of the execution strategy. Table-13 shows the detail of the projects type patterns.

Table 13. DMD Project Pattrens on 2006

Project Type	Number of Projects	FEEP in-house by DMD	DEP in-house	DEP by Design Office	EPC
Building	49	49	6	12	31
Process	132	132	12	-	120
Firefighting	37	37	-	-	37
Utility	78	78	20	10	48
Security	17	17	-	-	17
Environment	50	50	-	-	50
Total	**363**	**363**	**38**	**22**	**303**
Percentage		**100%**	**10.5%**	**6.1%**	**83.5%**

6.1.4 DMD Design Quality

There is no quality control / quality assurance (QC/QA) system such as ISO 9001 (Quality Management Systems Requirements) applied in DMD. As mentioned earlier, Technical Assurance Team reviews the design packages once it is completed by design team. This practice leads to low quality outputs. Even with expert engineers and designers, quality control procedures are required to make sure that there are no design faults.

6.2 *Affiliates satisfaction*

Two project engineers from four different affiliates have been interviewed to evaluate the design services provided by DMD. These eight project engineers are selected randomly as a sample of other affiliates. The evaluation points were about quality of design, cost effectiveness of design, constructability and the overall evaluation of the design. Quality means that the design package is fulfilling affiliate's requirement as per the appropriate design standards and codes. While cost effectiveness means that the design has been completed in economic manners such as selecting the optimum alternatives and proposing the efficient construction methodology. Constructability means that project can be executed practically as per design without making change orders. The evaluation based on scale of poor, fair, good, very good and excellent. The result of the evaluation is summarized in Table-14. The result of the evaluation shows that, the degree of affiliate's satisfaction is good. That means DMD meets the design requirements of the affiliates but the affiliates are excepting more from the DMD as new organization.

Table 14. DMD Evaluation Result

Affiliate	Quality	Cost Effectiveness	Constructability	Overall Evaluation
HADEED	Good	Fair	Good	Good
SHARQ	Good	Good	Good	Good
KEMYA	Very Good	Good	Good	Good
GAS	Good	Good	Fair	Good

6.3 Recommendation

The main objective to identify and assess the design practices in SABIC and attempts to improve the current quality of design services practices provided by design management department (DMD). Design practices have been illustrated. The efficiency of DMD design practices is measured by the degree of clients (SABIC affiliates) satisfaction. The clients are practically satisfied with the provided services but they are expecting more from DMD. To improve the existing quality of design services provided by DMD the following recommendation are made.

1. DMD shall introduce quality control system such as ISO 9001,(Quality management system requirement) to improve the quality of design provided to its clients.
2. DMD shall include Constructability plan for each project to ensure the possibility of construction with optimum change in the existing facilities.
3. Obviously the feasibility study is not prepared by DMD, instead the feasibility study is prepared by the affiliate's engineers since they are close to the daily operation and maintenance problems. The practices is that the affiliate's management is approving the project before sending the Conceptual design Package (CDP) to DMD. The feasibility study shall be conducted by DMD and all required data shall be provided to facilitate their job.

4. Process engineer is very important in process projects. DMD shall have process engineers within the design team and not from affiliate staff.

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