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**PROGRESS MADE IN THE IMPLEMENTATION OF
THE WORK PROGRAMME**

**MASTERPLAN FOR THE DEVELOPMENT OF TECHNOLOGICAL
CAPABILITIES IN THE OIL REFINING,
PETROCHEMICAL AND FERTILIZER INDUSTRY**

A FRAMEWORK

Note by the Secretariat

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INTRODUCTION

The Joint ESCWA/UNIDO Industry Division (JEUID) undertook two activities in the field of manpower training in the 1982-83 work-programme, namely the organization of a Workshop on "Technology and process design update: petrochemicals; fertilizers and oil and gas processing", and of a symposium on "Plastic technology and applications".

As a continuation of these undertakings JEUID prepared a report on a framework for master plan for the development of process, plant and product design capabilities in the petrochemical (including fertilizer), industry under its 1984-85 work-programme.

In the course of the biennium, close co-operation with the Arab Industrial Development Organization (AIDO) was established and due to an increase in resources, the programme was expanded as follows:

- (a) To cover the following technological capabilities, pre-feasibility, feasibility, engineering and construction, supervision of construction, plant and customer technical services, marketing and R&D, besides process, plant and product-design capabilities;
- (b) The scope was enlarged to include the oil-refining industry;
- (c) To cover all Arab countries, thus including the North African Arab States.

The prepared report however, covers only the ESCWA member States. The remaining states are to be included subsequently in a joint JEUID/AIDO report.

The refining and petrochemical industries in the region have developed and evolved into a key element in the industrialization policies adopted in the region and in the structure of world markets. This rapid development was prompted by the desire of the petroleum-producing countries to fully utilize the oil and gas potentials available, capture the high value-added component of advanced oil processing projects, diversify production and exports and exploit the competitive advantages available because of the low price of energy and feedstock in the region. If the processing of raw materials is carried to the manufacturing stages, it will at the same time encourage local production of end-products. In this way the countries do not only diversify their industrial base but also create new jobs, provide training and technical experience and promote backward and forward linkages.

The study attempts to assess the present status and development of indigenous technological capabilities acquired in the process of technology transfer in the refining and petrochemical industry in the past period (1965-1985). It explores the means and ways of speeding-up this development and making increased use of human resources and institutions available within these countries. Finally, it develops a plan of action comprising end-measures for implementation by government agencies and private institutions in ESCWA member States for the development of indigenous technological capabilities taking into consideration the prospects for future advanced technologies in this industrial sector.

Part 1: Status of the industry

Most of the oil-producing countries, started on ambitious development plans for their petroleum-based industries and committed a large share of their oil revenues in new and World-scale size oil refineries and petrochemical complexes, as well as in infrastructural projects (airports, roads, ports, industrial sites), plus developing other sectors of the economy, such as health, education and housing.

Many of the petrochemical plants have only very recently come on-stream and therefore the relative "newness" of this industry has important consequences on the level of the development of technological capabilities.

The aforementioned study presents a more elaborate overview of the existing industries in this field on a country by country basis.

Part 2: Status of the technological capabilities

In the following paragraphs the results of the survey of the present technological capabilities in the ESCWA member States are given. The capabilities as listed in the introduction are reviewed and whenever possible, specific and detailed information is provided on the countries of the region.

2.1 Project identification, pre-feasibility and feasibility studies:

Examples of pre-feasibility and feasibility studies have been cited in the survey as being prepared by concerned government agencies, local consultancy firms or oil producing companies. These show that some petroleum organizations have gained enough experience in this field to enable them to perform this activity, in some cases, with the help of foreign specialized consultancy firms.

Iraq

Iraq has gradually developed its capabilities in project identification, pre-feasibility and feasibility studies. Trials in this field started in the 1950s, but produced only general sectoral studies, while feasibility studies were then mainly undertaken by foreign consultancy organizations. More technical and economic studies were performed later by local institutes and concerned departments.

Two state organizations in Iraq undertook the consultancy work related to the petroleum projects and are responsible for the evaluation of feasibility studies and negotiations with selected foreign companies. These are the State Organization for Industrial Design and Construction and the State Organization for Petroleum Projects.

Saudi Arabia

In the early 1970s studies were conducted for indentifying petrochemical projects for implementation, and organizations, such as SABIC, were created to co-ordinate the investment projects indentified by these studies. The Saudi Basic Industries Corporation (SABIC), in consultation with foreign consultancy organizations, thus identified a number of projects to be implemented as the first group of basic industries, later followed by the second generation of petrochemical industries.

Specific information on the extent of the involvement of foreign organizations on the identification of projects is not available, but there is scope to believe that at present SABIC has acquired substantial capabilities in this field. Petromin, was also entrusted with the task of implementing and administering public projects in petroleum-refining. It conducted the necessary studies for the new oil refineries, mostly in co-operation with the large oil companies, such as Mobil, Dow, Shell and Exxon, which were to become partners in these joint ventures.

Kuwait

The survey indicates that through actual experience the Kuwait National Petroleum Company (KNPC) has developed a domestic expertise in project identification and process technology selection. As an example: When KNPC started with the ambitious plan for expanding, modernizing and integrating the three operating refineries in Kuwait, its engineers were able to undertake refinery modelling and process identification. Pre-feasibility and feasibility studies of the planned refineries expansion were accomplished completely and independently by KNPC engineers and economists. KNPC has also been undertaking the responsibility of preparation of project specifications, invitation of tenders and examination and negotiation of bids.

The Petroleum Industries Company (PIC) undertook independently the pre-feasibility and feasibility studies for the implementation of an ammonium project, a chlorine-sodium chloride plant and the planned Polypropylene and Di Ammonium Phosphate (DAP) projects. The role of the Kuwait Santa Fe/Braun Organization (KSB) and the Kuwait Institute for Scientific Research (KISR) in project identification, pre-feasibility and feasibility studies is not mentioned in the survey, though it is mentioned that KSB does provide KNPC and PIC with the needed expertise whenever this is not available in these organizations or in the local market. It is also evident that no specialized consultancy firm is available in the local market to undertake related pre-feasibility and feasibility studies.

Qatar

In Qatar the Industrial Development Technical Centre (IDTC) reports that it has participated in the identification of new project ideas, and expansion plans of existing plants such as the Qatar Fertilizer Company (QAFCO) and the Qatar Petrochemical Company (QAPCO). It undertakes pre-feasibility and feasibility studies in-house and with the help of foreign experts. It is also charged with the responsibilities of negotiating with foreign parties, drafting of tender documents and finalizing contracts of joint ventures. Examples given of its role are: (1) development of the fertilizer plants expansion programme (QAFCO 2), (2) the development of the QAPCO project, for which it made a thorough investigation. It selected ethylene production as the most feasible for the use of the ethane-rich gas, which is to be produced by the Liquid Natural Gas (LNG) plants. IDTC also prepared the project specifications and finalized the contract negotiations.

Qatar General Petroleum Corporation (QGPC) was involved with foreign help in the preparation of the pre-feasibility and feasibility studies undertaken for the refineries and LNG plants.

Qatar has relied to a great extent on joint ventures and turnkey contracts for most of the established projects.

Egypt

In Egypt the specialized personnel in the General Egyptian Petroleum Company (GEPC) and in the concerned refineries, usually undertake with the help of experts and consultants from universities, the process of project identification and evaluation.

GEPC is currently involved in the implementation of some 13 projects in the refining and petrochemical sectors. Preliminary studies have been undertaken with the help of foreign companies and consultancy firms, or in collaboration with university staff and national engineering companies.

Jordan

Jordan has only two major petroleum-based industries, one is the oil refinery where the company depended on foreign skills for the feasibility study, the other is the Intermediate Petrochemical Industries. For this project many alternative production technologies were considered by a foreign firm. A technical committee from the company staff and the consulting firm was formed to carry out the evaluation process of these alternative technologies and to select one. The feasibility study of the project was conducted by the Industrial Development Bank of Jordan, which is also a partner in the project.

Syria

In Syria the General Company for Technical Consultancy and Studies, as well as the Homs and Baniyas refineries, mention their in-house abilities to perform pre-feasibility and feasibility studies, but no further information is provided.

The General Fertilizers Company (GFC) reports that it is currently undertaking two feasibility studies with the help of the General Company for Technical Consultancy and Studies, one for changing the feedstock of its plants from Naphta to natural gas, the other for a new DAP production line.

2.2 Engineering and plant design capabilities

The Survey undertaken has shown that in several of the countries of the region some progress has been made.

Kuwait

Kuwait, through its National Oil Company, KPC, has acquired Santa Fe Corporation which through its engineering subsidiary CF Braun, can provide the KPC companies like the KNPC and PIC, the supporting capabilities needed. Since the KSB company was established only in 1982, limited information is available to assess the impact this acquisition has had on the engineering capabilities of KNPC and PIC.

KNPC's technological capabilities in the areas of process design and detailed engineering were limited. However, it has taken some modest but accelerated steps towards the strengthening of its capabilities in these areas. The steps include developing the career of technical staff assigned to process engineering departments within the refineries, borrowing technical manpower from KSB to assist KNPC engineers, and sending degreed engineers to attend career development programmes organized by C.F Braun Engineering at their headquarters in Alhambra, California, where training on all facets of projects is provided.

CF Braun's capabilities in design, detailed engineering and in product and process design should help the engineering staff at KNPC refineries and PIC to identify projects, and select the technology that suits Kuwait's needs, taking into consideration its market size, availability of production factors and whether certain qualifications are required for technical personnel.

However, the contemplated expansion by KNPC refineries has been accorded for execution and commissioning to foreign contractors.

In the case of PIC, there is a strong dependence on foreign capabilities when capital investments are involved to revamp processing units, to undertake debottlenecking projects, to replace obsolete equipment, or mitigate environmental pollution and safety hazards.

Saudi Arabia

In the past, Saudi Arabia relied completely on turnkey projects to establish its refineries and lube oil plants, but attempts were made to build-up local capabilities in engineering and design. Both Petromin and SABIC have engineering departments, but from the information provided in the survey, it followed that the engineering activities required at the initial construction of the refineries were carried out exclusively by foreign consultancy organizations.

In the case of the basic petrochemical industries being constructed by SABIC, no specific information was available, but from published literature it is evident that these capabilities were also provided by foreign companies.

Local capabilities are stated to be used in the case of expansions and/or modifications in already existing installations. Through specific legislation, stipulating a certain degree of Saudi involvement in industrial projects, local engineering and consulting organizations become more and more involved in engineering and design work. Since these organizations are mostly joint-ventures or have co-operation agreements with internationally operating corporations, the exact Saudi share and level in the work undertaken is difficult to assess.

The only national organization that reportedly carried out engineering and design studies, is the Saudi Consulting House, established in 1967. However, its role in the oil refining and petrochemical industry is still very limited.

Qatar

The establishment of Qatar's petroleum-related projects and its lack of technological capabilities as well as skilled manpower, to operate these technologically advanced enterprises, necessitated a very strong reliance on foreign capabilities in every stage of project implementation and operation. Projects were executed on the basis of joint ventures and turnkey contracts, including special management and marketing agreements.

As far as engineering and design capabilities are concerned, these have not sufficiently been built-up to carry out independent studies however, capacities exist to review engineering studies undertaken by foreign consultants. An important role is being played in this respect by IDTC.

The Qatar General Petroleum Company (QGPC) has an engineering section which acts as a project development department. It relies, however, to a large extent on the services of outside consultants to carry out engineering and plant design.

Iraq and Syria

The two countries, Iraq and Syria established their industries much earlier than most of the Gulf states, therefore their experiences and technological capabilities have evolved to a greater extent.

In Iraq there are two state organizations which undertake most of the consultancy and engineering design work for the petroleum sector. These are:

- (a) The State Organization for Industrial Design and Construction;
- (b) The State Organization for Petroleum Projects,

They work in close co-operation with the foreign companies contracted to implement the projects.

Active participation in engineering and design work has taken place in all petrochemical projects undertaken. These comprise, among others, new refinery units and lube oil plants, chemical fertilizer plants, and an ethylene plant.

The participation generally involves close collaboration with the foreign contractor in all stages of project implementation, preparing specification and capacity of the project, participating in engineering design, selecting the process technology, supervising the erection of the installations, and undergoing training in each of these stages.

Iraq has through this well-planned process of technology transfer managed to develop engineering and plant design capabilities to a considerable extent.

In Syria, there are three major establishments in the petroleum-based industry consisting of two refineries, one in Homs and the other in Banias, together with a fertilizer complex in Homs.

The two refineries were designed and built on a turnkey basis by Czech and Romanian companies. The three plants of the fertilizer complex were also turnkey contracts involving Soviet, Italian, Czech, French and Romanian contractors.

In addition, GFC reported that for their two ongoing engineering projects which are the change of feedstock from naphtha to natural and associated gas, and the establishment of a production line for diammonium phosphate, the engineering and plant design activities were being undertaken by foreign consultants. These are, however, no longer turnkey projects, but are carried out under the overall responsibility of the GFC.

The role of the Syrian General Company for Technical Consultancy and Studies lies more in the undertaking of techno-economic pre-feasibility studies and civil engineering design as well as overall supervision of large construction projects. Its activities in the petroleum-based industry were not detailed.

Egypt

At present, many activities are underway to expand, modernize and to diversify the petroleum-based industry in Egypt. Although in the past, the country used to rely on national capabilities to expand and modify their refineries, with little assistance from expensive foreign sources, in recent years a number of projects are being carried out with an important degree of participation of foreign companies. This was necessitated in part by the need to acquire "modern" technology, as well as by the need to speed up the development plans.

In 1978, GEPC has set up the Company for Engineering for the Petroleum and Process Industry (ENPPI). Its main activities are engineering design, project execution and management in the petroleum-related industries. It has undertaken already several projects, and works in collaboration with foreign experts.

For the various projects being undertaken by the refining industry, the national engineering capabilities have been involved in the following: preparing technical descriptions for plant equipment; preparing plant lay-out, as well as the detailed designs of tools, spare parts and equipment to be locally manufactured; technical evaluation of proposals for purchase of equipment; and performing engineering modifications where needed. Also production units at Suez were renovated, distillation and asphalt producing units erected and production capacities expanded by local engineering capabilities.

At present ENPPI has several engineering design contracts under implementation for installations and equipment of a number of plants such as distillation units, a coke complex, butagas recapturing project, chlorine plant, etc.

In conclusion, it can be said that Egypt has developed a wide range of engineering and design capabilities over the past two decades which are still being further developed by foreign consultants due to the numerous expansion and modernization programmes under way in the petroleum sector.

2.3 Process and product design capabilities

From the survey and other sources it was clear that no process and product design capabilities as such exist in any of the countries of the region. It seems that transfer of technology in the petrochemical industry has not taken place to a large extent.

Some countries reported, however, that they have absorbed the foreign processing technology to such a degree that they are able to introduce modifications in original processing designs, or to select an alternative technology.

2.4 Plant construction and supervision of erection

Iraq

This capability has been reported to be one of the first capabilities that have been promoted in Iraq through the experience gained in previously executed projects. Iraq has established two state organizations specialized in industrial design and construction and project execution. They both undertook responsibilities in plant construction planning and supervision of construction through direct execution using local companies or through contracts to foreign companies depending on the project requirements and available skills in civil, mechanical and electrical engineering. The examples cited for supervision of construction are in the Daura refinery expansion programme, and the second lube oil refinery, where local personnel participated in the supervision of construction with foreign experts, and had on-site, as well as foreign training in this field. Both these projects were executed in the late 1960s. Since then local personnel and concerned organizations undertook execution of projects and supervision of construction with limited assistance from foreign companies, in a few cases there was equal participation of foreign and local expertise.

Examples of fertilizer plants executed since 1971 show that the local partner participated effectively with the foreign company in the supervision of construction of works. As regards the execution process of the petrochemical complex, the local partners undertook total supervision of construction, inspection of plant drawings and machinery design, while a special on-site group of engineers -civil, mechanical and electrical- performed this activity.

Saudi Arabia

In Saudi Arabia the manpower required to construct the large refineries, petrochemical plants and other infrastructural projects during the last decade was not available in the Kingdom itself. Not only the huge numbers of unskilled workers could not be found in the Kingdom, but equally important, the required skilled manpower and supervisory staff were not available. This situation necessitated the large influx of expatriate workers and supervisory staff.

Although a number of Saudi or Arab companies in the building and construction sector have been established, (e.g. Consolidated Contractors Company, CCC), their involvement in the construction of refineries and petrochemical plants was rarely cited in the survey. For example, the recently constructed refineries in Yanbu and Al-Jubail were constructed by Far Eastern companies working under the supervision of Japanese or US contractors. ARAMCO also reported that they were only involved in supervisory activities. In these supervisory activities a limited Saudi involvement could be found, mainly through the local affiliate of the foreign contracting company.

Syria

In Syria the refining and fertilizer plants were all constructed by foreign companies with some local participation; the Homs refinery was constructed by Technoexport of Czechoslovakia. The Baniyas refinery by Industrial Export of Romania. The three plants of the Homs fertilizer company were constructed as follows:

(a) The calcium ammonium nitrate plant: civil construction was undertaken by the General Establishment for Execution of Industrial Projects, a Syrian public sector enterprise, with the assistance of foreign consultants;

(b) The ammonia-urea plant: a turnkey project constructed by the French firm, Creusot-Loire Enterprise;

(c) The triple super phosphate plant: a turnkey project executed by the Romanian firm, Industrial Export;

(d) For the current upgrading schemes, the company plans to involve the state organization in plant construction and supervision of erection.

The General Company for Technical Consultancy and Studies has reported its ability to undertake management planning for plant construction and supervision of construction though there is no specific involvement by this company mentioned in the refining or fertilizers projects.

Jordan

The Jordanian refinery and petrochemical plants were all constructed by the foreign technology owner and local manpower was involved in the plants construction and in the supervision of the construction phase.

Egypt

In Egypt most of the refineries were built by foreign contracting companies, using Egyptian labour, which gained enough experience to execute some plant construction in the period after 1967. Examples were the construction of refining units in Cairo and Tanta, the relocation of the naphtha beneficiation plant from the Suez to Cairo area, the renovations of the refining units in Suez, and the construction of distillation, asphalt and lubricant units. These activities were undertaken by the engineering and operation divisions within the refining companies themselves.

Lately in 1976 and 1978 two engineering companies (Petrojet and ENPPI) were established to undertake plant construction and supervision of construction activities as part of other capabilities required in the petroleum sector. These companies have reportedly undertaken construction jobs and management planning of project execution including supervision of construction. They performed these jobs either independently or with foreign assistance.

Qatar

In Qatar both IDTC and QGPC report their participation in the supervision of the installation of the refining, fertilizer and petrochemical plants which have all been accomplished through turnkey or joint venture agreement with foreign companies and a foreign labour force.

The only local company mentioned in the survey to have undertaken construction jobs in the petroleum industry is the Mideast Constructors (MECON), which is a mechanical and electrical contractor.

Kuwait

Kuwait's petroleum refining and fertilizer plants were originally constructed through foreign companies. The fertilizer plants were contracted to Hitachi Zosen of Japan, Daelem Engineering of Korea and Techni Petrole of Italy.

Expansions for the three refineries of KNPC have been accorded for execution and commissioning to foreign contractors, namely Chiyoda and Japan Gasoline Company. As for the planned projects of polypropylene and DAP, PIC is depending wholly on the contribution of CF Braun. No mention is given of any local construction companies participating in the execution of petroleum projects, nor of involvement of local manpower.

2.5 Production management capabilities

When a new plant is using a technology or a processing method for the first time the local labour market has no experienced manpower with the technical knowhow in the new technology, and therefore they have to be trained at an early stage of the project implementation.

If a country has been running a petroleum refinery for a long time such as is the case with many countries of the region - it has a good basic pool of operational skills for the petrochemical industry. Then some of the oil refinery operators, technicians, and managers can carefully be moved into petrochemical operations.

From the survey results it can be concluded that all refineries are managed and to a large extent operated by nationals. These capabilities have been built up over a period of 20 years or so, and through regular training programmes to update or train new operators and technicians, refineries have been able to rely on local capabilities.

The situation is somewhat different for petrochemicals, including fertilizers. Although some of the fertilizer plants have been operating since the 1960s, they each use foreign employees in different numbers in accordance with their particular requirements, especially when the plant is a joint venture project with a foreign partner. The same applies to other petrochemical plants, some of which are still under construction and for which the manpower is being trained.

2.6 Capabilities in plant and customer technical services

Local capabilities, as far as maintenance and quality control are concerned, are found to exist in all oil-refining and petrochemical plants. In countries like Egypt, Iraq, Jordan, Kuwait and Syria, enough locally available, skilled personnel can be found to undertake most of the tasks involved.

In the refining sector, all companies have divisions responsible for plant maintenance and technical services, in addition use is made of local companies specializing in petroleum maintenance and plant technical services.

In some countries, efforts are underway to co-ordinate and rationalize some specialized jobs in the various refineries into one organization, which will then serve all the plants. This is the case in Egypt and Kuwait, where the national petroleum organizations have initiated these policies respectively.

However, major annual overhauling of proprietary machinery and complicated maintenance or repair tasks, are mostly carried out by foreign specialized companies.

Often local Arab companies, such as the Kuwait Refinery Maintenance and Engineering Company (KREMENCO), and Consolidated Contractors Company (CONCO),

provide a variety of services for the petroleum-based industry, such as sandblasting of equipment, painting, lining of tanks and pipes, testing, cleaning etc. which are not typical oil-refining or petrochemical industry-related activities.

The manufacture of spare parts has not been well developed in the region. Partly this is a result of the fact that many spare parts include proprietary technology, and partly because of the fact that the local or regional market is not large enough to warrant the setting up of a regional industry.

The results of the survey showed that all organizations are wholly responsible for the plant and customer technical services. Most of the companies reported to have good contacts with their clients and co-operated closely with them to solve differences in quality of products, performing continuous testing and adapting these products to the needs of their customers.

The latter capability was more readily established in petrochemical plants than in the oil refineries.

2.7 Research and development

A meaningful R&D activity at the national level, necessitates mobilization of considerable resources, both in manpower allocations and investments. This indispensable activity can have an effect only when there is a well developed scientific infrastructure with technical institutions and a strong linkage to industry. R&D includes basic scientific research, process and product know-how and quality control or technical improvements of plant performance and productivity. Applied research is the improvement made on plant equipment and facilities or on product application (quality control), after the technology has been deployed.

The required number of highly-qualified scientists and engineers backed with adequate facilities and equipment is clearly at this period beyond the technical capabilities available in the region's countries. Another important factor is the linkages between R&D centres, universities and production facilities which are necessary for a continuous and substantial feedback process.

In the survey, this technological capability is mentioned by most of the refining, petrochemical and fertilizers plants as an internal capacity, but closer examination of information provided, reveals that in most cases the activities consist mainly of quality control, standardization and other research in areas of less immediate impact on the petroleum-based industry.

2.8 Marketing Services

In each country either the producing company itself or a specialized agency undertakes the responsibility of marketing products.

In Qatar, QAPCO and NODOC undertake the local and international marketing of processed products and the NGL, while the petrochemical products ethylene and LDPE, as well as the fertilizers, are sold through the foreign partners.

In Saudi Arabia most of the refineries reported that either the company itself or the parent company, Petromin, undertakes the local marketing, while the export-oriented refineries, which came on stream only in 1985, plan to partly market their products through the network of their foreign partners. SABIC's share of the output of petrochemical plants is marketed through bilateral arrangements, and the national marketing organization. Some strategic acquisitions of distribution and storage facilities around the world have been made for this purpose.

Egypt is locally marketing its fertilizers and its refined products through a number of specialized national marketing companies and bilateral agreements. Its petrochemical complex is currently under construction and no information on any marketing agreements were reported.

In Jordan, the refinery and the Intermediate Petrochemical Company were established to fulfil the internal demand and are reported to undertake their own marketing.

Syria also manages its internal and international marketing through the production companies.

In Kuwait, KNPC and PIC undertake the marketing of their products with foreign assistance. Rights for international distribution and storage facilities have also been acquired.

Iraq has a specialized state organization for marketing its refining and fertilizer products, but its petrochemicals plant has not yet entered into the marketing phase.

Part 3. Future advanced technologies

3.1 Future technological trends and implications

The oil, gas, petrochemical and fertilizer industries are relatively mature industries. Therefore, it is not anticipated that there will be major technological break-throughs or technical restructuring of these industries. Oil and gas exploration will continue to extend into offshore and frontier areas. The pressure in production technology will be on development of enhanced recovery by a variety of already considered techniques. As oil resources begin to deplete during the next decade, more natural gas will be obtained from non-associated gas fields, in contrast with the current emphasis on associated gas. Since non-associated gas tends to be much richer in methane than associated gas, there will be a significant change in the mix of the petrochemical products that would be produced from natural gas. More emphasis will be placed on development of petrochemical processes involving "single carbon chemistry". Already, processes exist for the manufacture of products like ethylene, ethanol, and gasoline directly from methane or methane derivatives. This pressure will continue, especially since some of the synthesis gas produced from future coal technologies could be used in conjunction with the "single carbon chemistry" processes.

In refineries, the emphasis will continue to be on the conventional refinery products: gasoline, kerosine, fuel oils, lube oils, etc. Automotive fuel will continue the trend towards the use of more diesel, methanol and Methyl Tertiary Butyl Ether (MTBE) for octane enhancement as lead is removed from gasoline. Improved car engine efficiencies and the possible development of high temperature ceramic or super-metal automotive engines will further reduce demand for oil products (gasoline). This will be reinforced by the continuing decline in the weight of the automobile and aircrafts as more conventional metal parts are replaced by plastics, thin metals and composites. To meet the changing product mix requirements and to achieve optimization of production and profitability, the refineries will be designed with more flexibility and will incorporate modern computer control facilities.

Refinery capacity in the ESCWA region will represent an important proportion of overall world refining capacity. In view of this, the competitive position of the ESCWA region can be protected by insuring access to up-to-date developments in enhanced oil recovery and the most recent innovations in refinery and gas-processing technologies. As market demands for gasoline and other refinery products change, it would be necessary to respond at a reasonable rate to compensate for the reduced demand. Moreover, as demand for methanol and MTBE grows, countries in the ESCWA region should be ready to supply the market with these products. To achieve this, capabilities in market analysis and forecasting are of the utmost importance. Also, capabilities in the production management and optimization of refinery and petrochemical plant operations are critical.

Some of the most significant developments relating to downstream petrochemical products will be associated with the expanded growth of plastics

and composites in the packaging and transportation fields. In packaging, the thrust will be to practically replace all existing metal cans and glass bottles with plastic products.

In transportation, the major thrust for use of plastics and composites will be for the manufacture of body panels to replace metal panels currently in use.

Under the hood of the car, there will be significant growth in the use of composites and high temperature and high performance engineering plastics. Similar trends will be observed in the aircraft industry but with more sophisticated products.

The expansion of plastics into packaging and transportation applications will involve materials that could be manufactured in the ESCWA region. However, to realize a significant portion of these new markets, it would be necessary to develop substantial research and development and technical service capabilities in the relevant fields.

Obviously, for successful penetration of the above very important markets and to insure a long-term competitive position, it would be important for the relevant countries in the ESCWA region to develop the appropriate technological capabilities and marketing knowledge in the associated fields of polymer science, plastics technology, packaging, food processing and automotive applications. Expertise required would involve market studies, product and process research and development, plant and customer technical service.

The key to establishing a beachhead in the field of high performance materials would be in supporting research and development at universities and research and development institutions in material science and engineering, with emphasis on chemistry, physics, chemical engineering and mechanical engineering.

Part 4. Conclusions and recommendations

4.1 Conclusions

The study was based on the information collected from and presented by the various countries, and thus its analysis depends completely on the quality and quantity of the information supplied.

It has been found that two separate groups of countries with similar characteristics exist, namely the countries with a relatively long history of industrial development, and thus a fairly wide-based industrial sector and technical infrastructure, such as can be found in Egypt, Iraq, Jordan and Syria. The second group includes the Gulf countries, Saudi Arabia, Kuwait, Qatar, and the United Arab Emirates, who have an industry solely based on oil production and refining, and have only recently embarked on developing downstream petrochemical complexes and widening their industrial base.

In all countries the various government departments and enterprises involved recognize the important role of human resources development to meet the technological challenge. As a result, each one of these countries has established structures and mechanisms to meet the requirements. They also have put into motion various schemes to develop their long-term technological infrastructure and technical human resources. Thus, the aforementioned countries have strengthened the science and engineering faculties in the universities, encouraged the establishment of vocational schools, established some research and development laboratories and industrial development institutes. Governments and establishments have in-house training programmes and spend substantial effort and money on training their personnel abroad. Access to technological information is enhanced by the many on-line hookups to international data-base and information services, and some effort is underway to establish indigenous data-bases. As a result of all the above, the technological infrastructure and capacity to deal with technological growth have expanded substantially in these countries in recent years.

Since the petroleum processing and petrochemical industries are relatively young in the countries of the region and due to the phenomenal rates of growth of these industries in the region, gaps exist in the organizational build-up and linkages between various infrastructural activities. There is overlap and misunderstandings regarding the roles of universities and government research laboratories. Moreover, both universities and research laboratories have yet to gain the confidence of industrial establishments. Governments and enterprises have recognized these problems and, in some cases, they are initiating a dialogue and formulating plans to improve co-ordination and communications. They are also devising procedures for enhancing the utility of research carried out at national laboratories. Another aspect relates to the rapid growth of some of the national laboratories, leading to overstaffing and poor definition of projects and responsibilities. As a reaction, some laboratories have adopted a policy of allowing the size of staff to drop.

One of the main factors influencing shortages in technological infrastructure and technical human resources in the region relates to the

small population of the countries involved. In fact, the Gulf region is rather unique in this regard. An approach that has been employed, to some extent, in order to alleviate the effects of the small populations is to deal with infrastructural and manpower problems on a sub-regional basis (e.g. the Gulf region). This has led to the establishment of joint petrochemical industries (e.g. Gulf Petrochemical Industries Company (GPIC) and infrastructural establishment (e.g. Gulf Organization for Industrial Consulting (GOIC)). However, the total population of the Gulf region is rather small, and this approach alone could not solve the problem. The regional approach to dealing with the problems of infrastructure and manpower resources should not be isolated from the regional market-size, since many of the technological requirements are market-based.

It has been indicated in our survey that qualified nationals from the various countries in the region do not receive sufficiently attractive incentives, especially in terms of income, to choose technological jobs. Nationals with comparable education are able to realize much higher incomes in other aspects of economic activity. Also, it has been indicated that many of the qualified nationals expect to obtain managerial responsibility very early, before they have accumulated appropriate experience. These aspects suggest the need to develop suitable personnel and incentive practices.

More specific conclusions can be drawn from part two: for all of the assessed technological capabilities, it can be said that these are not yet fully developed in the region, although some of these are further developed than others and some countries are more advanced than others. In particular the capabilities in production management and plant technical services are relatively well developed in a number of countries such as Egypt, Iraq and Syria. These countries benefit clearly from their longer established and broaded industrial base, as well as their better developed educational facilities. A third capability which is more readily found in almost all countries of the region, is the capacity to undertake techno-economic pre-feasibility and feasibility studies. This is largely due to the fact that these experiences have already been build-up in a variety of different economic sectors, and can be applied to a large extent similarly in the petroleum-based industry.

Consequently, a second group of capabilities is less well represented in the countries of the region. These include the technological capabilities in process and product design, engineering and plant design and research and development. These capabilities are closely related, and are based on the availability of technological capabilities from the first group above. In the absence of production management or maintenance capabilities, it will be difficult to undertake basic or applied research, or to undertake process design or engage in product development in the petrochemical industries.

As for the capability to construct and supervise the installation of petrochemical plants, it is believed that after a period of unprecedented growth in the number and size of refineries and petrochemical complexes in the region, this rate will eventually decrease to a much lower level, especially in view of the reduced growth in demand in the coming decade for the products

of these plants. Therefore, it is a question for further investigation whether there is a need to acquire the specific skills related to this activity.

As is shown in part 3, future petrochemical technologies are being developed that have an impact on the demand for certain types of products, and consequently the countries of the region should be ready to adapt to the changes in demand patterns this brings along.

4.2 Recommendations

Finally, a number of specific recommendations can be given for each or for a group with regard to the capabilities discussed in this report.

The development of these technological capabilities can be undertaken in two phases. The first phase will encompass the development of the following as a first priority:

- (a) Production management;
- (b) Plant technical services;
- (c) Pre-feasibility and feasibility studies.

Production management

This capacity is one of the most developed of the technological capabilities in the region, and can be found to exist in almost all plants and projects covered by the survey projects with a few exceptions. Despite this considerable degree of independence, a further strengthening of this capability is needed. This can be achieved through the training of nationals at all levels of plant operations, and securing that training on-the-job is a mandatory obligation in the contracts awarded to the foreign technology or equipment supplier.

It is recommended that training programmes are developed in the establishments for training of new employees, as well as for upgrading the skills of existing staff, which can thus be given additional responsibilities. At the same time this will support and accelerate the indigenization process which is being implemented by several countries in the region.

Also training and upgrading programmes should be developed for the management development institutes which already exist in countries like Egypt, Iraq and Syria.

Plant technical services

This essential function in each production process has to be developed further, since together with production management they form the basis on which technological capabilities can be built upon.

For this, vocational training centres and engineering faculties in universities should be strengthened by attracting more students as well as

staff, and better adapting their curricula to the needs of the national industry. For example, in some countries it was found that enrolment in these training institutes actually decreased after a few years of initial growth, for reasons not yet known.

It is also recommended that maintenance resources should be pooled wherever feasible, as some countries in the region have already attempted as, for example, Kuwait. This would enhance the building up of experienced personnel.

Pre-feasibility and feasibility studies

In most countries, capabilities to undertake the above activities sufficiently exist. They have been built up through long experience in other sectors of the economy, not necessarily petroleum-related, and can be applied in the petrochemical industry in a similar way.

However, since many projects still relied on foreign consultants to undertake these studies, there is a need to strengthen the organizations or divisions undertaking these capabilities.

The establishment of more local engineering consultancy companies and strengthening existing ones by providing them with part of the work undertaken, are two factors enabling them to build up experience and to penetrate the local and regional markets. Although some countries have laws and decrees stipulating the degree of involvement of national organizations in each project, others have not yet extended this practice to all levels of this activity.

After the above three priority areas for technological development are achieved, a reasonable degree of independence from foreign sources can be expected and a second group of priority areas can be specified. These are as follows:

- (a) Engineering and plant design;
- (b) Supervision of construction;
- (c) Process and product design;
- (d) Marketing;
- (e) Customer technical services;
- (f) Research and development.

These capabilities can only be successfully developed if an established petrochemical industry is functioning and also managed to a large degree by nationals.

Engineering and plant design

This capability is hardly found in the region at present, and it may be difficult to develop these capabilities at a national level. Therefore a regional approach is recommended. Strengthening an organization such as the Arab Engineering Company (AREC) can be considered a good approach. As with

many other capabilities the building up of experience is an important prerequisite and therefore the role of AREC in implementing projects should be actively encouraged.

Process and product design

The Arab Engineering Company (AREC) as a regional organization can play an important role in developing the process and product design capabilities, since the national market is too small in most countries to warrant the establishment of national organizations. The tasks and the manpower required are of such a nature that a regional approach, where manpower and financial resources can be pooled, is advisable.

Supervision of construction activities

This capability is not restricted to only the petrochemical industry and therefore national organizations specialized in construction and supervision of civil engineering should be further developed to acquire these capabilities.

Marketing

Marketing capabilities for the petrochemical industries are being built up in the region by a process of acquiring established marketing firms, storage and distribution channels.

The capability to conduct market studies, however, has to be developed. This can be done by building up a regional data information system whose function is to collect and disseminate trade and other relevant data. This facility could be connected to a regional agency such as GOIC for collecting information on patents, trademarks, historical records of licensors and contractors. A further step could be to augment this by a patent bank to advise relevant organizations in the region on all matters connected with the acquisition of a patented technology.

Customer technical services

The capability to be able to advise and support the clients of petrochemical industries will have to be developed in connection with the production operation capabilities to enable the industry to implement necessary modifications in the specifications of their products.

Research and development

Research and development centres exist in all countries of the region. However, their linkage with the petroleum-based industry is weak in many instances. To develop this capability, links should be established between industry and these centres; research programmes should be adapted to the needs of petroleum-related industries; and programmes should be initiated in relation to future developments in the petrochemical technology, such as research on "single carbon chemistry" and high-performance composites. By devoting resources to future developments, research centres can play an important role in the future needs of the petrochemical industry in the region.